# AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92200 NEUILLY SUR SEINE FRANCE

AGARD
Index of Publications
1989-1991

(Index des publications 1989-1991)

This Index has been prepared as part of the programme of the Technical Information Panel of AGARD.

NORTH ATLANTIC TREATY ORGANIZATION

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North Atlantic Treaty Organization
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The Mission of AGARD

According to its Charter, the mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

— Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;

— Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);

— Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;

— Improving the co-operation among member nations in aerospace research and development;

— Exchange of scientific and technical information;

— Providing assistance to member nations for the purpose of increasing their scientific and technical potential;

— Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

Preface

This volume provides abstracts and indexes for AGARD unclassified publications during the period 1989-1991. By an arrangement with U.S. National Aeronautics and Space Administration (NASA) in Washington, DC, the computerized NASA STI Database has been used to prepare this publication.

Full bibliographic citations and abstracts for all the documents in this publication are given in the abstract section, which is organized in the major subject divisions and specific categories used by NASA in abstract journals and bibliographies. The major subject divisions are listed, together with a note for each that defines its scope and provides any cross-references. Category breaks in the abstract section are identified by category number and title, and a scope note. Within each category, the abstracts are arranged by series and year.

Six indexes — Subject (based on *NASA Thesaurus nomenclature*), Personal Author, Corporate Source, Panel, Report/Accession Number, and Accession Number — are included. Sample entries are shown on the first page of each index.

Details of AGARD's classified publications for the same period are contained in a companion, classified, index.

Préface

Ce volume contient des résumés et des indexes relatifs aux publications non-classifiées de l'AGARD parues entre 1989 et 1991. Selon l'accord qui existe entre l'AGARD et l'US National Aeronautics and Space Administration (NASA) à Washington DC, la base de données informatisée STI de la NASA a été utilisée pour la préparation de la présente publication.

Des résumés et des citations détaillées relatifs à tous les documents figurant dans cette publication sont inclus dans la section résumés de l'ouvrage, qui est organisée selon les domaines et les catégories spécifiques employés par la NASA dans ses recueils de résumés et ses bibliographies. Les domaines principaux sont énumérés, avec une note pour chacun d'entre eux, définissant son contenu et indiquant d'éventuels renvois. Les changements de catégorie au sein de la section résumés sont identifiés par un numéro de catégorie, un titre et une note de contenu. Les résumés sont classés par série et par année à l'intérieur de chaque catégorie.

Six indexes en tout sont presentés, à savoir, Matière (selon la nomenclature du Thesaurus de la NASA) Auteur individuel, Source collective, Panel, Numéro de rapport/d'acquisition. Des exemples d'entrées sont donnés à la première page de chaque index.

Le détail des publications classifiées de l'AGARD pour la même période est donné dans un autre index, classifié, dans la même série.

Contents

Subject Categories

AERONAUTICS For related information see also *Astronautics.*

ASTRONAUTICS For related information see also *Aeronautics.*

N.A.—no abstracts were assigned to this category for this issue.

GEOSCIENCES For related information see also *Space Sciences.*

LIFE SCIENCES

MATHEMATICAL AND COMPUTER SCIENCES

SPACE SCIENCES For related information see also *Geosciences.*

GENERAL

Includes aeronautical, astronautical, and space science related histories, biographies, and pertinent reports
too broad for categorization; histories or broad ∩verviews of NASA programs.

Typical Citation

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ACCESSION NUMBER → N91-14292*# National Aeronautics and Space Administration. ← CORPORATE SOURCE
Langley Research Center, Hampton, VA.

TITLE → ASYMMETRIC SUPERSONIC FLOW AROUND CONES WITH NONCIRCULAR SECTIONS

AUTHORS → OSAMA A. KANDIL, TIN-CHEE WONG (Old Dominion Univ., Norfolk, VA.), and C. H. LIU *In* AGARD, Missile Aerodynamics 11 p (SEE N91-14278 06-02) Oct. 1990 ← PUBLICATION DATE

REPORT NUMBER OF PARENT ITEM → (Contract NAS1-18584) — DETAILS OF PARENT:

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- NASA ACCESSION NUMBER (N91-14278)
- ISSUE OF NASA STAR (06)
- SUBJECT CATEGORY IN THIS INDEX (02)
  (Ie section in which it will be found)

ABSTRACT →

The unsteady, compressible, single and double thin-layer, Navier-Stokes equations are used to solve for steady and unsteady, asymmetric, supersonic flow around pointed bodies with noncircular sections at high incidence and zero side slip. The equations are solved by using an implicit, upwind, flux-difference splitting finite-volume scheme. Since the flow is locally conical, the solutions are presented on a cross-flow plane at the axial station of unit. The grid is generated by using a modified Joukowski transformation. The computational applications cover noncircular sections with elliptic and diamond shapes. Unsteady asymmetric vortex shedding has been captured at large angles of attack. It is shown that for the same flow conditions and same cross-section fineness ratio, the diamond-section cones develop less flow asymmetry than the elliptic-section cones. Passive control of flow asymmetry was also demonstrated computationally. Author

NB Many AGARD publications, such as Conference Proceedings and Lecture Series, contain a number of individual papers. There is a separate citation in this index for each such paper, each containing a cross-reference (02 in this instance) to the parent publication in the form shown above. To locate the parent in this index, refer to the subject category given in the cross-reference. Within each category citations are in numerical order.

AGARD INDEX OF PUBLICATIONS (1989 – 1991)

ABSTRACT SECTION

01

AERONAUTICS (GENERAL)

N90-15041# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
FLIGHT IN ADVERSE ENVIRONMENTAL CONDITIONS
Sep. 1989 379 p In ENGLISH and FRENCH Symposium held in Gol, Norway, 8-11 May 1989
(AGARD-CP-470; ISBN-92-835-0527-1; AD-A217606) Copyright
Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Four aspects of adverse environmental conditions of interest to the flight mechanics specialist were addressed: atmospheric disturbances, reduced visibility, icing, and electromagnetic disturbances. All four of these can seriously affect flight safety, comfort, and operational capability. The topic was considered to be particularly relevant to the needs of the military community which is putting increased emphasis on the ability of today's and tomorrow's aircraft to fly safely and effectively in the types of adverse conditions. For individual titles, see N90-15042 through N90-15067.

N91-12579# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SEMINAR ON THE STRUCTURE OF AERONAUTICAL R AND D
May 1990 108 p Seminar held in Lisbon, Portugal, 31 May - 1 Jun. 1990; in Patras, Greece, 4-5 Jun. 1990; and in Ankara, Turkey, 7-8 Jun. 1990
(AGARD-R-782; ISBN-92-835-0564-6; AD-A225264) Copyright
Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Background material and experiences in planning and execution of aeronautical research and developments obtained by the various American and European authors are covered. They served as a basis for a Seminar held in Greece, Portugal and Turkey which aimed at assisting the authorities in planning aeronautical research and development. Various aspects of national and international cooperation in aerospace are highlighted. For individual titles, see N91-12580 through N91-12586.

N91-12580# National Center for anced Technologies, Washington, DC.
THE PROSPECTS OF AERONAUTICS
J. M. SWIHART In AGARD, Seminar on the Structure of Aeronautical R/D 24 p (SEE N91-12579 04-01) May 1990
(AGARD-R-782) Copyright Avail: NTIS HC/MF A06;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

When considering aeronautical research and development it is useful to begin by reviewing the prospects of aeronautics for the next decades. As is clear from the other papers, the participation in any major development in aeronautics requires a sustained effort of many years and so major contributions are considered, nationally or internationally, which will come to fruition in the next century. The 20th century saw the development of aeronautics on a global scale. The question is asked if this development now has levelled off and if from now on only marginal improvements and utilization will take place. It is indicated that

there will be tremendous challenges and opportunities in the coming decades. The essence of the 50th Wright Brothers Lecture, first given in St. Louis, Missouri, USA on 14 September 1987 is contained. The lecture concentrated on civil aeronautics, but of course many identical technical developments apply equally to military and civil aviation. In fact the history of aeronautical development shows that there is an intimate relationship between civil and military aeronautical developments. The developments since 1987, when the paper was written, suggest that the outlook for technical aeronautical developments has not become less and, in fact, the developments may far exceed the expectations of a few years ago. Author

N91-12581# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THE PROBLEM OF RESEARCH IN LDDI (LESS DEVELOPED DEFENSE INDUSTRY) COUNTRIES
A. AURIOL In AGARD, Seminar on the Structure of Aeronautical R/D 7 p (SEE N91-12579 04-01) May 1990
(AGARD-R-782) Copyright Avail: NTIS HC/MF A06;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

Topics addressed include: the need for applied research; existing baseline resources; cooperation with other countries; some characteristics of the aeronautical and armament industries; some characteristics of modern technology; and future needs (the choice of possible developments, and planning research). The appendices include the Estoril communique; and the NATO science program. Author

N91-12582# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AERONAUTICAL R AND D IN SMALLER COUNTRIES
JAN A. VANDERBLIEK In its Seminar on the Structure of Aeronautical R and D 15 p (SEE N91-12579 04-01) May 1990
(AGARD-R-782) Copyright Avail: NTIS HC/MF A06;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

Aeronautics fulfills an important function in education (engineering sciences), industry, traffic and trade. It is quite often considered as a major factor in the economic future of a country, together with electronic computers, atomic energy (recently with more emphasis). This, combined with the necessity to maintain an effective air defense, makes it mandatory for industrially developing countries to evaluate carefully to what extent they want to invest in aeronautics and, more generally, in aerospace. The planning and organization of aeronautical research and development and its role in aeronautics in general are discussed. Special attention is given to the situation of smaller countries. The paper is to a large extent based on experiences gained in Canada, the USA and especially in the Netherlands. Although this experience may be only of limited direct use to industrially developing countries, it may assist in charting the course of those countries. Author

N92-12538# National Aerospace Lab., Amsterdam (Netherlands).
A KNOWLEDGE-BASED ASSISTANT FOR DIAGNOSIS IN AIRCRAFT MAINTENANCE
M. A. PIERS and J. C. DONKER *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 7 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A feasibility study on the application of knowledge based systems for diagnosis of complaints in aircraft systems is described. The specific application selected for the Knowledge-based Assistant for Diagnosis in Aircraft Maintenance (KADAM) Project is a knowledge based system to be used by ground engineers for troubleshooting of an aircraft air conditioning system. The approach is addressed, and the results, including the design of the proof-of-concept system, are reviewed. Particular attention is paid to the identification and formalization of methods for diagnosis.
Author

02

AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

N89-26817# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
TECHNICAL STATUS REVIEW ON DRAG PREDICTION AND ANALYSIS FROM COMPUTATIONAL FLUID DYNAMICS: STATE OF THE ART
Jun. 1989 156 p In ENGLISH and FRENCH Review held in Lisbon, Portugal, 5 May 1988
(AGARD-AR-256; ISBN-92-835-0516-6; AD-A212809) Copyright Avail: NTIS HC A08/MF A01

The papers presented at the AGARD Fluid Dynamics Panel Technical Status Review on, Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art, are contained. Speakers presented a state of the art review from their individual nation. The Program Chairman summarized the key conclusions from all the papers presented. It is recommended that the Fluid Dynamics Panel consider possibilities for further stimulation of progress in the field of CFD-based drag prediction and analysis. For individual titles, see N89-26818 through N89-26825.

N89-26819# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
DRAG PREDICTION AND ANALYSIS FROM CFD STATE-OF-THE-ART IN GERMANY
WOLFGANG SCHMIDT and PETER SACHER (Messerschmitt-Boelkow G.m.b.H., Munich, Germany, F.R.) *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 22 p (SEE N89-26817 21-02) Jun. 1989
(AGARD-AR-256) Copyright Avail: NTIS HC A08/MF A01

Consistent and accurate prediction of absolute drag for aircraft configurations is currently beyond reach computationally as well as experimentally using wind tunnel model testing. This is attributed to several elements ranging from lack of physical understanding up to limitations in numerical methods and scaling laws. To access drag by computational methods, drag components and the overall drag built-up have to be specified. For the individual drag component semi-empirical as well as theoretical estimates are discussed. Problems and limitations in drag estimates using computational fluid mechanics (CFD) are demonstrated for different types of flowfields. Within the scope of the present conference, our survey over the state-of-the-art in Germany will cover industrial aspects for commuter and transport aircraft, trainer, as well as fighter configurations, missiles, and space vehicles. Author

N89-26820# National Technical Univ., Athens (Greece). Lab. of Thermal Turbomachines.
SOME RESULTS ON FLOW CALCULATIONS INVOLVING DRAG PREDICTION
K. D. PAPAILIOU *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 24 p (SEE N89-26817 21-02) Jun. 1989
(AGARD-AR-256) Copyright Avail: NTIS HC A08/MF A01

Different calculation methods were developed in the Thermal Turbomachinery Lab. of the Athens National Technical University concerning drag prediction. A Navier-Stokes solver, based on a fractional step method, was developed in order to solve viscous incompressible flow in ducts. A second Navier-Stokes solver was developed for transonic flow using, again, a fractional step method, but this time for quasi-three dimensional cascade flow. Integral methods were developed as well in order to predict secondary flows in compressors and shear layer development on blades. High speed laminar and turbulent flow is predicted, attached and separated. Viscous inviscid interaction techniques were developed for the stabilization of the separated flow calculation. Phenomena such as transitional flow, laminar separation bubbles and shock/shear layer interaction for turbulent flow are predicted with good accuracy. The general methods will be reviewed briefly and results will be presented. Author

N89-26821# Aeritalia S.p.A., Turin (Italy). Combat Aircraft Group.
STATE-OF-THE-ART OF AIRCRAFT DRAG PREDICTION IN ITALY BY MEANS OF THEORETICAL METHODS
G. BUCCIANTINI and M. BORSI *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 12 p (SEE N89-26817 21-02) Jun. 1989
(AGARD-AR-256) Copyright Avail: NTIS HC A06/MF A01

The state-of-the-art in Italy on the aerodynamic drag prediction, based on theoretical methods, is presented and discussed. A brief description of the methods used is given, with examples of application for typical aircraft configurations. A survey of critical areas is provided, together with present research activities to improve the drag prediction capabilities and accuracy. Author

N89-26822# National Aerospace Lab., Amsterdam (Netherlands). Informatics Div.
AIRCRAFT DRAG PREDICTION FOR TRANSONIC POTENTIAL FLOW
J. VANDERVOOREN *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 17 p (SEE N89-26817 21-02) Jun. 1989 Sponsored in part by Netherlands Agency for Aerospace Programs (NIVR)
(AGARD-AR-256) Copyright Avail: NTIS HC A08/MF A01

The state-of-the-art on computational drag prediction and diagnostics in The Netherlands for transport aircraft in the transonic flight regime is described. Subsequently, a method is discussed that is currently being developed at NLR to calculate wave drag in transonic potential flow. The method is a generalization and extension of Garabedian's and McFadden's idea of determining wave drag by volume-integration of the artificial viscosity. The generalization involves the introduction of a reference artificial viscosity which provides a solid theoretical basis. At the same time this ensures that calculated wave drag is to a certain extent independent of the specific details of the artificial viscosity in different codes. The extension accounts for the fact that artificial viscosity does not smear out supersonic/subsonic shock waves completely, but leaves room for a truly discontinuous sonic/subsonic shock remainder that contributes substantially to the wave drag. A number of first results that illustrate the potential of the method are presented and discussed. Author

N89-26823# Royal Aircraft Establishment, Bedford (England).
CFD METHODS FOR DRAG PREDICTION AND ANALYSIS CURRENTLY IN USE IN UK
P. R. ASHILL *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 19 p (SEE N89-26817 21-02) Jun. 1989
(AGARD-AR-256) Copyright Avail: NTIS HC A08/MF A01

Computational methods developed in UK for the prediction of the drag of aircraft components at subsonic and supersonic speeds

are critically reviewed. In many cases, the flow modeling is found to be lacking in certain respects. Despite this, however, the review suggests that these methods have a useful function both in the early stages of aircraft design, when they may be used to study differences in the drag of various shapes, and later in support of wind-tunnel tests as a diagnostic tool and also to extrapolate the data to full scale.   Author

N89-26824*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA. Applied Computational Fluids Branch.
COMPUTATIONAL FLUID DYNAMICS DRAG PREDICTION: RESULTS FROM THE VISCOUS TRANSONIC AIRFOIL WORKSHOP
TERRY L. HOLST *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 12 p (SEE N89-26817 21-02)   Jun. 1989   Previously announced as N88-22009
(AGARD-AR-256)   Copyright   Avail: NTIS HC A08/MF A01 CSCL 01/1
    Results from the Viscous Transonic Airfoil Workshop held in January 1987, are compared with each other and with experimental data. Test cases used include attached and separated transonic flows for the NACA 0012 airfoil. A total of 23 sets of numerical results from 15 different author groups are included. The numerical methods used vary widely and include: 16 Navier-Stokes methods, 2 Euler/boundary-layer methods, and 5 potential/boundary-layer methods. The results indicate a high degree of sophistication among the numerical methods with generally good agreement between the various computed and experimental results for attached or moderately separated cases. The agreement for cases with larger separation is only fair and suggests additional work is required in this area.   Author

N89-26825# Grumman Aerospace Corp., Bethpage, NY. Aircraft Systems Div.
CFD DRAG PREDICTION FOR AERODYNAMIC DESIGN
CHARLES W. BOPPE   *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 28 p (SEE N89-26817 21-02)   Jun. 1989
(AGARD-AR-256)   Copyright   Avail: NTIS HC A08/MF A01
    Consistent and accurate Computation Fluid Dynamics (CFD) prediction of absolute drag level for aircraft configurations is currently beyond reach. This is attributed to several elements characterizing state-of-the-art computer algorithms and hardware. With considerable research focused on the 2-D airfoil analysis problem, an exercise is conducted to quantify the implications for 3-D wings. Recent highlights in the U.S.A. which have advanced drag prediction capabilities or improved understanding of the problem are described. Examples are taken from the areas of computational physics, viscous airfoil simulation, component analysis, hypersonics, and conceptual design/configuration optimization. Primary attention is concentrated on aircraft but helicopter, missile, and automobile cases are also included. A near term solution to the CFD drag prediction problem can not be identified. Instead, means based on CFD's strengths are discussed which make computational methods valuable for drag reduction/prediction during aerodynamic design processes.
                                                                     Author

N89-26736# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.
LARGE SCALE MOTIONS IN SUPERSONIC TURBULENT BOUNDARY LAYERS (Computer Diskette Supplement)
A. J. SMITS and J. H. WATMUFF   *In* AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 14 p (SEE N89-28734 23-34)   May 1989   Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315)   Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set
    The results from a number of experiments are summarized. The experiments encompassed zero pressure gradient and adverse pressure gradient flat-plate boundary layers, flows over concavely curved walls, and shock-wave/boundary layer interactions. The Reynolds-averaged turbulent stresses and the corresponding

mean-flow data were obtained along with a large number of other measurements taken in an attempt to describe the time-dependent behavior of the turbulent field. Observations on large-scale structures are discussed. The suitability of various conditional sampling techniques is examined with particular attention being given to the limitations of the VITA method of Blackewlder and Kaplan (1976).   M.G.

N89-28738# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.
HOT-WIRE ANEMOMETRY IN SUPERSONIC FLOW (Computer Diskette Supplement)
A. J. SMITS and J. P. DUSSAUGE (Aix-Marseilles Univ., France) *In* AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 14 p (SEE N89-28734 23-34)   May 1989   Sponsored in part by CNRS, France   Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315)   Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set
    The theory and practice of both the constant current and constant temperature modes of hot-wire anemometry are summarized, and the advantages and disadvantages are discussed. Probe designs suitable for supersonic flow are considered first. Next, the behavior of a single wire placed normal to the flow direction is examined, including its quasi-static response and its dynamic response. The behavior of inclined and crossed-wire probes is discussed. The effects of low Mach and Reynolds numbers are considered. Finally, two examples illustrating the uncertainties in measurements are given and discussed.   Author

N89-28740# Aix-Marseilles Univ. (France). Inst. de Mecanique Statistique de la Turbulence.
LASER DOPPLER ANEMOMETRY IN SUPERSONIC FLOWS: PROBLEMS OF SEEDING AND ANGULAR BIAS (Computer Diskette Supplement)
M. ELENA   *In* AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 6 p (SEE N89-28734 23-34)   May 1989   Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315)   Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set
    The application of laser Doppler anemometry in supersonic flows is examined with particular attention being given to the problems associated with seeding and angular bias. The response of seed particles to abrupt changes in flow condition is discussed along with the effects of injection methodology. The mechanism underlying the measurement distortions caused by angular bias is described. The use of Bragg cells to reduce the effect of angular bias is also briefly discussed.   B.G.

N89-29306# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON AEROTHERMODYNAMICS OF HYPERSONIC VEHICLES
Jun. 1989   336 p   Course held in Rhode-Saint-Genese, Belgium, 30 May - 3 Jun. 1988; sponsored by AGARD and the Von Karman Inst. of Fluid Dynamics
(AGARD-R-761; ISBN-92-835-0515-8; AD-A214027)   Copyright Avail: NTIS HC A15/MF A02
    This AGARD Fluid Dynamics Panel/von Karman Institute Special Course was inspired by new ventures in the hypersonic domain moving forward on both sides of the Atlantic-HERMES in Europe and the NASP (X-30) in the United States. Following the review of basic principles including real gas effects, a series of lectures were presented on experimental and computational methods specific to hypersonic flows. Stress was placed on measurement techniques developed primarily for flows with heat transfer, chemical reactions, strong shocks, and compressible boundary layers. Both surface measurements and flow field measurements including species concentration techniques, were discussed. The same spirit governed the lecture on computational methods: stress was placed on the new problems in CFD posed by high speeds and chemical reactions. The course finished with

state of the art reviews on three critical flow problems: transition to turbulence; ininteractions between shocks and boundary layers; and shock/shock impingement. For individual titles, see N89-29307 through N89-29315.

N89-29307# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
MISSIONS AND REQUIREMENTS
RICHARD D. NEUMANN *In* AGARD, Special Course on Aerothermodynamics of Hypersonic Vehicles 18 p (SEE N89-29306 24-02) Jun. 1989
(AGARD-R-761) Copyright Avail: NTIS HC A15/MF A02
The lifting entry from low earth orbits is evaluated. Hypersonic systems; experimental test facilities and numerical simulations; the reference temperature techniques; computational fluid dynamics in design; validation of numerical solutions; computational fluid dynamic products for aerothermodynamic applications; experimentation; and instrumentation are described. B.G.

N89-29308# Maryland Univ., College Park. Dept. of Aerospace Engineering.
INVISCID AND VISCOUS HYPERSONIC AERODYNAMICS: A REVIEW OF THE OLD AND NEW
JOHN D. ANDERSON, JR. *In* AGARD, Special Course on Aerothermodynamics of Hypersonic Vehicles 25 p (SEE N89-29306 24-02) Jun. 1989
(AGARD-R-761) Copyright Avail: NTIS HC A15/MF A02
Both inviscid and viscous hypersonic aerodynamics are reviewed. It is tutorial in manner, and is addressed to students and workers who want to learn the subject, or need to review various aspects of the discipline. Also represented is a survey of hypersonics, contrasting the old with the new. It covers both classical hypersonic considerations as well as the new hypersonics, which is heavily based on computational fluid dynamic methods. High temperature flows are also considered. Author

N89-29309# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. of Aerothermodynamics.
AN INTRODUCTION TO REAL GAS EFFECTS
B. AUPOIX *In* AGARD, Special Course on Aerothermodynamics of Hypersonic Vehicles 56 p (SEE N89-29306 24-02) Jun. 1989
(AGARD-R-761) Copyright Avail: NTIS HC A15/MF A02
Real gas effects are due to the transformation of an hypervelocity flow into an hyperenthalpy flow. The flow is thus the room of various phenomena, chemical reactions leading to dissociation and ionization, energy exchanges between degrees of freedom of particles. The physical background is introduced in the first section. The thermodynamic properties of molecules and atoms are first described. The flow equations are derived from description of the microscopic behavior of particles. The chemistry, either in the gas or at gas/surface interfaces is discussed. Results for air at chemical equilibrium are presented as an illustration. A simple model is also given. Examples of flow with real gas effects, relevant to space shuttle reentry, are given in the second part. The relaxation behind the shock wave is first studied. Shock layer and boundary layer flows around the body are then investigated. At last, the ionization problem is mentioned. Author

N89-29311# Complere, Inc., Palo Alto, CA.
MEASUREMENTS OF HYPERSONIC FLOWFIELDS
F. K. OWEN *In* AGARD, Special Course on Aerothermodynamics of Hypersonic Vehicles 43 p (SEE N89-29306 24-02) Jun. 1989
(AGARD-R-761) Copyright Avail: NTIS HC A15/MF A02
Although extensive progress was made in computational fluid mechanics, reliable flight vehicle designs and modifications still cannot be made without recourse to extensive wind tunnel testing. Future progress in the computation of hypersonic flowfields is restricted by the need for a reliable turbulence modeling data base which could be used for the development of empirical models for use in numerical codes. Currently, there are few compressible flow measurements which could be used for this purpose and, since additional shear stress terms may be significant at high Mach numbers, models based on incompressible measurements may not be realistic. Techniques for mean, transitional and turbulent flow measurements will be reviewed and the status of transition and turbulence research in support of turbulence modeling programs discussed. Procedures for hot wire and hot film measurements in hypersonic flows will be outlined and

assessments made of the potential for hot wire and laser velocimeter measurements of turbulent fluctuations in hypersonic flow fields. The results of recent experiments conducted in two hypersonic wind tunnels will be presented and comparisons made with previous hot wire turbulence measurements. Author

N89-29312# Calspan Corp., Buffalo, NY.
SPECIES COMPOSITION MEASUREMENTS IN NONEQUILIBRIUM HIGH-SPEED FLOWS
DONALD W. BOYER *In* AGARD, Special Course on Aerothermodynamics of Hypersonic Vehicles 23 p (SEE N89-29306 24-02) Jun. 1989
(AGARD-R-761) Copyright Avail: NTIS HC A15/MF A02
Descriptions of some diagnostic methods for species concentration measurements are reviewed which are applicable to high-speed flows. Some of the theoretical framework was included but only as background to support the descriptions. Referral is intended, of course, to the literature cited, and references therein, for greater detail concerning analysis and implementation. The summaries can help to appraise as well as guide in the selection of a method most suitable for a given flow situation. Some of the methods are not new. The more recent and yet-developing laser techniques have singular advantages by virtue of their ability to interrogate very fast flows, and to be applicable to reactive and hostile environments. However, the techniques can be quite complex both analytically and in their optical requirements and configurations. Author

N89-29313# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Theoretical Fluid Mechanics.
COMPUTATIONAL TECHNIQUES FOR HYPERSONIC FLOWS: SELECTED RECENTLY APPLIED TECHNIQUES
W. KORDULLA *In* AGARD, Special Course on Aerothermodynamics of Hypersonic Vehicles 24 p (SEE N89-29306 24-02) Jun. 1989
(AGARD-R-761) Copyright Avail: NTIS HC A15/MF A02
Some insight is provided into several currently used numerical techniques to simulate hypersonic flows. After describing the particular features of hypersonic flows occuring e.g., during reentry of vehicles such as Hermes the necessary input for computational methods is discussed including the simulation of viscous flow which is emphasized. It then becomes evident that dedicated experimental work is badly needed to determine thermo-physical and chemical property data as well as to provide appropriate tests for the prediction methods needed to support the designer in his work. Finally, selected recently applied numerical methods are presented for high-speed (cold) hypersonic flows. for flows in equilibrium and in non-equilibrium. Thereby weaknesses and strengths are being pointed out. Author

N89-29314# Centre d'Etudes et de Recherches, Toulouse (France). Dept. d'Aerothermodynamique
LAMINAR-TURBULENT TRANSITION PROBLEMS IN SUPERSONIC AND HYPERSONIC FLOWS
DANIEL ARNAL *In* AGARD, Special Course on Aerothermodynamics of Hypersonic Vehicles 45 p (SEE N89-29306 24-02) Jun. 1989
(AGARD-R-761) Copyright Avail: NTIS HC A15/MF A02
Theoretical and experimental problems related with boundary layer transition at high speeds were surveyed. On the theoretical point of view, emphasis is given on the linear stability theory, which describes the first stages of the transition process. It allows to explain the effects of various factors affecting transition, such as wall cooling or bluntness. In incompressible flow, it is often associated with the e(sup n) method for predicting transition onset. The extension of this method to compressible flows will be discussed. As far as the experimental results are concerned, the main problem is that free-flight conditions are very difficult to simulate in conventional wind tunnels, where the transition location depends on the noise radiated by the nozzle walls. Typical experimental results are presented in order to illustrate the influence of unit Reynolds number, wall curvature, and wall roughness. Three-dimensional problems are also considered. Author

N89-29315# Office National d'Études et de Recherches Aeronautiques, Paris (France).
SHOCK/SHOCK AND SHOCK-WAVE/BOUNDARY-LAYER INTERACTIONS
J. DELERY *In* AGARD, Special Course on Aerothermodynamics of Hypersonic Vehicles 52 p (SEE N89-29306 24-02) Jun. 1989
(AGARD-R-761) Copyright Avail: NTIS HC A15/MF A02
Shock interference phenomena and shock-wave/-boundary-layer interactions are of special importance in hypersonic flows since they can be at the origin of extremely high local heat transfer rates and loss of control effectiveness. The physical aspects of these phenomena are first considered by examining the characteristic features and the scaling laws of typical 2-D interacting flows. Correlation laws allowing the prediction of separation pressures, peak heat-transfer rates and incipient shock-induced separation are presented. Various methods were developed to obtain a more complete prediction of shock-wave/boundary-layer interactions. These methods can be classified into four categories, namely: global methods, Inviscid-Viscous Interactive methods, analytical methods and solution of the Navier-Stokes equations. Here, emphasis is placed on the solution of the problem by integration of the full time averaged Navier-Stokes equations. A review of the turbulence models most currently used to compute strongly interacting turbulent flows is presented. Examples of applications concerning both 2-D and 3-D flows are discussed.   Author

N90-10051*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE PRESENT STATUS AND THE FUTURE OF MISSILE AERODYNAMICS
JACK N. NIELSEN *In* AGARD, Stability and Control of Tactical Missile Systems 18 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
CSCL 01/1
Recent developments in the state of the art in missile aerodynamics are reviewed Among the subjects covered are: (1) Tri-service/NASA data base, (2) wing-body interference, (3) nonlinear controls, (4) hypersonic transition, (5) vortex interference, (6) airbreathers, supersonic inlets, (7) store separation problems, (8) correlation of missile data, (9) CFD codes for complete configurations, (10) engineering prediction methods, and (11) future configurations. Suggestions are made for future research and development to advance the state of the art of missile aerodynamics.   Author

N90-10055# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
PREDICTION OF DYNAMIC DERIVATIVES
HEINZ FUCHS *In* AGARD, Stability and Control of Tactical Missile Systems 19 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
The prediction methodology of dynamic derivatives is presented as derived from semiempirical calculation procedures like USAF Stability and Control Datcom in combination with some modifications necessary for tactical missile configurations at higher angles-of-attack. The main subject is the longitudinal stability derivatives and the roll damping derivativum. A comparison of theoretical and experimental results is presented where different dynamic wind tunnel test equipments are explained including the data evaluation theory. Some aspects of modification of the present linear data evaluation method to nonlinear terms at high angles-of-attack are shown with an example of a fighter aircraft configuration using the MOD test rig in the Dornier wind tunnel.   Author

N90-10056# Lockheed Missiles and Space Co., Sunnyvale, CA.
PREDICTION OF TACTICAL MISSILE DYNAMICS
L. E. ERICSSON *In* AGARD, Stability and Control of Tactical Missile Systems 22 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
The aerodynamic information needed for preliminary design of tactical missiles was always obtained through the combined use of theory and experiments. In regard to the static aerodynamics this has resulted in a prediction capability that often is satisfactory for preliminary design. However, the vehicle dynamics cannot be predicted with the same confidence, especially not at the high angles of attack where high performance missiles often must

operate. In this case dependence is still upon continuous efficient interactions between theoretical and experimental methods. The limitations of both methods are delineated and the means of how to circumvent them in order to predict tactical missile dynamics over the required range of operational parameters are described.
                Author

N90-10359*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STABILITY OF A SUPERSONIC BOUNDARY LAYER ALONG A SWEPT LEADING EDGE
MUJEEB R. MALIK and IVAN E. BECKWITH *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 9 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
CSCL 01/1
The instability of an attachment-line boundary layer formed on a swept cylinder in a supersonic freestream is considered in the linear regime. The supersonic attachment-line boundary layer is shown to be susceptible to oblique Tollmien-Schlichting wave instability which may be controlled by wall cooling. The critical Reynolds number based upon momentum thickness is found to be about 230. The onset of transition in the attachment-line boundary layer is also studied using the e (sup N) method and results are compared with the experimental data obtained at M (sub infinity) = 3.5 in the absence of any trips or spanwise contamination.   Author

N90-10360# Centre d'Etudes Aerodynamiques et Thermiques, Poitiers (France). Lab. d'Etudes Aerodynamiques.
LEADING EDGE TRANSITION BY CONTAMINATION IN HYPERSONIC FLOW [TRANSITION PAR CONTAMINATION DE BORD D'ATTAQUE EN ECOULEMENT HYPERSONIQUE]
J. L. DACOSTA, D. AYMER DELACHEVALERIE, and T. ALZIARY DEROQUEFORT *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 14 p (SEE N90-10356 01-34) Apr. 1989 In FRENCH; ENGLISH summary
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
Transition by attachment-line contamination in hypersonic flow was studied. Experiments are carried out on a swept circular cylinder fitted with streamwise end plates at Mach number 7.1. The sweep angle is 74 degrees. Pressure and heat fluxes are measured along the attachment-line. The occurrence of transition is detected by an increase of the Stanton number. The cylinder can be cooled by liquid nitrogen which allows the influence of the wall temperature to be tested. Either a laminar or turbulent incoming boundary layer can be achieved at the cylinder base. Results compare favorably with the predictions given by Poll's criterion.
                Author

N90-10361*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DIRECT NUMERICAL STUDY OF LEADING-EDGE CONTAMINATION
P. R. SPALART *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 13 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
CSCL 01/1
Instability, turbulence, and relaminarization in the attachment-line region of swept and unswept cylindrical bodies are studied by numerical solution of the full Navier-Stokes equations. The flow is simulated over a strip containing the attachment-line and treated as homogeneous in the spanwise direction; the disturbances decay exponentially upstream. Transpiration through the wall may be prescribed. The new method, which admits completely general disturbance, agrees with published linear-stability results, which were limited to an apparently restrictive form of disturbance. Fully developed turbulent solutions with sweep are generated and compare well with the experiment. The turbulence is subcritical (except for blowing), resulting in large hysteresis loops. By lowering the sweep Reynolds number, or increasing the suction, the turbulent flow is made to relaminarize. The relaminarization Reynolds number is much less sensitive to suction than the linear-stability Reynolds number Extensive attempts to detect the postulated nonlinear instability of the unswept flow failed, suggesting that this flow is linearly and nonlinearly stable.   Author

N90-10364*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GOERTLER INSTABILITY ON AN AIRFOIL: COMPARISON OF MARCHING SOLUTION WITH EXPERIMENTAL OBSERVATIONS
VIJAY KALBURGI, SIVA M. MANGALAM (Analytical Services and Materials, Inc., Hampton, VA.), and J. RAY DAGENHART *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 16 p (SEE N90-10356 01-34) Apr. 1989
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CSCL 01/1

Theoretical predictions based on the marching technique are compared with experimental observations on an airfoil with a concave region. Theoretical predictions of the wavelength of the most amplified Goertler vortex are in excellen. agreement with the experimental observation for the range of chord Reynolds numbers from 1.0 to 3.67 million. In the convex zone, solutions from the marching technique showed that the initial counter-rotating vortex pairs lift off the surface and dissipate while another layer of vortex pairs of opposite rotation develops near the surface. This confirms the experimentally observed double peaked streamwise velocity perturbations. Furthermore, the streamwise velocity perturbations which dominate spanwise variation in the surface shear stress distribution shift by half a wavelength in the convex region. The experimental flow visualization photographs clearly confirm this phenomena. Author

N90-10367# Bristol Univ. (England). Dept. of Aerospace Engineering.
THE THREE-DIMENSIONAL VORTEX SHEET STRUCTURE ON DELTA WINGS
MARTIN V. LOWSON *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 16 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

Preliminary results are reported from flow visualization studies of the separated shear layers on slender delta wings in air at Reynolds numbers from 3000 to 100,000 based on chord. The work confirms the existence of a systematic structure in the shear layer paralleling the classic instabilities occurring in other cases. Both quasi two-dimensional instabilities traveling at mean flow velocities and a new form of streamwise instability, believed to result from curvature of the vortex sheet, were identified. Both instabilities are found to be stabilized by the stretching process towards the center of the core. For the case studied the interaction between the two instabilities causes the vortex sheet to become turbulent at Reynolds numbers above 20,000 based on local chord. Forced response studies of the vortex sheet have demonstrated the existence of new mechanisms for vortex formation in the shear layer. The results are believed to be relevant to more complex three dimensional shear layers, and have implications for full scale flows on aircraft at high angles of attack. Author

N90-10373# California State Univ., Long Beach. Dept. of Aerospace Engineering.
A THREE-DIMENSIONAL LINEAR STABILITY APPROACH TO TRANSITION ON WINGS AT INCIDENCE
TUNCER CEBECI, H. H. CHEN, and D. ARNAL *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 13 p (SEE N90-10356 01-34) Apr. 1989 Sponsored in part by Navy
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

The calculation of transition of an infinite swept wing was investigated for a range of sweep angles, Reynolds numbers, and angles of attack The method solves boundary layer and Orr-Sommerfeld equations by a finite-difference procedure and involves interaction with the inviscid flow. Amplification rates in the e (sup n) method are determined with an eigenvalue procedure which determines the relationship between the wave numbers The calculation method is evaluated in terms of measurements reported for the flow around an ONERA-D wing equipped with a cambered leading edge and attached to a half fuselage. It is shown to be convenient to use, particularly because the neutral stability curves (zarfs) facilitate the calculation and avoid uncertainties associated with the choice of magnitude and location of the critical frequencies. In general, the calculated values of the onset of transition are in good agreement with measured values, for the eight cases examined. Author

N90-10379# McDonnell-Douglas Research Labs., Saint Louis, MO.
TRAILING-EDGE SWEEP AND THREE-DIMENSIONAL VORTEX INTERACTIONS IN JETS AND MIXING LAYERS
V. KIBENS, R. W. WLEZIEN, F. W. ROOS, and J. T. KEGELMAN *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 12 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

Three-dimensional vortex interactions are investigated in jets with slanted indeterminate-origin exit nozzles, and in mixing layers behind a splitter plate with a swept trailing edge. Flow visualization images were quantitatively processed to characterize complex three-dimensional vortex interactions in non-axisymmetric jets. Phase-conditioned, pulsed laser-sheet illumination was used to obtain a series of sectional images while rotating the asymmetric nozzle. The section images were recombined into an unwrapped representation of the developing vortex systems in the shear layer. Partial pairing of sections of adjacent vortex systems was shown to be responsible for asymmetric shear-layer growth. Flow visualization in the flow behind the swept trailing edge showed that two families of instability waves can develop with different orientations with respect to the trailing-edge angle. Excitation was shown to enhance waves with orientation parallel to the trailing edge or perpendicular to the mean flow direction, depending on excitation frequency. The wavelengths of the two wave families were identical, and the streamwise spacing depended on the sweep angle. Author

N90-10380# National Aerospace Lab., Amsterdam (Netherlands). GARTEUR Action Group AD.
A EUROPEAN COLLABORATIVE INVESTIGATION OF THE THREE-DIMENSIONAL TURBULENT SHEAR LAYERS OF A SWEPT WING
B. VANDENBERG *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 19 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

The turbulent shear layers of a swept wing are described. The measurements will comprise both the upper and lower wing boundary layer, as well as, the three-dimensional near-wake behind the wing. Starting from required viscous flow properties, a wing geometry was designed by flow calculations. The theoretical wing design was checked by pilot model tests. The results suggest that the viscous flow may become an interesting test case for turbulence models for three-dimensional shear flows. The measurements in the turbulent shear layers will comprise mean flow quantities, skin friction data, and the six Reynolds stress tensor components. To establish the measurement accuracy, several data checks will be performed, including independent tests with similar models in two different wind tunnels. Author

N90-15064# Boeing Commercial Airplane Co., Renton, WA. Configuration and Certification Group.
FLIGHT AND WIND TUNNEL INVESTIGATION OF AERODYNAMIC EFFECTS OF AIRCRAFT GROUND DEICING/ANTIICING FLUIDS
L. JAMES RUNYAN, THOMAS A. ZIERTEN, and EUGENE G. HILL *In* AGARD, Flight in Adverse Environmental Conditions 11 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03, Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A flight and wind tunnel investigation of the effects of aircraft ground deicing/anti-icing fluids on the aerodynamic characteristics of a Boeing 737-200ADV airplane was conducted. The flight test was performed in Kuopio, Finland, and the wind tunnel test was carried out in the NASA Lewis Research Center Icing Research Tunnel. Fluids tested in both flight and the wind tunnel include a newtonian deicing fluid and three nonnewtonian anti-icing fluids commercially available during or prior to 1988. Both the flight test results and the wind tunnel results show that fluids remain on the wing after liftoff and cause a measurable lift loss and drag increase. Eight newly developed nonnewtonian fluids, tested only in the wind tunnel, show significantly improved aerodynamic characteristics relative to the existing nonnewtonian fluids that were tested. Wind tunnel results also indicate that the fluid effects are configuration dependent. For a configuration with deflected leading edge high-lift devices, the fluid effect is largest at the maximum

lift condition. For a configuration without leading edge high-lift devices, the fluid effect is very small at the maximum lift condition. It was also found that the fluid aerodynamic effects are related to the fluid surface roughness, particularly in the first 30 percent chord. Author

N90-17565# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON THREE-DIMENSIONAL SUPERSONIC/HYPERSONIC FLOWS INCLUDING SEPARATION
Jan. 1990 395 p Special course held in Rhode-Saint-Genese, Belgium, 8-12 May 1989, and at Moffett Field, CA, 10-14 Jul. 1989
(AGARD-R-764; ISBN-92-835-0537-9; AD-A219740) Copyright
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The objective was to provide a status report on the understanding and ability to predict three-dimensional compressible flows including the complex effects of flow separation. An overview presentation of the requirements for this technology set the stage for the course. This was followed by two lectures which discussed topics that are basic to all that followed. The capabilities and limitations of computational fluid dynamics to describe these complex flows was addressed; and a review of turbulence models appropriate to compressible flows was presented. A series of generic shock-shock boundary-layer interaction problems which may be viewed as either a means to understand flow physics or as building blocks for vehicle design were presented. How the chemical reactions present in highly hypersonic flows will influence three-dimensional hypersonic flows fields was discussed. For individual titles, see N90-17566 through N90-17573.

N90-17566*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OPPORTUNITIES FOR IMPROVED UNDERSTANDING OF SUPERSONIC AND HYPERSONIC FLOWS
ROBERT A. JONES *In* AGARD, Special Course on Three-Dimensional Supersonic/Hypersonic Flows Including Separation 44 p (SEE N90-17565 10-02) Jan. 1990
(AGARD-R-764) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01/1

This overview describes some of the diverse applications which are foreseen in the supersonic and hypersonic regime, and points out both the need and the opportunity for improved understanding of the subject. New facilities and experimental test techniques combined with computational fluid dynamics methods are described to illustrate challenging flows over supersonic wings, separated free-shear mixing layers, and in scramjet-airframe integration.
Author

N90-17567# Technische Hochschule, Aachen (Germany, F.R.). Aerodynamisches Institut.
COMPUTATION OF COMPRESSIBLE VISCOUS FLOWS
D. HAENEL *In* AGARD, Special Course on Three-Dimensional Supersonic/Hypersonic Flows Including Separation 33 p (SEE N90-17565 10-02) Jan. 1990
(AGARD-R-764) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Computational methods for the compressible Navier-Stokes equations are examined with special consideration of hypersonic flows. In the first part the governing equations and relations for equilibrium flow are described, and their basic numerical approaches, in particular for the Euler terms are discussed. As a selected topic the application of the multigrid method to solutions of the Navier-Stokes equations is considered. As a further topic the influence of the numerical damping on the numerical solution of the conservation laws is discussed, and their influence on steady-state, and unsteady solutions of the Navier-Stokes equations is demonstrated. The special numerical problems arising in hypersonic, viscous flows are discussed by means of an upwind relaxation method, and modifications of the scheme to overcome these problems will be presented. Conclusions will be drawn for the specific requirements of hypersonic, viscous flows to the numerical methods. Author

N90-17568# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Department d'Aerothermodynamique.
TURBULENCE MODELS FOR COMPRESSIVE FLOWS
J. COUSTEIX and B. AUPOIX *In* AGARD, Special Course on Three-Dimensional Supersonic/Hypersonic Flows Including Separation 53 p (SEE N90-17565 10-02) Jan. 1990
(AGARD-R-764) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The main objective is the presentation and the discussion of turbulence models devoted to calculate aerodynamic flows characterized by high speeds and heat exchanges. The basic equations of the average flow are obtained from the Navier-Stokes equations. After a discussion of various possible ways for defining the averaging process, the equations are written by using the mass-weighted averages. A general background of turbulence models is presented in incompressible flow and several models applied in compressible flow are described. This includes mixing length models, one-equation models, two-equation models and Reynolds stress models. The effects of compressibility and the development of turbulent heat flux equation models are also presented. Finally a few comparisons between computed and experimental data are given. Author

N90-17569# Calspan-Buffalo Univ. Research Center, NY.
SHOCK-SHOCK BOUNDARY LAYER INTERACTIONS
MICHAEL S. HOLDEN *In* AGARD, Special Course on Three-Dimensional Supersonic/Hypersonic Flows Including Separation 134 p(SEE N90-17565 10-02) Jan. 1990
(AGARD-R-764) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A study is presented of the aerothermal characteristics of shock/shock boundary layer interactions generated by single and multiple shocks. A review is presented of experimental studies which were conducted over the Mach number range from Mach 2 to 19 in the continuous and short duration test facility. The results of recent experimental studies in which detailed measurements of the distribution of heat transfer and pressure were made for Types 3 and 4 interactions in laminar flows at Mach 6 and 19 are discussed in detail. In these studies measurements at Mach 6 to 19 indicated that the severity of the interaction increased with transition and increasing Mach number, as suggested from simple models. Some Type 4 interactions where maximum heating occurs can also be unstable and, therefore, may be difficult to predict with accuracy. The studies of multiple shock interaction demonstrated that the largest heat loads are generated on the cylinder if the shocks coalesce before they are incident on the cylinder. While the flow fields and aerothermal loads generated by multiple shock impingement provide test cases for code prediction, the peak heating loads are significantly less than for a single shock of the same strength. Because of the low Reynolds numbers at which transition occurs in the free shear layers developed from either single or multiple shock/shock interactions, coupled with the occurrence of flow instabilities for Type 4 interactions, it will be difficult to accurately predict the maximum heating in such flows over a large and important part of the flight regime. However, the major feature of the flow field and pressure distributions were predicted with good accuracy with finite difference and finite element schemes for the solutions of the Navier-Stokes equations. Author

N90-17570# Technische Univ., Brunswick (Germany, F.R.). Institut fuer Stroemungsmechanik.
AXIAL FLOW IN CORNERS AT SUPERSONIC AND HYPERSONIC SPEEDS
DIETRICH HUMMEL *In* AGARD, Special Course on Three-Dimensional Supersonic/Hypersonic Flows Including Separation 37 p (SEE N90-17565 10-02) Jan. 1990
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The intake-type of corner configurations basically formed by two intersecting wedges is treated in a survey. Symmetrical and unsymmetrical wedge/wedge combinations are considered including the limits of plate/plate and wedge/plate configuration. Variations of leading-edge sweep and corner angle are also taken

into account. The present knowledge on the supersonic and hypersonic axial flow in such configurations is summarized. On the basis of experimental investigations the structure of the flowfield and the pressure and heat transfer distributions at the surface are analyzed in detail. The effects of various geometric parameters as well as those of Mach number and Reynolds number are described. The status of numerical solutions of the Euler and Navier-Stokes equations for the problem under consideration is also reviewed. Remarkable theoretical results were achieved so far. Some details of the flow structure are still in question and further experimental and theoretical investigations are suggested.
Author

N90-17571# Cranfield Inst. of Tech., Bedford (England). Coll. of Aeronautics.
GLANCING SHOCK-BOUNDARY LAYER INTERACTIONS
JOHN L. STOLLERY   *In* AGARD, Special Course on Three-Dimensional Supersonic/Hypersonic Flows Including Separation 30 p (SEE N90-17565 10-02) Jan. 1990
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There is no universally agreed definition of glancing interaction but it is usually taken to include those situations where the shock wave generated by one body cuts across the boundary layer growing over another and the intersection line is swept. Such flows are essentially three dimensional and are a sub-set of the many swept interactions. In the simplest glancing interactions the only shock wave of interest is that formed by the shock wave generator. Similarly the only boundary layer of interest is the one affected by shock impingement. The boundary layer development on the shock generator and any shock from the surface supporting the boundary layer are secondary in importance. Thus the more complex corner flows and shock-shock interactions are played in categories of their own and enjoy individual treatment. Just four of the many geometries available will be discussed. These four cover the effects of sweep and bluntness on a fin mounted at right angles to a flat plate. Discussed are sharp unswept fins, sharp swept fins, blunt unswept fins, and blunt swept fins. These models can easily be tested experimentally with the fin mount on a sharp leading edge flat plate or mounted directly from the wall of a wind tunnel test section. However, even with these relatively simple geometries it would be foolish to ignore the mutual interference between the two surfaces. In particular the bow shock generated by a blunt fin will often cause boundary layer separation ahead of the fin root. This in turn generates an oblique shock which interacts with the bow shock so producing an example of the shock-shock interactions treated in detail elsewhere in this course. Similarly, a turbulent boundary layer at the base of a swept blunt fin may trigger leading-edge contamination along the attachment line with consequent increases in heat transfer rate. Hence wherever possible the flow pattern over both the plate and fin surfaces will be investigated.
Author

N90-17572# Texas Univ., Austin. Dept. of Aerospace Engineering and Engineering Mechanics.
UNSTEADINESS OF SUPERSONIC AND HYPERSONIC SHOCK INDUCED TURBULENT BOUNDARY LAYER SEPARATION
D. S. DOLLING   *In* AGARD, Special Course on Three-Dimensional Supersonic/Hypersonic Flows Including Separation 26 p (SEE N90-17565 10-02) Jan. 1990
(AGARD-R-764) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The unsteadiness of supersonic and hypersonic shock-induced turbulent separated flows is reviewed. Both two-dimensional (2-D) and three-dimensional (3-D) flows are discussed. For organizational reasons, more than physical ones, they are largely discussed in separate sections. The focus in both sections is mainly on the intermittent region, which is the streamwise zone in which the unsteady separation shock moves. The topics discussed include: the qualitative description of the wall pressure signals and unsteady separation process, quantitative aspects of the separation shock wave dynamics and the effects of model geometry and flow conditions, and the mechanisms that were proposed as being the cause of the unsteadiness. Also included, is a brief discussion of the dynamics of the separated flow and the outgoing boundary layer downstream of reattachment. Finally a few remarks are made

regarding future work needed to answer some of the many remaining questions.
Author

N90-17573*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
REACTING FLOWS
GEORGE S. DEIWERT and GRAHAM V. CANDLER   *In* AGARD, Special Course on Three-Dimensional Supersonic/Hypersonic Flows Including Separation 28 p (SEE N90-17565 10-02) Jan. 1990
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Features of chemically reacting separated hypersonic flows are identified and issues concerning their analysis and simulation are discussed. Emphasis is placed on flows of high temperature dissociating and ionizing air and current methods for studying and characterizing these flows, including separation, are reviewed. The aeroassist orbital transfer vehicle and its flight trajectory are used for illustration. Thermochemical nonequilibrium phenomena are emphasized and extension of continuum analysis to the high altitude slip-flow regime is considered.
Author

N90-18427# Vrije Univ., Brussels (Belgium). Dept. of Fluid Mechanics.
MEASUREMENT OF VELOCITY PROFILES AND REYNOLDS STRESSES ON AN OSCILLATING AIRFOIL
J. DERUYCK, B. HAZARIKA, and C. HIRSCH   *In* AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 15 p (SEE N90-18405 11-07) Feb. 1990
(Contract DAJA45-85-C-0039)
(AGARD-CP-468) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The flow around a sinusoidally oscillating NACA 0012 airfoil in the presence of the leading edge separation bubble and with leading edge stall, including laminar-turbulent transition is described. The airfoil oscillates about an axis at 25 percent chord from the leading edge, with a nominal reduced frequency of 0.3 and Reynolds number of 300,000. The experiments are made at 4 to 14 deg, 5 to 15 deg, 6 to 16 deg, and 8 to 18 deg angle of attack, covering flow conditions from no stall to full leading edge stall. It is found that the most probable cause of leading edge stall is due to the leading edge separation bubble burst and it occurs as soon as the static stall limit is exceeded. The leading edge stall is not due to the rapid upstream movement of the trailing edge separation. The velocity vectors and the Reynolds stress tensors are measured using a slanted rotating single sensor hot-wire. The complete suction side boundary layer profile and the near wake is surveyed at 5 to 15 deg oscillation where no interaction is observed between the leading edge and the trailing edge flows, and at 8 to 18 deg in full stall conditions.
Author

N90-20977# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Theoretical Fluid Mechanics.
PROGRESS IN INVERSE DESIGN AND OPTIMIZATION IN AERODYNAMICS
HELMUT SOBIECZKY   *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 10 p (SEE N90-20976 14-05) Mar. 1990
(AGARD-CP-463) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Aerodynamic design was developed to an advanced state of the art: inverse methods allow for strong control of aerodynamic airfoil or wing performance so that optimization strategies are no longer beyond practical use and knowledge bases can be established for the implementation in aerodynamic expert systems. Some recent steps into this direction are reviewed.
Author

N90-21013# Centre National de la Recherche Scientifique, Ecully (France).
PARABOLIZED CALCULATIONS OF TURBULENT THREE DIMENSIONAL FLOWS IN A TURBINE DUCT
P. FERRAND, F. LEBOEUF, F. POMMEL, and E. PARKINSON *In* AGARD, Secondary Flows in Turbomachines 9 p (SEE N90-21009 14-07) Feb. 1990 Sponsored by Direction des Recherches et Etudes Techniques, France
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

For a number of practical flows with a dominating convective direction, it is often possible to neglect the diffusive phenomena in this direction. This hypothesis is particularly true in turbomachinery ducts where the Reynolds numbers are usually very high. In this case, the diffusive terms in the main convective direction are eliminated. Concerning the velocity, the problem described by the Navier-Stokes equations becomes parabolic. However, in all the subsonic zones, the pressure tends to transfer the downstream information in the upstream direction, which is typical of an elliptical behavior. As a consequence, eliminating those diffusive terms in the Navier-Stokes equations is not sufficient to obtain a pure problem. The momentum equations have a parabolic nature and can be treated by a space marching resolution. On the opposite, the elliptic nature of the pressure equation has to be taken into account. In a subsonic flow, with highly curved ducts, it is then necessary to define an hybrid parabolic-elliptical method called quasi-elliptical. The idea, based on parabolized methods recognizing the elliptical pressure effect, was already used successfully by Kulisa-Belloir for local reverse flows. In this case, a boundary-layer model is used in strong interaction with a pressure calculation based on a small potential perturbation method generated by the viscous wall flow. The integral equation obtained with Green's theorem restores properly the elliptical effect on the wall, if the elliptical pressure is to be restored in a supersonic boundary-layer. A new method calculating three dimensional flows in turbomachinery ducts with a quasi-ellipticity hypothesis for the velocity field is presented. The main ideas of the method are presented; then its specific aspects are detailed. At last, its capacity is viewed on a representative test case typical of a turbine duct.
Author

N90-21980# Aerospatiale, Chatillon (France). Tactical Missiles Div.
GEOMETRY AND GRIDS OF COMPLEX CONFIGURATIONS FOR AERODYNAMIC CALCULATION [GEOMETRIE ET MAILLAGE DE CONFIGURATIONS COMPLEXES POUR LES CALCULS AERODYNAMIQUES]
GILBERT RANOUX, JEROME LORDON, and JEAN DIET *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 16 p (SEE N90-21975 15-34) Mar. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The methods which are used at Aerospatiale Tactical Missiles Division in order to calculate missile aerodynamics numerically in an industrial way are described. The problems in linking geometry and mesh are stressed. After a few comments about computer aided design (CAD) and its use in a mesh generation scheme, two procedures are presented: the first one, based on the space marching principle, is designed for supersonic flows and the second one propose a multizonal approach for transonic and subsonic flows. Mesh examples and flow results are given for different types of configurations in order to illustrate the two procedures.
Author

N90-21982# Mississippi State Univ., Mississippi State. Dept. of Aerospace Engineering.
UNSTEADY EULER SOLUTIONS ON DYNAMIC BLOCKED GRIDS FOR COMPLEX CONFIGURATIONS
DAVID L. WHITFIELD, J. MARK JANUS, and ABDOLLAH ARABSHAHI *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 13 p (SEE N90-21975 15-34) Mar. 1990
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A numerical method for solving the three-dimensional unsteady Euler equation on dynamic multiblocked grids about complex configurations in transonic flow is presented. Two configurations are considered. The first is a wing-pylon-store configuration with the store in the captive position, and then vertically launched from the wing-pylon. The second is a counter-rotating unducted propfan. The numerical results are validated by comparisons with available experimental data.
Author

N90-21985# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F R) Military Aircraft Div.
GRID PATC APPROACHES FOR COMPLEX THREE-DIMENSIONAL CONFIGURATIONS
W. SCHWARZ, G. HARTMANN, and M. A. SCHMATZ *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 14 p (SEE N90-21975 15-34) Mar. 1990
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Three examples of different grid generation procedures are reported. The first one is based on a single-block approach but nevertheless it is able to handle very complex aircraft configurations and requires only a minimum of user input. This system was the base for the development of the following patched grid method. The next example shows the application of the patched grid technique for the zonal solution of Euler, boundary-layer and Navier-Stokes equations and demonstrates the ability of this method to achieve the necessary local grid refinement for viscous calculations. Finally an application of a patched grid method for an Euler code with a shock fitting approach for supersonic calculations is presented. The grid near the body surface is fixed while the grid in the outer region is moved so that it can be adapted to the location of the bow shock.
Author

N90-21996*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
APPLICATION OF THE TRANAIR RECTANGULAR GRID APPROACH TO THE AERODYNAMIC ANALYSIS OF COMPLEX CONFIGURATIONS
FORRESTER T. JOHNSON, SATISH S. SAMANT, MICHAEL B. BIETERMAN, ROBIN G. MELVIN, DAVID P. YOUNG, JOHN E. BUSSOLETTI (Boeing Advanced Systems Co., Seattle, WA.), and MIKE D. MADSON *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 12 p (SEE N90-21975 15-34) Mar. 1990 Sponsored in part by Boeing Co.
(Contract NAS2-12513)
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 20/4

A numerical method is described which uses a rectangular grid to solve the nonlinear full potential equation about complex configurations. The grid is locally refined to resolve high velocity gradients arising from leading edge expansions or shock waves. The grid penetrates the boundary (described by networks of quadrilateral panels) and is generated automatically. Discrete operators are constructed using the finite element method. The system of nonlinear discrete equations is solved iteratively using a Krylov subspace method preconditioned by an exterior Poisson solver and a direct sparse solver. The primary emphasis is to provide design engineers with an aerodynamic analysis tool (the TRANAIR code) which is accurate, reliable, economical, and flexible to use. Computational results for many interesting configurations are presented.
Author

N90-25947# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
TECHNICAL EVALUATION REPORT ON THE FLUID DYNAMICS PANEL SYMPOSIUM ON COMPUTATIONAL METHODS FOR AERODYNAMIC DESIGN (INVERSE) AND OPTIMIZATION
PRESTON A HENNE and J. W. SLOOFF, ed. (National Aerospace Lab., Amsterdam, Netherlands) Apr. 1990 16 p Symposium held in Loen, Norway, 22-23 May 1989
(AGARD-AR-267; ISBN-92-835-0557-3; AD-A223935) Copyright Avail: NTIS HC A03/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The papers presented at the symposium are reviewed as a whole. Strengths and weaknesses are identified for many of the contributions as each is reviewed. The reviewer closes with some general comments. The 23 papers presented at the Meeting have been collected in AGARD-CP-463. Author

N90-26792# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
EXPERIMENTAL TECHNIQUES IN THE FIELD OF LOW DENSITY AERODYNAMICS
JEAN ALLEGRE, MICHEL RAFFIN, and J. J. BERNARD, ed. (Paris VI Univ., France) Apr. 1990 87 p In FRENCH Original contains color illustrations
(AGARD-AG-318(FR); ISBN-92-835-2115-3) Copyright Avail: NTIS HC A05/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Over the last decade, the development of space programs created some experimental research which has resulted in a better understanding of the character and properties of rarefied gas flow dynamics. Some measurement techniques are examined which are most commonly used in a low density wind tunnel or in the case of altitude simulation. The measurements are designed for subsonic, supersonic, and hypersonic flow at low Reynolds number, and are related to the conditions of reentry flight. The instrumentation used in the average test of low density differs fundamentally from the usual instrumentation of wind tunnel in the ratio of the rarefaction of flow, which limits the amplitude of large measurements (forces, pressure, mass volume) and changes the conditions of viscosity and flow interaction. The rarefaction of the drawn flow generally thickens the boundary layer and alters the shock wave structure. After a short description of the experimental techniques, some discussion is presented of their limits along with certain measurement results from the low density flow. Transl. by E.R.

N91-14278# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
MISSILE AERODYNAMICS
Oct. 1990 391 p In ENGLISH and FRENCH Symposium held in Friedrichshafen, Fed. Republic of Germany, 23-26 Apr. 1990
(AGARD-CP-493; ISBN-92-835-0589-1; AD-A238325) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Current progress and achievements were reviewed, outstanding problems highlighted, and pointers established for planning future research programs. Topics considered were: computational methods and validation; empirical tools and experimental techniques; flow separation and interference effects; unconventional shapes and projectiles; propulsion and base flows; aerothermodynamics; and hypersonics. For individual titles, see N91-14279 through N91-14305.

N91-14279# Aerospatiale, Chatillon (France). Div. Engins Tactiques.
SOME TRENDS IN MISSILE AERODYNAMICS
R. G. LACAU and M ROBERT In AGARD, Missile Aerodynamics 24 p (SEE N91-14278 06-02) Oct. 1990
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The requirements for the next generation of tactical missiles, the corresponding new aerodynamic problems, and the new wind tunnel testing techniques and computational methods were highlighted. Special attention is focused on unconventional shapes as airbreathing missiles, stealth considerations, pyrotechnical lateral jet control, high angles of attack, and non-rigid airframe. The computational codes presented are based on the resolution of the Euler equations; they are illustrated by numerous industrial examples. Author

N91-14280# Royal Aerospace Establishment, Farnborough (England). Dept. of Attack Weapons.
REVIEW OF THE SPRING 1988 AGARD FMP SYMPOSIUM
H. A. TORODE In AGARD, Missile Aerodynamics 8 p (SEE N91-14278 06-02) Oct. 1990
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Missile stability and control topics summarized include aerodynamic prediction codes; high incidence dynamics; wind tunnel experiments; configuration and control; aeroelasticity; test and evaluation; and project descriptions. B.G.

N91-14282# Royal Aerospace Establishment, Bedford (England). Weapon Systems Aerodynamics Div.
PRESSURE MEASUREMENTS ON SLENDER BODIES AT SUPERSONIC SPEEDS AND DEVELOPMENT OF FLOW SEPARATION CRITERA FOR EULER CODES
J. HODGES, L. C. WARD, and T. J. BIRCH In AGARD, Missile Aerodynamics 12 p (SEE N91-14278 06-02) Oct. 1990 Previously announced as X90-72605
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Surface pressure measurements on a cylindrical body with a tangent-ogive nose are described. The Mach number range is 0.7 to 4.5 with incidence angles up to 26 degrees. The high density of the measurements has allowed surface pressure contours to be constructed and detailed flow features can be observed. The measurements have suggested the use of a 2-element approximation to represent the line along which flow separation occurs. Calculations were made using a space-marching Euler code (ZEUSB) both with and without forcing flow separation. Comparisons with experimental data are presented which show that forcing flow separation significantly improves both the surface pressure and force predictions. Conclusions are drawn regarding the use of a 2-element separation line representation within Euler codes. Author

N91-14283# Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.
COMPUTATION OF VISCOUS SUPERSONIC FLOWS
Y. NOGUCHI, J. M. R. GRAHAM, and R. HILLIER In AGARD, Missile Aerodynamics 6 p (SEE N91-14278 06-02) Oct. 1990 Sponsored in part by Ministry of Defence, England
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Finite difference computations aimed at the prediction of the viscous flow field around projectiles and slender bodies at transonic and low supersonic speeds are described. Following a step by step validation process to ensure reliability in the computer program development, the code is tested with an axisymmetric body of revolution at a free stream Mach number of 1.4 and length based Reynolds number of Rex $= 1.0 \times 10(\exp 7)$. Results using Baldwin-Lomax and Johnson-King turbulence models are shown. Author

N91-14284# Naval Surface Warfare Center, Silver Spring, MD. Information and Mathematical Sciences Branch.
SUPERSONIC TACTICAL MISSILE COMPUTATION USING EULER'S EQUATION WITH CROSSFLOW SEPARATION MODELING
F. J. PRIOLO and A. B. WARDLAW, JR. In AGARD, Missile Aerodynamics 11 p (SEE N91-14278 06-02) Oct. 1990
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The space-marching Euler solver, ZEUS, is coupled with a separation model to predict the fully three-dimensional separated flows for supersonic tactical missiles. ZEUS incorporates a multiple zone, gridding technique and a second-order extension of Godunov's method. The separation model assumes a vortex sheet

leaves the surface at the experimentally observed separation point. Computations are performed on missiles which have bodies of circular and elliptic cross sections at incidences high enough to exhibit boundary layer separation. Results show that the separation model was most effective in improving predictions on missiles with circular bodies at Mach numbers below 3.5; but, at higher Mach numbers, predicted loads are not significantly affected. Qualitatively, calculated and measured flow field structures exhibit improved agreement which increases the accuracy of the predicted body and fin loads, however, quantitative flow field differences remain. For elliptic bodies, inviscid solutions are in close agreement with measured surface pressures except near the shoulder where calculations display a crossflow shock. Inclusions of the separation model diminishes the strength of the inviscid crossflow shock in the vicinity of the shoulder but has little influence on the missile loads.   Author

N91-14286# National Aeronautical Establishment, Ottawa (Ontario).
APPLICATION OF EULER AND NAVIER-STOKES CODES TO MISSILE TYPE BODIES WITH HIGH L/D RATIOS
D. J. JONES, J. EVANS, F. J. PRIOLO, WALTER B. STUREK, and A. B. WARDLAW, JR. (Naval Surface Warfare Center, Silver Spring, MD.) *In* AGARD, Missile Aerodynamics 15 p (SEE N91-14278 06-02) Oct. 1990
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Several Euler codes and a parabolized Navier-Stokes code are used to predict normal forces, pitching moments, and centers of pressure on long axisymmetric bodies which are cone cylinders or tangent ogive cylinders one of which has 3 fins. Only supersonic flow situations are considered so that downstream marching methods are valid. The Mach number range is from 2 to 5 and the incidence range is up to 15 degrees.   Author

N91-14287# British Aerospace Public Ltd. Co., Bristol (England). Dept. of Aerodynamics and Vulnerability Research.
NUFA: A SEMI-EMPIRICAL METHOD FOR THE PREDICTION OF ISOLATED WEAPON AERODYNAMICS
S. MCDOUGALL, A. J. PRESS, and P. S. BARRATT *In* AGARD, Missile Aerodynamics 18 p (SEE N91-14278 06-02) Oct. 1990
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The NUFA method was developed from the ABACUS program to provide estimates of weapon aerodynamic loads when immersed in nonuniform, as well as uniform, onset flows. Being semi-empirical in nature, the method is relatively simple and inexpensive to use. The body load prediction method within NUFA has recently undergone significant development to both the inviscid and viscous load contributions including the introduction of an initial square body capability. Results from each of these developments are presented. A feature of NUFA is the ability to provide estimates of body load distributions. This capability was exploited to predict pitch damping derivatives. A comparison with experiment demonstrates a first application of NUFA to aerodynamic derivative prediction. The load distribution facility is further illustrated by predictions using a nonuniform flow as input. It is hoped that the flexibility of the body load prediction method was demonstrated.   Author

N91-14288# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
A SEMI-EMPIRICAL PREDICTION METHOD FOR MISSILE AERODYNAMICS
K.-W. BOCK *In* AGARD, Missile Aerodynamics 11 p (SEE N91-14278 06-02) Oct. 1990
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The calculation procedure of the new semiempirical computer code AAVEX (Aerodynamics of Air Vehicles, Extended version) for the static aerodynamic coefficients of missiles with a body of revolution and up to three cross wings is described. The range of application is: Mach-number M is equal or less than 4, angle of incidence i is equal to or less than 90 degrees, roll angle arbitrary, and all fins independently deflectable. An existing program for

missiles at zero roll angle with wings in + position is extended with respect to the roll angle influence and an improved front to rear wing interference. Special emphasis is set on this extension because it is applicable to other zero roll angle codes and thus might be of general interest. The whole procedure can be roughly divided into three different stages: calculation for wings in + position at zero roll angle; empirical modification of forces and moments for wings in arbitrary position, at given roll angle; and calculation of front to rear wing interference. Especially the second stage is based on a wide data base with systematically varied cross wings at a body of revolution. Although the code is new and has a potential for improvement, the examples presented agree well with experiments.   Author

N91-14289# Istanbul Univ. (Turkey). Dept. of Aeronautics and Astronautics.
AERODYNAMIC CHARACTERISTICS OF CYLINDRICAL BODIES WITH POINTED AND TRUNCATED CONICAL NOSES
V ATLI *In* AGARD, Missile Aerodynamics 12 p (SEE N91-14278 06-02) Oct. 1990
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The aerodynamic characteristics of cylindrical bodies, with pointed and truncated conical noses, are investigated experimentally and theoretically, at a low Mach number, over the range of angle of attack from 0 to 20 deg. The Reynolds number, based on the maximum body diameter is about $4.1 \times 10(exp 4)$. The surface-flow visualization is performed by applying the oil method. The balance measurements are made by using a sting-type strain-gage balance which is designed and constructed under the project T40 of FDP of AGARD. The results of the balance measurements are compared with the potential theory and the method of viscous crossflow analogy. It is observed that the method of viscous cross flow analogy is applicable to the cylindrical bodies with pointed and truncated conical noses even at high angles of attack, unlike the potential theory. The nose-cone angle and the bluntness are the parameters affecting the flowfield around and the aerodynamic characteristics of a pointed or truncated one-cylinder body.   Author

N91-14290# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. fuer Experimentelle Stroemungsmechanik.
SYSTEMATIC INVESTIGATIONS OF BODY-WING-TAIL INTERFERENCE AT HIGH ANGLES OF ATTACK
K. HARTMANN and D. NIKOLITSCH (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Germany, F.R.) *In* AGARD, Missile Aerodynamics 16 p (SEE N91-14278 06-02) Oct. 1990
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Six component measurements were carried out on several combinations of an ogive-circular cylinder body without and with lifting surfaces having rectangular planform and sharp leading and trailing edges. These experiments were performed in the subsonic compressible speed range at various Reynolds numbers up to high angles of attack. For the same geometries the forces and moments were calculated and compared with the experimental results. It was the aim of this combined investigation to get a better understanding of the vortex flows over such body-wing-tail combinations and to generate a reliable data base for the validation and improvement of prediction methods and to obtain hints for a more accurate theoretical modeling of the flow fields.   Author

N91-14291# Aerospatiale, Chatillon (France). Div. Engins Tactiques.
SUPERSONIC VORTEX FLOWS AROUND A MISSILE BODY: BASIC EXPERIMENT AND EULER NUMERICAL COMPUTATION
JEROME LORDON, JEAN-CHRISTOPHER FARE, and DIDIER PAGAN (Office National d'Etudes et de Recherches Aerospatiales, Paris, France) In AGARD, Missile Aerodynamics 15 p (SEE N91-14278 06-02) Oct. 1990 Sponsored in part by Direction des Recherches, Etudes et Techniques, France Original contains color illustrations
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

At high or moderate angles of attack, boundary layers separate and vortices develop on the leeside of tactical missile bodies. The purpose is to validate a numerical approach simulating these supersonic separated flows. In this iterating coupling technique, the inviscid flow is computed by means of an Euler solver in which separation is forced by a parietal treatment. The location of the separation line is given by a boundary layer calculation based on a three-dimensional field method. A detailed experimental study was performed to provide a wide range of comparisons with computations over an ogive-cylinder configuration at Mach 2. Experiments are first described, then computational results are presented for different angles of attack. Calculations over a body-tail configuration finally evaluate the vortical flow interaction with wings. Author

N91-14292*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ASYMMETRIC SUPERSONIC FLOW AROUND CONES WITH NONCIRCULAR SECTIONS
OSAMA A. KANDIL, TIN-CHEE WONG (Old Dominion Univ., Norfolk, VA.), and C. H. LIU In AGARD, Missile Aerodynamics 11 p (SEE N91-14278 06-02) Oct. 1990
(Contract NAS1-18584)
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01/1

The unsteady, compressible, single and double thin-layer, Navier-Stokes equations are used to solve for steady and unsteady, asymmetric, supersonic flow around pointed bodies with noncircular sections at high incidence and zero side slip. The equations are solved by using an implicit, upwind, flux-difference splitting finite-volume scheme. Since the flow is locally conical, the solutions are presented on a cross-flow plane at the axial station of unit. The grid is generated by using a modified Joukowski transformation. The computational applications cover noncircular sections with elliptic and diamond shapes. Unsteady asymmetric vortex shedding has been captured at large angles of attack It is shown that for the same flow conditions and same cross-section fineness ratio, the diamond-section cones develop less flow asymmetry than the elliptic-section cones. Passive control of flow asymmetry was also demonstrated computationally. Author

N91-14293# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
COMPARISON OF DIFFERENT CALCULATION METHODS APPLIED TO A LENTICULAR FUSELAGE SECTION [COMPARASON DE DIFFENENTES METHODES DE CALCUL APPLIQUEES A UN FUSELAGE DE SECTION LENTICULAIRE]
P. DESPINEY In AGARD, Missile Aerodynamics 15 p (SEE N91-14278 06-02; Oct. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Measurements on a non-circular body were made in the ONERA wind tunnels. This model representative of non-conventional missile shapes, was studied for Mach numbers from 0.4 to 4.5, angles of attack up to 20 deg and sideslip angles up to 10 deg. The data base mainly consists of wall static pressure measurements but also of flowfield measurements at Mach number 2 for angles of attack 10 deg and 20 deg. Comparisons between calculations and experiments obtained with different codes are reported: SHABP (a semi-empirical prediction method), ECOPAN, HISSS (panel method), and FLU3C (Euler method). After a brief survey of the

codes their advantages and drawbacks in terms of accuracy and cost-time are shown. Author

N91-14294# Ballistic Research Labs., Aberdeen Proving Ground, MD. Launch and Flight Div.
THREE DIMENSIONAL FLOW CALCULATIONS FOR A PROJECTILE WITH STANDARD AND DOME BASES
JUBARAJ SAHU and CHARLES J. NIETUBICZ In AGARD, Missile Aerodynamics 9 p (SEE N91-14278 06-02) Oct. 1990
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Test firings of the 155 mm XM825 artillery projectile have shown that its flight performance was affected by configurational changes to the base cavity. This was an unexpected result and a clear understanding of why these changes affected the flight behavior did not exist. A computational study was made for the two different base cavity configurations which were flight tested. Flowfield computations were performed at 0.8 is less than M is less than 1.5 and alpha was 4.0 deg using a recently developed 3D Navier-Stokes code. The computed results show the qualitative features of the base region flow field for the two base cavities. The base changes are found to alter the recirculation patterns in the wake which in turn affect the expansion at the base corner. These changes in the flow structure contribute to small changes in the base pressure. Aerodynamic force and moment coefficients were obtained from the computed pressures and are presented as a function of Mach number. Computed results show small differences in normal force and pitching moment coefficients similar to that found in the range data. Author

N91-14295# Ballistic Research Labs., Aberdeen Proving Ground, MD. Launch and Flight Div.
NAVIER-STOKES PREDICTIONS OF STATIC AND DYNAMIC AERODYNAMIC DERIVATIVES FOR HIGH L/D FINNED PROJECTILES
PAUL WEINACHT and WALTER B. STUREK In AGARD, Missile Aerodynamics 12 p (SEE N91-14278 06-02) Oct. 1990
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The current research effort has examined several aspects of the aerodynamics of finned projectiles. These are (1) static aerodynamics at angle of attack, (2) aerodynamics in pure rolling motion, and (3) aerodynamics in steady coning motion. In each case, three-dimensional viscous flow field computations were performed over a range of supersonic Mach numbers using the parabolized Navier-Stokes technique of Schiff and Steger. The computational approach were applied to two high L/D finned projectiles. From the flow field predictions at constant angle of attack, determination of the normal force, pitching moment, and side moment coefficients were made. Computation of the flow field about the projectile in rolling motion has allowed the determination of the roll producing and roll damping moment coefficients, and the equilibrium spin rate. Finally, the predictions of the flow field about the projectile in steady coning motion has allowed prediction of the pitch-damping aerodynamic coefficients. Where possible, comparisons were made between computational results and results obtained from range fringe. Author

N91-14297# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
ANTICIPATION OF AERODYNAMIC COEFFICIENTS OF MISSILE AIR INTAKES [PREVISION DES COEFFICIENTS AERODYNAMIQUES DE MISSILES MUNIS DE PROSES D'AIR]
P. CHAMPIGNY, D. BAUDIN, and P. GONIDEC (Laboratoire de Recherches Balistiques et Aerodynamiques, Vernon, France) In AGARD, Missile Aerodynamics 11 p (SEE N91-14278 06-02) Oct. 1990 In FRENCH; ENGLISH summary
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One of the most promising systems for the propulsion of high performance (velocity, range) missiles of the next generation is the airbreathing propulsion concept (turbojet or ramjet), but it leads to complex configuration with air-intakes. That is why parametric experimental studies were conducted in the LRBA (Laboratoire de Recherches Balistiques et Aerodynamiques) C4 wind-tunnel in

order to evaluate air-intake influence on body lift and center of pressure. Some of the results obtained during this study as well as the prediction method included in the MISSILE code for airbreathing missiles calculations are presented. Author

N91-14298# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Dept. of Aerodynamics.
COMPUTATION OF AXISYMMETRIC BASE FLOW WITH DIFFERENT TURBULENCE MODELS
F. MAGAGNATO *In* AGARD, Missile Aerodynamics 10 p (SEE N91-14278 06-02) Oct. 1990
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The flow past axisymmetrical missile afterbodies with base is calculated using a finite-volume technique. The compressible Reynolds-averaged Navier-Stokes equations are solved with different turbulence models for the approximation of the Reynolds-stresses. Two algebraic eddy-viscosity models, which were adjusted for the use in free-shearlayers, as well as the well known K-epsilon low Reynolds number turbulence model are used. Calculations were done on a conical afterbody with and without a centered propulsive jet. The results are found in good agreement with the experiments although some discrepancies occur in critical flow regions. The algebraic turbulence models were extended to allow a meaningful application in those regions where the performance formerly was poor. Author

N91-14299# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
RESULTS OF GARTEUR ACTION GROUP AG09 ON FLOW PAST MISSILE AFTERBODIES
J. DELERY and B. WAGNER (Dornier-Werke G.m.b.H., Friedrichshafen, Germany, F.R.) *In* AGARD, Missile Aerodynamics 35 p (SEE N91-14278 06-02) Oct. 1990 Original contains color illustrations
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Accurate prediction of the aerodynamic behavior of missiles is still hampered by the lack of knowledge of afterbody flow, the influence of which increases with the complexity of the geometrical configuration. In a recent past, the AGARD Working Group 8 made a rather thorough review of afterbody flow studies by examining both the experimental and the theoretical sides of the question. However, the large majority of calculations were relative to aircraft afterbodies. Thus, due to the lack of reliable information on the aerodynamics of missile afterbodies, the GARTEUR Group of Responsibles for Aerodynamics decided in 1986 the creation of an Action Group (AG09) on this subject. In the course of its activity, the AG has executed the following tasks: constitution of a comprehensive data base on base pressure results containing 158 test cases, testing of 12 semiempirical or multicomponent methods by comparison with the data base, constitution of a data base made of 6 well documented experiments including LDV measurements to test Euler and Navier-Stokes calculation, execution of Navier-Stokes calculations and confrontation of their results with the data base. Author

N91-14300# Rheinmetall G.m.b.H., Duesseldorf (Germany, F.R.).
EXPERIMENTAL AERODYNAMICS FOR HOT GAS JET REACTION CONTROL SYSTEMS
H. SCHILLING, R. FRIEDRICHS, and D. CHRIST (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany, F.R.) *In* AGARD, Missile Aerodynamics 13 p (SEE N91-14278 06-02) Oct. 1990
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The aerodynamic interferences which arise from the interactions between the flow around a configuration and the flow of lateral blowing thrusters are well-known in the supersonic case due to many missile applications. Here some results and experimental investigations which are planned for the very near future, are reported for the case of a subsonic configuration. The EPHRAM concept is a terminal guided submunition which is designed to improve the hit accuracy and effectiveness of

conventional artillery rounds. The flight condition for this concept is typically Mach 0.5 in low altitudes. EPHRAM is controlled by four lateral hot gas thrusters with a design based on mechanical valve switching technology. By applying lateral forces, the configuration develops an angle of attack which is utilized for flight path corrections. Extrapolations from the literature show that there might be a negative jet spoiler effect reducing the aerodynamic normal forces due to interferences between the lateral jet and the configuration flow field. Therefore, experimental investigations have to be performed in order to learn more about the aerodynamic behavior of such systems. In a first test series, the complete model with the operating jet control system was installed in a low speed wind tunnel. The results showed that in the case under investigation there were no severe interferences. However, only a few tests could be performed for a single configuration. So additionally an experimental research program was launched in order to learn more about the basic effects. The experimental apparatus which shall be used is presented and the facilities that are involved in the planned tests are described. The investigations show the importance of a thorough understanding of the phenomena. There is some evidence that by a suitable design the perfomance of subsonic concepts using jet reaction control systems can be improved considerably. Author

N91-14301# Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (Germany, F.R.). Intelligent Systems Div.
LAMINAR/TURBULENT FLOW TRANSITION EFFECTS ON HIGH-SPEED MISSILE DOMES
UWE G. HINGST *In* AGARD, Missile Aerodynamics 8 p (SEE N91-14278 06-02) Oct. 1990
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The new generation of high-speed short range missile has to withstand extreme aerokinetic heating. For IR seeking missiles with its fragile domes the aerokinetic heating effects make further velocity increase difficult. The main driving parameter is the aerothermodynamically imposed stress within the IR-window material. The induced thermal stress is a function of the aerodynamic flow properties around the missile dome, the relevant local boundary layer characteristics and the resulting aerokinetic heating. The analysis of the heat transfer coefficients and resulting temperature fields on hemispherical domes for the laminar and turbulent flow and especially for the transient behavior in between are examined. It will be demonstrated that just the boundary transition from the laminar to the turbulent flow has a significant influence on the imposed window stress. The different influences of the characteristic Reynolds-Numbers, start and end of transition zone, and the resulting stress parameters are investigated. Problems related to the definition of correct transition behavior are discussed. Author

N91-14302# Royal Aerospace Establishment, Farnborough (England).
INVESTIGATIONS OF AEROTHERMODYNAMIC EFFECTS ON AXISYMMETRIC BODIES AT HIGH MACH NUMBERS
J. D. REGAN and T. J. ROOKE *In* AGARD, Missile Aerodynamics 12 p (SEE N91-14278 06-02) Oct. 1990
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
This memorandum describes experimental studies carried out at RAE in the Shock Tunnel and Gun Tunnel to measure the heat transfer rates to a 7 deg blunted cone, to provide data for validation of flow field prediction codes. The tests were carried out at Mach numbers of 7.1 in the Shock Tunnel and at 12.8 in the Gun Tunnel at angles of incidence of up to 25 deg. Some observations are made about the general nature of the flow around the body that can be deduced from surface heat transfer contours and flow field photographs and exemplified for 0, 1, 5, and 20 deg of incidence, and some comparisons between experimental results and theoretical predictions are presented. Author

N91-14303# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Experimental Fluid Mechanics.
THERMAL IMAGING ON MISSILES IN HYPERSONIC FLOW
HENNING SCHOELER In AGARD, Missile Aerodynamics 8 p (SEE N91-14278 06-02) Oct. 1990 Original contains color illustrations
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The method of thermal imaging with liquid crystals developed at DLR Goettingen is briefly described, and some applications in the DLR Ludwieg tube are presented. As the temperature sensor is sprayed on the model no expensive instrumentation is required. Responding to temperature variation the liquid crystals show a color play which directly visualizes surface temperature fields. For qualitative heat transfer measurements, it is sufficient to photograph or video record the model while it is exposed to the flow. Author

N91-14304# Nielsen Engineering and Research, Inc., Mountain View, CA. Engineering Aerodynamics Div.
CHORDWISE AND SPANWISE CENTERS OF PRESSURE OF MISSILE FINS
DANIEL J. LESIEUTRE and MARNIX F. E. DILLENIUS In AGARD, Missile Aerodynamics 12 p (SEE N91-14278 06-02) Oct. 1990
(Contract N00014-80-C-0700; F33615-86-C-3626)
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The extensive triservice experimental data base was investigated and used to obtain a fin chordwise and spanwise center of pressure data base for use in the preliminary analysis and design of missile fins. Correlations and curve fits of the center of pressure data were performed to reduce the storage and computation time required to obtain engineering level predictions of fin hinge and bending moments. The method developed is simple to use and is easily incorporated into comprehensive missile aeroprediction methods. The method is extremely valuable because it includes effects due to real flow and fin-body gaps inherent in the experimental data base. The experimental data base, its manipulation, and its implementation into a prediction method are described. Author

N91-14305# Science Applications International Corp., Fort Washington, PA. Fluid Sciences Div.
COMPUTATIONAL MODELS WITH ADVANCED THERMOCHEMISTRY FOR THE ANALYSIS OF MISSILE/PLUME FLOWFIELD INTERACTIONS
S. M. DASH, N. SINHA, and B. J. YORK In AGARD, Missile Aerodynamics 30 p (SEE N91-14278 06-02) Oct. 1990
(Contract N00014-87-C-0549)
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Advanced computational models which solve the full (FNS) and parabolized (PNS) Navier-Stokes equations for the analysis of missile aerodynamic problems with exhaust plume interactions are described. The models utilize conservative implicit algorithms and include finite-rate chemistry, two-equation turbulence models, and preliminary multi-phase flow capabilities. In the tactical missile arena, a 3D Navier-Stokes code, PARCH, was developed to analyze missile/plume interactions with both conventional nozzle exhausts, as well as with bifurcated/scarfed nozzle exhausts. The PNS work has focused on supersonic/hypersonic applications utilizing time-iterative upwind numerics for enhanced robustness and accuracy, and has included the analysis of aerodynamic, plume, and propulsive problems for missiles as well as for reentry and aerospace vehicles. Author

N91-14331# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Aeroelasticity.
UNSTEADY AERODYNAMIC FORCES ON AN OSCILLATING WING AT HIGH INCIDENCES AND FLOW SEPARATION
H. W. FOERSCHING In AGARD, Aircraft Dynamic Loads Due to Flow Separation 18 p (SEE N91-14324 06-05) Sep. 1990
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Based on wind tunnel measurements on a low-aspect-ratio trapezoidal half-wing model in incompressible flow, some characteristic features of motion-induced unsteady airloads at high incidences and flow separation are presented and discussed. Special emphasis is placed on the effect of the motion of the wing on the flow separation processes and on the investigation of the interactions between the separated flow phenomena on the stationary wing and the motion-induced unsteady airloads on the oscillating wing. It is shown that these airloads are strongly affected by the flow separations and that their prediction from inviscid potential-flow theory may lead to rather unrealistic results in buffeting response calculations. Author

N91-14340*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
UNSTEADY AIRLOADS DUE TO SEPARATED FLOW ON AIRFOILS AND WINGS
JOHN W. EDWARDS In AGARD, Aircraft Dynamic Loads Due to Flow Separation 18 p (SEE N91-14324 06-05) Sep. 1990
Previously announced in IAA as A90-33311
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Experimental and computational studies of airloads due to separated flows over airfoils and wings conducted at the NASA Langley Research Center are surveyed. Results are presented for cases involving local flow separation such as shock-induced separation, for the initiation of leading-edge vortex flows, and for cases involving unsteady airloads due to flows separating over remote aircraft components. Good correlation is obtained between experiment and computation for cases of locally separating flow and steady computations of vortex flow over delta wings and complex forebody geometries are shown. Physical flow modeling issues and computational requirements for the case of vertical tail buffeting are developed. Author

N91-18035# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON INVERSE METHODS FOR AIRFOIL DESIGN FOR AERONAUTICAL AND TURBOMACHINERY APPLICATIONS
Nov. 1990 259 p Course held in Rhode-Saint-Genese, Belgium, 14-18 May 1990; sponsored by AGARD and the von Karman Inst.
(AGARD-R-780; ISBN-92-835-0591-3; AD-A230761) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Three major aspects of airfoil design are examined for both aeronautical and turbomachine application. Optimization of target pressure distribution and velocity distribution are studied. Both direct optimization resulting from an inverse boundary layer calculation and an iterative optimization of the losses are presented. Airfoil design by means of inverse methods is also studied. This ranges from simple parametric definitions of 2-D cross sections to a detailed numerical definition of 3-D shapes. The methodology to account for a large number of constraints and off-design operation is also discussed and illustrated by a large number of applications. For individual titles, see N91-18036 through N91-18047.

N91-18036# Pennsylvania State Univ., University Park. Dept. of Aerospace Engineering.
AERODYNAMIC SHAPE DESIGN
GEORGE S. DULIKRAVICH In AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 10 p (SEE N91-18035 10-02) Nov. 1990
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Design of aerodynamic shapes can be accomplished by using the methodologies from computational fluid dynamics and optimization. Two basic categories of the inverse (design) formulations are surface flow design and flow field design. A number of methods in both categories are discussed and critically evaluated. Open questions remain to be specified of a more appropriate surface pressure, acceleration of iterative algorithms, increased versatility of the design methods, direct use of the existing and future flow field analysis software. Author

N91-18037# National Technical Univ., Athens (Greece). Thermal Turbomachinery Lab.
ARBITRARY BLADE SECTION DESIGN BASED ON VISCOUS CONSIDERATIONS
K. D. PAPAILIOU and B. BOURAS In AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 53 p (SEE N91-18035 10-02) Nov. 1990
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Theoretical tools are proposed that may help the designer in aerodynamic design. In fact, a complete (viscous and inviscid) inverse procedure is proposed, but, it is pointed out that in order to obtain results, it has to be combined with a sound direct (analysis) one. Various examples are chosen in order to demonstrate the use of the proposed tools. These examples do not cover all cases, but rather converge to the conclusion that the proposed tools may prove to be quite useful, while each design must be considered as a separate case. Author

N91-18038# National Aerospace Lab., Amsterdam (Netherlands).
OPTIMIZATION OF TARGET PRESSURE DISTRIBUTIONS
R. F. VANDENDAM, J. A. VANEGMOND, and J. W. SLOOFF In AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 13 p (SEE N91-18035 10-02) Nov. 1990
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An overview is presented of the possibilities and problems associated with the use of numerical optimization techniques in aerodynamic design. First, an inventory is made of the alternative aerodynamic design methods, the numerical optimization approach being one of them. The development of optimizing design methods is outlined and a short exposition of the state of the art in numerical optimization is given. This is followed by a discussion on the practical use of numerical optimization techniques in aerodynamic design, in particular the inverse numerical optimization approach. An important step in this approach is the optimization of target pressure distributions, which are used in inverse methods to find the corresponding geometry. The procedure for finding target pressure distributions is explained and illustrated by some examples. Author

N91-18039# Grumman Aerospace Corp., Bethpage, NY.
GEOMETRIC AND SURFACE PRESSURE RESTRICTIONS IN AIRFOIL DESIGN
G. VOLPE In AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 14 p (SEE N91-18035 10-02) Nov. 1990
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In order to design a physically acceptable airfoil that corresponds to a prescribed surface pressure or speed distribution, various restrictions have to be met by the imposed target and by the contour. It is shown that the need to meet geometric prerequisites and a specified free stream value imposes constraints on the prescribed surface values which, unless satisfied, inhibit the existence of a solution. In this classical problem of airfoil design, the prescribed surface distribution must contain enough degrees of freedom in order that it may be modified sufficiently to satisfy the contraints. The nature of the constaints is discussed, and they are expressed in forms which are amenable to numerical solution procedures in transonic as well as incompressible flows. THe discussion is accompanied by a description of the general characteristics of airfoil geometries and surface flows. Author

N91-18040# Grumman Aerospace Corp., Bethpage, NY.
TRANSONIC SHOCK FREE WING DESIGN
G. VOLPE In AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 16 p (SEE N91-18035 10-02) Nov. 1990
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The problem of constructing wing profiles that yield specified pressure distributions and/or performance characteristics is discussed. A practical solution to the problem, which consists of a physically acceptable profile, exists only if certain constraints are satisfied by the prescribed characteristics and by the profile itself. These constraints are addressed in various manners by the several methodologies that are proposed. The various approaches are discussed along with the relative advantages and disadvantages of each. The inverse approach is considered in detail to provide a link to the classical incompressible design problem and to establish a raison d'etre for the other methodologies. Author

N91-18041# Pennsylvania State Univ., University Park. Dept. of Aerospace Engineering.
A STREAM-FUNCTION-COORDINATE (SFC) CONCEPT IN AERODYNAMIC SHAPE DESIGN
GEORGE S. DULIKRAVICH In AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 6 p (SEE N91-18035 10-02) Nov. 1990
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A new approach to the inverse design of 2-D aerodynamic shape was developed. This formulation is based on a Stream Function Coordinate (SFC) concept for steady, irrotational, compressible, inviscid, planar flows. It differs from the classical stream function formulation in that it treats the y coordinate of each point on a streamline as a function of the x coordinate and the stream function psi, i.e., Y = Y(x,psi). This new formulation is especially suitable for the computation of stream line shapes, and therefore, for determination of aerodynamic shapes subject to specified surface pressure distributions. An additional advantage of this new formulation is that it requires the generation of only a 1-D grid in the x direction. The grid in the y direction is computed as a part of the solution since y coordinates of the streamlines are treated as the unknowns in the SFC formulation. In addition, the SFC method is equally suitable for the analysis of the flow fields around given shapes. A computer code was developed on the basis of SFC formulation. It is capable of performing flow field analysis and inverse design of airfoil cascade shapes by changing a single input parameter. Author

N91-18042# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
SUBSONIC AND TRANSONIC CASCADE DESIGN
OLIVIER LEONARD In AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 18 p (SEE N01-18035 10-02) Nov. 1990
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Two iterative methods for blade design, using direct flow solvers and a blade geometry change algorithm, are presented. Both procedures start with the analysis of a given cascade geometry using an existing flow solver. The difference between the calculated velocity distribution and the required one is used to calculate a flow distortion. In the first method, this flow distortion is produced by singularities while in the second method the distortion is derived by imposing the required velocity distribution as a boundary

condition. This flow distortion is used by the modification algorithm and results in a new blade shape for which the calculated velocity is closer to the desired one. Examples for both subsonic and transonic flows are presented and show a rapid convergence to the geometry required for the desired velocity distribution. The main advantage of the proposed method is that existing analysis codes can be used, for the design and for the off-design analysis. Some restrictions which have to be imposed on the required velocity distributions are also discussed. Author

N91-18043# Politecnico di Torino (Italy).
INVERSE METHODS FOR 3D INTERNAL FLOWS
LUCA ZANNETTI and FRANCESCO LAROCCA (Fiat Aviazione S.p.A., Turin, Italy) *In* AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 16 p (SEE N91-18035 10-02) Nov. 1990
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   The objective was a numerical method for designing 3-D ducts and blade rows. The method applies to inviscid compressible rotational flow, and it is based on the time dependent technique. The walls where the design pressure is prescribed are considered as flexible and impermeable. Starting from some initial guessed configuration, the computation follows the transient which occurs while the flexible walls move and finally reach a steady shape. Author

N91-18044# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.
VISCOUS AND INVISCID INVERSE SCHEMES USING NEWTON'S METHOD
MARK DRELA *In* AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 16 p (SEE N91-18035 10-02) Nov. 1990
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   Developments in design analysis methodology for airfoils and cascades are presented. Shortcomings of standard inverse methods in flows involving shock waves are overcome by a modal geometry perturbation inverse method driven by a least squares pressure mismatch minimization. The method is incorporated into an existing viscous inviscid zonal method. Simultaneous solution of the flow field equations and the pressure mismatch minimization equations is obtained by a full Newton method. This leads to very large computational savings compared to traditional minimization methods. The method is also applicable to viscous flows with or without separation regions present. The Newton based solution scheme, which yields sensitivity information as a by-product, also allows very efficient solution of general optimization problems. Perturbation of the geometry and flow field is specified outside of the Newton solver so as to drive any aerodynamic and/or geometric quantity to its minimum. The availability of free sensitivity information and the rapid reconvergence property of the Newton method after each optimization cycle again gives very large computational savings. Author

N91-18045# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Dept. of Aerodynamics.
ONE POINT AND MULTI-POINT DESIGN OPTIMIZATION FOR AIRPLANE AND HELICOPTER APPLICATION
J. J. THIBERT *In* AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 47 p (SEE N91-18035 10-02) Nov. 1990
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   Numerical optimization techniques are described and the use is shown as to how these techniques can be used. Emphasis is put on the applications with various optimization cases described in details. One point optimization cases for airfoil and wing designs with different objective functions, constraints and design variables are presented as well as multiple design point cases for helicopter blade airfoil applications. Author

N91-18046# National Aerospace Lab., Amsterdam (Netherlands).
CONSTRAINED SPANLOAD OPTIMIZATION FOR MINIMUM DRAG OF MULTI-LIFTING-SURFACE CONFIGURATIONS
R. F. VANDENDAM *In* AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 15 p (SEE N91-18035 10-02) Nov. 1990
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   A method is presented for the determination of optimal spanloads for multi lifting surface configurations. Algorithms are given for choosing the spanwise distributions of lift, pitching moment, chord and thickness to chord ratio of lifting elements. The choices are optimal in that they minimize induced plus viscous drag while satisfying constraints of aerodynamic, flight mechanical, and structural nature. The configuration that can be dealt with, may consist of a number of segments representing, for instance, wings or parts of wings, horizontal tails or canards, winglets, flap rail fairings, etc. Also the interaction between propellers and lifting elements may be included in the procedure. The induced drag is computed using the Trefftz plane integral, while the viscous drag follows from form factor methods. Novel mathematical formulations of the constrained optimization problem are used, that are based on the calculus of variations. The method can be used as a first step in the inverse numerical optimization approach to provide a starting point for the specification of target pressure distributions. Theoretical models and methods underlying the analysis and optimization are presented. Author

N91-18047# Sverdrup Technology, Inc., Eglin AFB, FL.
AERODYNAMIC OPTIMIZATION BY SIMULTANEOUSLY UPDATING FLOW VARIABLES AND DESIGN PARAMETERS
M. H. RIZK *In* AGARD, Special Course on Inverse Methods for Airfoil Design for Aeronautical and Turbomachinery Applications 22 p (SEE N91-18035 10-02) Nov. 1990 Previously announced as N90-20991
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   The application of conventional optimization schemes to aerodynamic design problems leads to inner-outer iterative procedures that are very costly. An alternative approach is presented based on the idea of updating the flow variable iterative solutions and the design parameter iterative solution simultaneously. Two schemes based on this idea are applied to problems of correcting wind tunnel wall interference and optimizing advanced propeller designs. Computations are performed to test the schemes' efficiency, accuracy, and sensitivity to variations in the computational parameters. Author

N91-18048# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
AERODYNAMICS OF ROTORCRAFT
Nov. 1990 307 p Special course held in Rhode-Saint Genese, Belgium, 2-5 Apr. 1990, in Ankara, Turkey, 9-11 Apr. 1990, and at Moffett Field, CA, 14-17 May 1990; sponsored by AGARD and the von Karman Inst.
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   The course first summarizes the various configurations of different rotary-wing aircraft and the simple methods to calculate their performance. Methods for designing efficient rotors are explained and justified. The optimization codes for airfoil and blade determinations are described. The rotor design can be improved by using advanced three dimensional aerodynamic codes, whose actual possibilities are presented. The consequences of specific aerodynamic phenomena are examined, such as rotor wake on blade airloads and on rotor noise prediction. The state of the art of fuselage aerodynamics and on the problems related to rotor wake and fuselage interactions is given. An important part of the course is devoted to the experimental methods used for wind-tunnel and flight tests, in order to understand correctly the physical phenomena involved, and to acquire reliable data necessary for code validation. For individual titles, see N91-18049 through N91-18058.

N91-18049# Sikorsky Aircraft, Stratford, CT. Research and Advanced Design Div.
OVERVIEW OF HELICOPTER AND V/STOL AIRCRAFT
EVAN A. FRADENBURGH *In* AGARD, Aerodynamics of Rotorcraft 18 p (SEE N91-18048 10-02) Nov. 1990
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     The development and history of the helicopter are briefly reviewed. Fundamental mechanisms of the helicopter are then described. The addition of auxiliary propulsion to a winged helicopter eliminates the restriction to normal speed. Rotorcraft configuration for high speed performance is examined. V/STOL concepts and economic impact are discussed. The roles of system complexity and reliability are discussed with an emphasis on cost effectiveness The relationship of technical aerodynamics is examined against a background of other aspects of rotorcraft.
B.G.

N91-18050# Sikorsky Aircraft, Stratford, CT. Research and Advanced Design Div.
BASIC AERODYNAMICS FOR ROTOR PERFORMANCE
EVAN A. FRADENBURGH *In* AGARD, Aerodynamics of Rotorcraft 12 p (SEE N91-18048 10-02) Nov. 1990
(AGARD-R-781) Copyright Avail: NTIS HC/MF A14;
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     Basic physics fundamental to helicopter flight; rotor and propeller performance in axial flight; hover performance; helicopter power requirements for forward flight; autorotation; ground effect and vertical drag effect; blade element theories; use of dimensionless coefficients for helicopter performance; and rotor lift drag ratio as a measure of aerodynamic efficiency are briefly discussed.
B.G.

N91-18051# Aerospatiale, Marignane (France). Helicopter Div.
ROTOR AND BLADE AERODYNAMIC DESIGN
A. VUILLET *In* AGARD, Aerodynamics of Rotorcraft 59 p (SEE N91-18048 10-02) Nov. 1990
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     This course is mainly related to the main rotor while the tail rotor and fenestron design are also discussed. The rotor is one of the helicopter's most specific component and plays a significant role as far as performance is concerned. The objective is to describe methods and give effective results that are useful in the design of a helicopter. The rotor's general sizing is discussed first. Studying engine failures and performance in autorotation as well as the power required in hover usually determines the rotor diameter; peripheral speed is selected in accordance with noise criteria; and the chord is dependent on the target maximum speed and load factor. The selection of the number of blades is more difficult and decided according to the vibration level transmitted at the airframe or noise rather than aerodynamic criteria. The rotor calculation methods, i.e., blade balance energy, blade element theory, and vortex theory are then described with a judgment as to their efficiency. The numerical optimization techniques are presented with their advantages by giving application examples on the selection of airfoil distribution spanwise. Fine optimization of the blade itself where the evolution of the airfoil design methods is explained with OA airfoils as an example is presented. The results obtained with blade planforms and tip shapes are largely discussed and two contradictory trends, i.e., blade tapering and enlarged tip as on WHL's BERP blade are presented. The influence of the anhedral and twist optimization are discussed. Tail rotor and fenestron designs are discussed.
Author

N91-18052# Westland Helicopters Ltd., Yeovil (England). Dept. of Aerodynamics.
FUSELAGE AERODYNAMIC DESIGN ISSUES AND ROTOR/FUSELAGE INTERACTIONAL AERODYNAMICS. PART 1: PRACTICAL DESIGN ISSUES
F. T. WILSON *In* AGARD, Aerodynamics of Rotorcraft 16 p (SEE N91-18048 10-02) Nov. 1990
(AGARD-R-781) Copyright Avail: NTIS HC/MF A14;
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     The more important helicopter fuselage aerodynamic design issues and also interactional problems faced by the helicopter airframe aerodynamicist, including performance and handling optimization and special effects caused by rotor downwash impingement on the fuselage at low and high speeds are addressed. The experimental approach remains the principal tool for the solution of helicopter fuselage aerodynamic problems since existing theoretical methods still possess deficiencies such as an inability to model strong three dimensional effects and separated flow areas both on the fuselage and aft of the rotor head. Flight testing is not generally used for helicopter fuselage aerodynamic research work and the use of small scale wind tunnel models remains the principal experimental tool for airframe design. However, CFD methods are being increasingly used to supplement wind tunnel testing and research programs are underway to constantly improve and update techniques in both fuselage and rotor/fuselage interactional aerodynamics.
Author

N91-18053# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).
FUSELAGE AERODYNAMICS DESIGN ISSUES AND ROTOR/FUSELAGE INTERACTIONAL AERODYNAMICS. PART 2: THEORETICAL METHODS
S. R. AHMED *In* AGARD, Aerodynamics of Rotorcraft 38 p (SEE N91-18048 10-02) Nov. 1990
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     Theoretical methods currently available to predict helicopter fuselage flow and interaction phenomena are reviewed. In view of the enormous challenge a helicopter flow field poses for CFD, only inviscid flow codes with subsequent viscous corrections have found applications in industry. The basic modules of such methods to treat the isolated fuselage flow are explained and the predictions compared with experimental data. Also newer developments, to devise codes based on time-averaged or time-dependent Navier-Stokes equations are discussed and their present capabilities indicated. Interaction phenomena remains for the foreseeable future beyond the possibilities of present viscous flow codes. Status and development trends of inviscid codes to simulate rotor/body/wake interaction phenomena is discussed and evaluated.
Author

N91-18054*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE APPLICATION OF CFD TO ROTARY WING FLOW PROBLEMS
F. X. CARADONNA (Army Aviation Research and Development Command, Saint Louis, MO.) *In* AGARD, Aerodynamics of Rotorcraft 38 p (SEE N91-18048 10-02) Nov. 1990
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     Rotorcraft aerodynamics is especially rich in unsolved problems, and for this reason the need for independent computational and experimental studies is great. Three-dimensional unsteady, nonlinear potential methods are becoming fast enough to enable their use in parametric design studies. At present, combined CAMRAD/FPR analyses for a complete trimmed rotor solution can be performed in about an hour on a CRAY Y-MP (or ten minutes, with multiple processors). These computational speeds indicate that in the near future many of the large CFD problems will no longer require a supercomputer. The ability to convect circulation is routine for integral methods, but only recently was it discovered how to do the same with differential methods. It is clear that the differential CFD rotor analyses are poised to enter the engineering workplace. Integral methods already constitute a mainstay. Ultimately, it is the users who will integrate CFD into

the entire engineering process and provide a new measure of confidence in design and analysis. It should be recognized that the above classes of analyses do not include several major limiting phenomena which will continue to require empirical treatment because of computational time constraints and limited physical understanding. Such empirical treatment should be included, however, into the developing CFD, engineering level analyses. It is likely that properly constructed flow models containing corrections from physical testing will be able to fill in unavoidable gaps in the experimental data base, both for basic studies and for specific configuration testing. For these kinds of applications, computational cost is not an issue. Finally, it should be recognized that although rotorcraft are probably the most complex of aircraft, the rotorcraft engineering community is very small compared to the fixed-wing community. Likewise, rotorcraft CFD resources can never achieve fixed-wing proportions and must be used wisely. Therefore the fixed-wing work must be gleaned for many of the basic methods. Author

N91-18055# Johnson Aeronautics, Palo Alto, CA.
AIRLOADS, WAKES, AND AEROELASTICITY
WAYNE JOHNSON In AGARD, Aerodynamics of Rotorcraft 20 p (SEE N91-18048 10-02) Nov. 1990 Previously announced as N90-21738
(AGARD-R-781) Copyright Avail: NTIS HC/MF A14;
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Fundamental considerations regarding the theory of modeling of rotary wing airloads, wakes, and aeroelasticity are presented. The topics covered are: airloads and wakes, including lifting-line theory, wake models and nonuniform inflow, free wake geometry, and blade-vortex interaction; aerodynamic and wake models for aeroelasticity, including two-dimensional unsteady aerodynamics and dynamic inflow; and airloads and structural dynamics, including comprehensive airload prediction programs. Results of calculations and correlations are presented. Author

N91-18056# McDonnell-Douglas Helicopter Co., Mesa, AZ. Aero/Acoustics Div.
AEROACOUSTICS OF ROTORCRAFT
R. D. JANAKIRAM In AGARD, Aerodynamics of Rotorcraft 33 p (SEE N91-18048 10-02) Nov. 1990
(AGARD-R-781) Copyright Avail: NTIS HC/MF A14;
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A review of the state-of-the-art of rotorcraft aeroacoustics with emphasis on helicopter noise is presented. The fundamentals of rotorcraft aeroacoustics are discussed in terms of the underlying source mechanisms, theoretical models and prediction methodologies in three categories of rotor noise: rotational (non-impulsive) noise; impulsive noise including high-speed impulsive noise, blade-vortex interaction noise and main rotor/tail rotor interaction noise; and broadband noise. Key model rotor and flight test experiments are also discussed. Recent developments, especially those that occurred in the 1980s in the area or rotorcraft (or helicopter) aeroacoustics are discussed in three categories: aeroacoustic testing and data base development, noise prediction, and noise reduction. Author

N91-18057# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
CONSIDERATIONS ON WIND-TUNNEL TESTING TECHNIQUES FOR ROTORCRAFT
J. J. PHILIPPE In AGARD, Aerodynamics of Rotorcraft 34 p (SEE N91-18048 10-02) Nov. 1990
(AGARD-R-781) Copyright Avail: NTIS HC/MF A14;
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For many years, wind-tunnel testing is a necessity when designing and building a rotorcraft. The first reason is certainly the fact that numerical methods are still far from being capable of accurate rotor and fuselage performance prediction. Even if now there are more and more sophisticated codes, more and more detailed experimental results are needed in order to validate these codes and to fix their domain of validity. The second reason for wind-tunnel testing is to reduce risks and costs in rotorcraft development, especially if using a new design or if flying in a flight domain not yet explored or one that is considered dangerous.

Try before flying is perhaps even more necessary for the rotary wing aircraft community than for the fixed-wing community, due to the complexity of the configurations involved in an aircraft having to assure vertical take-off, hover, and forward flight. The third reason for wind-tunnel testing is related to the need for optimized configuration: too many parameters are concerned with this aim and it would be unrealistic to try to build and test too many full-scale prototypes. Wind-tunnel testing is a good way to confirm the performance of a specific design and to select the most appropriate configuration to build for flight testing and validation. Author

N91-18058# Royal Aerospace Establishment, Bedford (England). Helicopter Aeromechanics Section.
EXPERIMENTAL TECHNIQUES IN HELICOPTER AERODYNAMICS FLIGHT RESEARCH
P. BROTHERHOOD and M. J. RILEY In AGARD, Aerodynamics of Rotorcraft 25 p (SEE N91-18048 10-02) Nov. 1990
(AGARD-R-781) Copyright Avail: NTIS HC/MF A14;
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The techniques used in the study of main and tail rotor aerodynamics by measurements on full-scale helicopters in flight are described. The strengths and weaknesses of flight research are discussed and some comparisons with wind tunnel techniques are drawn. The application of various types of sensors is discussed together with a more general discussion on data acquisition, recording, and processing. Airworthiness aspects including fatigue damage monitoring are also considered. Examples which illustrate the various techniques and provide informative comparisons with theory are presented. The use of comparative techniques in which opposite blades in a single rotor are individually modified and the use of indicator sensors to supplement or replace complete chordwise pressure distributions are highlighted. Author

N91-22105# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
UNSTEADY AERODYNAMICS OF SLENDER WINGS
ROBERT C. NELSON In AGARD, Special Course on Aircraft Dynamics at High Angles of Attack: Experiments and Modelling 26 p (SEE N91-22104 14-05) Mar. 1991
(AGARD-R-776) Copyright Avail: NTIS HC/MF A07;
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A review of unsteady aerodynamics for slender wings undergoing large amplitude motions is presented. Static and unsteady aerodynamics characteristics are discussed, and the relationship between the aerodynamic loads and the leeward structure is investigated. Data is presented showing the influence of the wing motion on the aerodynamic loads. Both large amplitude pitching and rolling motion experimental results are discussed. In the case of large amplitude pitching motions, significant aerodynamic hysteresis is apparent. The hysteresis in the aerodynamic loads is shown to be related to the delay in vortex breakdown on the upstroke and the delay in the re-establishment of the leading edge vortical flow after complete flow separation on the downstroke. A second example of unsteady aerodynamics, namely the phenomenon of wing rock, is examined. Author

N91-22108# National Research Council of Canada, Ottawa (Ontario).
LARGE AMPLITUDE OSCILLATIONS
E. S. HANFF In AGARD, Special Course on Aircraft Dynamics at High Angles of Attack: Experiments and Modelling 19 p (SEE N91-22104 14-05) Mar. 1991
(AGARD-R-776) Copyright Avail: NTIS HC/MF A07;
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Over the past several years a consensus has been developing that the locally linear analysis technique is inadequate for the prediction of aircraft behavior in the nonlinear regime. This situation arises mainly in flight at high angles of attack, particularly during large-amplitude and high-rate maneuvers, where the flow may be severely separated, vortex dominated, and time dependent. In recognition of this situation, work is currently underway to develop techniques that can provide a better physical understanding and more accurate prediction capabilities of aircraft behavior in this regime. Much of the effort is of a rather theoretical nature, essentially consisting of a attempt to identify and implement a

mathematical formalism capable of handling the various types of nonlinearities present under the above conditions. Presented here is a more empirical formulation for the treatment of aerodynamic nonlinearities and time dependence, which is based on a knowledge of the instantaneous values of the pertinent motion variables. A wind tunnel technique and rig used at the Institute for Aeronautical Research (IAR) to obtain the necessary data is described as well as some interesting results. A brief review of work involving large amplitude oscillations being conducted at the Royal Aircraft Establishment (RAE) is also included. Author

N91-22109# Royal Aircraft Establishment, Bedford (England). Aerodynamics Dept.
OSCILLATORY DATA FOR TYPICAL CONFIGURATIONS
C. O. OLEARY In AGARD, Special Course on Aircraft Dynamics at High Angles of Attack: Experiments and Modelling 18 p (SEE N91-22104 14-05) Mar. 1991
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Since the early 1950's many aircraft configurations, nearly all military, have been tested on a variety of oscillatory rigs. There is a need for reliable test data on new configurations prior to flight testing and for general research on dynamic flight characteristics of combat aircraft. Examples of published test data on small amplitude oscillatory derivatives from three research centers are presented in order to give some insight into the effects of configuration, model attitude, frequency parameter, etc. on the stability derivatives. Data is given on the effect of a wing planform on a fighter configuration; forced oscillation; the effects of canards, tails, and fuselage strakes on a three-surface configuration; and subsonic roll oscillation tests on the standard dynamics model. Author

N91-23161# Cranfield Inst. of Tech., Bedford (England). Coll. of Aeronautics.
SOME ASPECTS OF SHOCK-WAVE BOUNDARY LAYER INTERACTION RELEVANT TO INTAKE FLOWS
J. L. STOLLERY In AGARD, Hypersonic Combined Cycle Propulsion 14 p (SEE N91-23147 15-07) Dec. 1990
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Four main topics are discussed: (1) 2-D shock induced separation; (2) 3-D glancing interaction; (3) shock/snock boundary layer interaction; and (4) hypersonic viscous interaction. Wherever possible both laminar and turbulent flows are considered and reference is made to experimental data and to the results of mathematical modeling. Some thoughts on future research topics are presented along with the facilities needed to pursue them. Author

N91-23162*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPUTATIONAL MODELING AND VALIDATION FOR HYPERSONIC INLETS
LOUIS A. POVINELLI In AGARD, Hypersonic Combined Cycle Propulsion 10 p (SEE N91-23147 15-07) Dec. 1990 Previously announced as N90-22011
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20;
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Hypersonic inlet research activity at NASA is reviewed The basis is the experimental tests performed with three inlets. the NASA-Lewis Mach 5, the McDonnell Douglas Mach 12, and the NASA-Langley Mach 18. Both 3-D parabolized Navier-Stokes and Navier-Stokes codes were used to compute the flow within the three inlets. Modeling assumptions in the codes involve the turbulence model, the nature of the boundary layer, shock wave boundary layer interaction, and the flow spilled to the outside of the inlet. Use of the codes in conjunction with the experimental data are helping to develop a clearer knowledge of the inlet flow physics and to focus on the modeling improvements required in order to arrive at validated codes. Author

N91-23164# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst fuer Antriebstechnik.
AERODYNAMICS AND STABILIZATION OF COMBUSTION OF HYDROGEN JETS INJECTED INTO SUBSONIC AIRFLOW
J. KOOPMAN, M. RACHNER, H. WIEGAND, and H. EICKHOFF In AGARD, Hypersonic Combined Cycle Propulsion 16 p (SEE N91-23147 15-07) Dec. 1990
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The aerodynamics and stabilization of burning hydrogen jets, injected transversally into a subsonic airstream, were investigated. The structural behavior of deflecting cold and burning jets were studied by flow visualization. Experiments and numerical analysis on jet penetration were performed. Flame extinction limits of 'wake stabilized' flames were established and correlated. Author

N91-23174# Rome Univ. (Italy). Dipt. di Meccanica e Aeronautica.
REACTING SHOCK WAVES IN HYPERSONIC PROPULSION APPLICATIONS
M. ONOFRI In AGARD, Hypersonic Combined Cycle Propulsion 10 p (SEE N91-23147 15-07) Dec. 1990
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Problems connected to the occurrence of finite rate chemical processes behind shock waves in hypersonic flow fields are analyzed and a numerical technique is proposed for their solution. The computational difficulties connected with the presence of large gradients of the species concentrations are considered. A method is proposed, based on a shock-fitting technique for the gas dynamic model and a variable step integration along the streamlines for the energy and species conservation equations. This approach provides the needed resolution where it is actually required, without becoming cumbersome elsewhere, and the relaxation layer behind shocks can be computed efficiently and precisely. Author

N91-23175*# Sverdrup Technology, Inc., Cleveland, OH.
VISCOUS THREE-DIMENSIONAL ANALYSES FOR NOZZLES FOR HYPERSONIC PROPULSION
G. J. HARLOFF, D. R. REDDY, and H. T. LAI In AGARD, Hypersonic Combined Cycle Propulsion 18 p (SEE N91-23147 15-07) Dec. 1990 Previously announced as N90-17635
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A Navier-Stokes computer code was validated using a number of two- and three-dimensional configurations for both laminar and turbulent flows. The validation data covers a range of freestream Mach numbers from 3 to 14, including wall pressures, velocity pressure, and skin friction. Nozzle flow fields computed for a generic scramjet nozzle from Mach 3 to 20, wall pressures, wall skin friction values, heat transfer values, and overall performance are presented. In addition, three-dimensional solutions obtained for two asymmetric, single expansion ramp nozzles at a pressure ratio of 10 consists of the internal expansion region in the converging/diverging sections and the external superonic exhaust in a quiescent ambient environment. The fundamental characteristics that were captured successfully include expansion fans; Mach wave reflections; mixing layers; and nonsymmetrical, multiple inviscid cell, supersonic exhausts. Comparison with experimental data for wall pressure distributions at the center planes shows good agreement. Author

N91-26124# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
EXPERIMENTAL TECHNIQUES IN THE FIELD OF LOW DENSITY AERODYNAMICS
J. ALLEGRE, M. RAFFIN, and J. J. BERNARD, ed. (Paris VI Univ., France) Apr. 1991 60 p Original contains color illustrations
(AGARD-AG-318(E); ISBN-92-835-0613-8; AD-B156403L)
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Over the course of the past few decades, space programs have engendered a great deal of experimental and theoretical research aimed at improving the understanding of the

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characteristics and properties of flows in rarefied gas dynamics. A few of the more common measurement techniques used in low-density wind tunnels and altitude simulation chambers, for subsonic, supersonic, and hypersonic flows at low Reynolds numbers, chiefly compatible with spacecraft reentry flight conditions, are discussed. The instrumentation used in low-density testing is fundamentally different from that which is used in conventional wind tunnels, because of the level of rarefaction of the flows, which limits the forces, pressures, and mass densities to be measured and modifies the flow viscosity and interaction conditions. The rarefaction of flows generally tends to thicken the boundary layers and changes the structure of the shock waves.
Author

N91-32082# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
AERODYNAMICS OF COMBAT AIRCRAFT CONTROLS AND OF GROUND EFFECTS
G. K. RICHEY, D. H. PECKHAM, ed., and J. LEYNAERT, ed. (Office National d'Etudes et de Recherches Aeronautiques, Paris, France) 1991 22 p
(AGARD-AR-271; AD-A241365) Copyright Avail: NTIS HC/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The papers presented at the AGARD Fluid Dynamics Panel Symposium on the aerodynamics of combat aircraft controls and of ground effects are summarized and evaluated. The reviewer also provides some general conclusions relative to the effectiveness of the symposium in addressing the problems of the aerodynamics of combat aircraft controls and ground effects in an era when a stretched combat maneuverability envelope is needed to enhance both offensive and defensive combat capability. Recommendations for future experimental and computational fluid dynamics activities are also addressed. Author

N92-12996# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
VORTEX FLOW AERODYNAMICS
Jul. 1991 537 p In ENGLISH and FRENCH Symposium held in Scheveningen, Netherlands, 1-4 Oct. 1990
(AGARD-CP-494; ISBN-92-835-0623-5; AD-A244249) Copyright Avail: NTIS HC/MF A23; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The AGARD Fluid Dynamics Panel sponsored this symposium to provide an update review of the aerodynamic effects of separation-induced vortex flows on the design and off-design performance of fighter aircraft. A better understanding is needed to predict and control these vortex flows throughout the flight envelope at subsonic, transonic, and supersonic speeds, and especially during high lift operations for take-offs, landings, and sustained and instantaneous maneuvers. Topics of interest included vortex development and burst, modeling and validation of the full range of analytic methods, slender-body vortex flows at high angles of attack, vortex control and management, and unsteady vortex flow effects. In addition to the symposium papers, the results of the round table discussion are presented. For individual titles, see N92-12997 through N92-13028.

N92-12997# National Aerospace Lab., Amsterdam (Netherlands).
MODELING AND NUMERICAL SIMULATION OF VORTEX FLOW IN AERODYNAMICS
H. W. M. HOEIJMAKERS In AGARD, Vortex Flow Aerodynamics 46 p (SEE N92-12996 04-02) Jul. 1991 Sponsored in part by the Netherlands Agency for Aerospace Programs (NIVR) for the Netherlands Ministry of Defence
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A review is presented of mathematical models of different levels of approximation and their application to the numerical simulation of vortical flows occurring in subsonic and transonic aircraft aerodynamics. Computational methods for predicting the downstream development of vortex wakes are covered as well as methods for simulating the detailed characteristics of configurations with leading-edge or body vortices.The emphasis is on the later, strong-interaction type of vortical flows. Promising developments related to presently used methods are discussed in some detail.

The possibilities, limitations, and prospects for improving the methods are indicated and results of various methods are discussed. Also considered are some more fundamental aspects of the numerical simulation of phenomena such as separation at sharp and round leading edges, separation at a smooth part of a surface, the structure of the leading-edge vortex, and the merging of two vortices. Author

N92-12998# Royal Aircraft Establishment, Farnborough (England).
COMPARISON OF SOLUTION OF VARIOUS EULER SOLVERS AND ONE NAVIER-STOKES SOLVER FOR THE FLOW ABOUT A SHARP-EDGED CROPPED DELTA WING
B. R. WILLIAMS, W. KORDULLA, M. BORSI, and H. W. M. HOEIJMAKERS In AGARD, Vortex Flow Aerodynamics 12 p (SEE N92-12996 04-02) Jul. 1991 Previously announced as N91-30106 Sponsored in part by the Ministry of Defence, England; German Ministry of Defence; Italian Ministry of Defence; and the Netherlands Agency for Aerospace Programs for the Ministry of Defence
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For the flow about a sharp-edged cropped 65-deg delta wing numerical solutions obtained with different Euler methods are compared with each other, with the numerical solution of a Reynolds-averaged Navier-Stokes method, and with experimental data. At the selected free-stream Mach number of 0.85 and angle of attack of 10 deg the flow features a leading-edge vortex, is transonic, but contains weak shocks only. The results of the Euler methods have been obtained on one and the same C-H type of grid with close to 300,000 cells. This investigation, carried out within the framework of a four-nation collaborative program, indicates that for the test case considered there are, from a theoretical point of view, significant differences between results from different Euler methods, even if artificial dissipation is minimized. However, the correlation of the Euler solutions with experimental data shows much larger differences due to the failure to represent secondary separation in the Euler methods and is therefore unsatisfactory. The results of the Reynolds-averaged Navier-Stokes method demonstrate an improved correlation of theory and experiment. Author

N92-12999# Aeritalia S.p.A., Turin (Italy).
VORTICAL FLOW SIMULATION BY USING STRUCTURED AND UNSTRUCTURED GRIDS
M. BORSI, L. FORMAGGIA, E. HETTENA, S. SANTILLAN, V. SELMIN, and S. TARDITI In AGARD, Vortex Flow Aerodynamics 12 p (SEE N92-12996 04-02) Jul. 1991 Previously announced as N91-30107
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Two Euler equation solvers based on finite volume formulations on structured and unstructured grids are applied to the simulation of transonic vortical flow around a delta wing-body configuration. The mesh generation techniques are described, some details on the flow solvers are given, and a comparison between the methods is presented. Author

N92-13000# National Aerospace Lab., Amsterdam (Netherlands).
ANALYSIS OF RESULTS OF AN EULER-EQUATION METHOD APPLIED TO LEADING-EDGE VORTEX FLOW
J. I. VANDENBERG, H. W. M. HOEIJMAKERS, and J. M. J. W. JACOBS In AGARD, Vortex Flow Aerodynamics 12 p (SEE N92-12996 04-02) Jul. 1991 Sponsored in part by the Netherlands Agency for Aerospace Programs (NIVR) for the Netherlands Ministry of Defence
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The flow about a 65-deg sharp-edged cropped delta wing with and without an under-wing body is simulated by solving the Euler equations. Results are presented for the wing-body configuration at a transonic free-stream Mach number at incidences ranging from 10 to 20 deg for which in the flow field above the wing a strong vortex develops as well as shocks for the high incidence

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of 20 deg. Results for subsonic to transonic free-stream Mach numbers at high incidence are obtained for the wing-alone configuration for which in the presence of a strong vortex, at transonic free-stream Mach number, shocks appear in the solution. For the wing-body configuration, the computational results are compared with experimental data, and the solution in the near wake is investigated. Author

N92-13001# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.
EXPERIMENTAL AND NUMERICAL INVESTIGATION OF THE VORTEX FLOW OVER A DELTA WING AT TRANSONIC SPEED
E. M. HOUTMAN and W. J. BANNINK In AGARD, Vortex Flow Aerodynamics 11 p (SEE N92-12996 04-02) Jul. 1991
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The flow around a sharp-edged delta wing with 65-deg sweep and a flat upper surface was investigated experimentally as well as numerically. The experimental program consisted of surface pressure measurements, oil flow visualization, and flow field explorations at Mach numbers 0.60 and 0.85 and angles of attack up to 20 deg. The results show a transonic leeward flow structure with several shock waves. At a Mach number of 0.85 and 20 deg angle of attack vortex breakdown is observed. The vortex breakdown goes along with a double shock system in the symmetry plane region. In the numerical program a 3D Euler code is used with two upwind schemes; one of the flux-splitting type and one of the flux-difference-splitting type. The results show significant differences between the two discretization schemes, in particular in the region of the vortex. Between computations and experiments large differences are observed due to the absence of secondary separation, and, at the higher angles of attack, due to the absence of vortex breakdown in the computations. Author

N92-13002'# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RECENT PROGRESS IN COMPUTATIONAL VORTEX-FLOW AERODYNAMICS
JAMES M. LUCKRING In AGARD, Vortex Flow Aerodynamics 21 p (SEE N92-12996 04-02) Jul. 1991
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Recent progress in computational vortex flow aerodynamics at the Langley Research Center is reviewed. Emphasis is placed on Navier-Stokes methodology, both for compressible and incompressible flows, and results are presented from central and upwind-biased schemes for fully laminar, transitional, and fully turbulent flows. In addition, results are presented from selected potential-based methods to address the hierarchy of formulations presently available for the computational analysis of aerodynamic vortex flows. Some comparisons among this hierarchy of methods are shown. Author

N92-13003# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.).
ON THE SIMULATION OF COMPRESSIBLE TURBULENT FLOWS PAST DELTA WING, DELTA WING-BODY AND DELTA WING-CANARD
ACHIM HILGENSTOCK and HEINRICH VOLLMERS In AGARD, Vortex Flow Aerodynamics 13 p (SEE N92-12996 04-02) Jul. 1991
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The turbulent flow around a delta wing at incidence is simulated numerically using a finite volume Navier-Stokes method. The numerical simulation makes use of a simple algebraic turbulence model. Using a sharp leading edge delta wing, the influence of grid refinement is investigated. A realistic wing-body configuration with a round leading edge is used to discuss the influence of the position of the transition line. Experimental and numerical data are compared to validate the numerical method. The topological structure of the flow is discussed. An explanation is given for the low particle density area close to the primary vortex as it is visualized by the laser light sheet technique. First results for a

closed coupled delta-wing-canard configuration are also discussed. Author

N92-13004# Aeronautical Research Inst. of Sweden, Bromma.
CALCULATION OF HYPERSONIC LEESIDE VORTICES OVER BLUNT DELTA WINGS
ARTHUR RIZZI, EARLL M. MURMAN, PETER ELIASSON, and KUOK-MING LEE (Massachusetts Inst. of Tech., Cambridge.) In AGARD, Vortex Flow Aerodynamics 17 p (SEE N92-12996 04-02) Jul. 1991
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Hypersonic vortical flow on the leeside of a blunt delta wing using both the Euler equations and the Navier-Stokes equations with two different and independent numerical methods in order to evaluate the inviscid and viscous mechanisms of leeside vortex formation is investigated. Comparisons of results from the same method as well as comparisons of results from the two different methods are the focal point of this work. The intent is to reach a reasonable understanding of the computed flow structures, including flow separation, shear layers, vortices, shock waves, and entropy losses. It was found that instead of the concentrated vortex usually found over a delta wing in transonic speed, the flow in hypersonic speed is dominated by a shear layer that separates just past the blunt leading edge and forms a more distributed vortical region over the wing. Windside features like the bow shock agree well in all the numerical solutions. But there are substantial discrepancies in the prediction of the Stanton number on the wing surface Author

N92-13005# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.).
ON THE FOOTPRINTS OF THREE-DIMENSIONAL SEPARATED VORTEX FLOWS AROUND BLUNT BODIES: ATTEMPTS OF DEFINING AND ANALYZING COMPLEX FLOW STRUCTURES
UWE DALLMANN, ACHIM HILGENSTOCK, STEFAN RIEDELBAUCH, BURKHARD SCHULTE-WERNING, and HEINRICH VOLLMERS In AGARD, Vortex Flow Aerodynamics 13 p (SEE N92-12996 04-02) Jul. 1991
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An analysis of vortex flows around different configurations in very different Mach and Reynolds regimes is presented. Subsonic, transonic, and hypersonic separated flows are considered. The common interest was to study the relationships between the topologies of steady or unsteady, two dimensional or three dimensional separated vortex flow structures and their footprints which they leave on the boundaries (walls) or within any section across the flow field. From this point of view numerical Navier Stokes simulations are analyzed in the following respect: Topological changes of the instantaneous sectional streamlines and the skin friction patterns of incompressible flows are considered during vortex shedding and during onset of three dimensionality of the flow. Two dimensional separation bubbles, separation from a cylinder in crossflow, and separation from a sphere are analyzed. The formation of vortex cores and their relationship to so called open or closed flow separation, wall vorticity, wall pressure, wall heat flux, and various sectional flow data are investigated in compressible flows such as the transonic transitional flow around a round edged delta wing and the hypersonic laminar flow around a double ellipsoid. Author

N92-13006# East Anglia Univ., Norwich (England). School of Mathematics.
LAMINAR-FLOW SECONDARY SEPARATION ON A SLENDER WING
K. KIRKKOPRU and N. RILEY In AGARD, Vortex Flow Aerodynamics 10 p (SEE N92-12996 04-02) Jul. 1991
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High Reynolds number laminar flow of an incompressible fluid past a slender delta wing at incidence is considered. An interactive viscous inviscid calculation is carried out to determine the secondary separation flow properties on the wing. The overall interactive procedure includes a modification to the leading edge

vortex sheet configuration which represents the primary separation. Encouraging comparisons are made with experiment. Author

N92-13007*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NONEQUILIBRIUM TURBULENCE MODELING EFFECTS ON TRANSONIC VORTICAL FLOWS ABOUT DELTA WINGS
UNVER KAYNAK, EUGENE TU, MUSTAFA DINDAR, and REMZI BARLAS (Turkish Aerospace Industries, Ankara.) *In* AGARD, Vortex Flow Aerodynamics 13 p (SEE N92-12996 04-02) Jul. 1991 Sponsored in part by NASA
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The Johnson-King turbulence model that is a viable method for calculating two dimensional transonic separated flows was extended into three dimensions. The implementation was done for Navier Stokes flow solvers written in general curvilinear coordinates. The present approach used in turbulence modeling is based on streamwise integration of an ordinary differential equation (o.d.e.) that governs the maximum Reynolds shear stress behavior. Streamwise integration of the o.d.e. approach was found to offer great mathematical simplicity and economy for three dimensional Navier Stokes methods. Thus, the new method is quick, simple, and very cheap. The new method was first checked against the data of a well known transonic axisymmetric bump experiment, and a good agreement was obtained. Later, the new method was used to compute the flow around a low aspect ratio wing in a transonic wind tunnel. Finally it was employed to study the nonequilibrium turbulence effects on the transonic vortical flows about a 65 deg sweep round leading edge delta wing. Author

N92-13008# Royal Aircraft Establishment, Farnborough (England).
REVIEW OF AIRCRAFT DYNAMIC LOADS DUE TO FLOW SEPARATION
D. G. MABEY *In* AGARD, Vortex Flow Aerodynamics 10 p (SEE N92-12996 04-02) Jul. 1991
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A detailed review of the 70th meeting of the Advisory Group for Aerospace Research and Development (AGARD) Structures and Materials Panel, prepared for the AGARD Fluid Dynamics Panel, is presented. Accordingly emphasis is placed on the aerodynamic information presented, rather than the structural aspects. Experimental results and computations are described for flows with bubble and vortex separations. Some conclusions are drawn and recommendations are made for further research. In particular, the review suggests that much greater attention should be given to establishing the magnitude of possible scale effects (both in experiments and calculations) and to the prediction of fin buffeting. Author

N92-13009*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
IN-FLIGHT FLOW VISUALIZATION AND PRESSURE MEASUREMENTS AT LOW SPEEDS ON THE NASA F-18 HIGH ALPHA RESEARCH VEHICLE
JOHN H. DELFRATE, DAVID F. FISHER, and FANNY A. ZUNIGA *In* AGARD, Vortex Flow Aerodynamics 42 p (SEE N92-12996 04-02) Jul. 1991 Previously announced as N90-28505
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Inflight results from surface and off surface flow visualizations and from extensive pressure distributions document the vortical flow on the leading edge extensions (LEXs) and forebody of the NASA F-18 high alpha research vehicle (HARV) for low speeds and angles of attack up to 50 deg. Surface flow visualization data, obtained using the emitted fluid technique, were used to define separation lines and laminar separation bubbles (LSB). Off surface flow visualization data, obtained by smoke injection, were used to document both the path of the vortex cores and the location of vortex core breakdown. The location of vortex core breakdown correlated well with the loss of suction pressure on the LEX and with the flow visualization results from ground facilities. Surface flow separation lines on the LEX and forebody

corresponded well with the end of pressure recovery under the vortical flows. Correlation of the pressures with wind tunnel results show fair to good correlation. Author

N92-13010# Technische Univ., Brunswick (Germany, F.R.).
VORTEX FORMATION OVER A CLOSE-COUPLED CANARD-WING-BODY CONFIGURATION IN UNSYMMETRICAL FLOW
A. BERGMANN, D. HUMMEL, and H.-CHR. OELKER (Dornier System G.m.b.H., Friedrichshafen, Germany, F.R.) *In* AGARD, Vortex Flow Aerodynamics 14 p (SEE N92-12996 04-02) Jul. 1991
(Contract DFG-HU-254/8)
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A close coupled canard wing body combination was investigated in unsymmetrical flow. The configuration consisted of a delta canard, a delta wing, and a body of revolution as the fuselage. Six component and surface pressure distribution measurements as well as flow visualizations by means of the laser lightsheet technique were carried out at Reynolds numbers (based on wing inner chord) of Re = 1.1 x 10(exp 6) and Re = 1.4 x 10(exp 6) for the canard-off and the canard-on configuration. For large angles of attack distinct jumps of the aerodynamic coefficients have been detected in unsymmetrical flow which are due to sudden changes of the flow structure. In the canard-off configuration they are caused by the collapse of the vortex type flow on the windward side of the configuration into a deadwater type flow which takes place when the vortex breakdown position within the wing vortices reaches the wing apex. In the canard-on configuration the sensitive and favorable interference between canard and wing is suddenly disturbed. Apart from a small region in the vicinity of the symmetrical flow in which a vortical flow at the canard can be maintained up to extremely large angles of attack, in unsymmetrical flow at high angles of attack the flow over the windward side of the canard collapses from a vortex type flow to a deadwater type flow due to a sudden loss of favorable interference, and this causes the jumps in the slope of the aerodynamic coefficients. Author

N92-13011# National Aerospace Lab., Amsterdam (Netherlands).
AN EXPERIMENTAL STUDY OF THE FLOW OVER A SHARP-EDGED DELTA WING AT SUBSONIC AND TRANSONIC SPEEDS
A. ELSENAAR and H. W. M. HOEIJMAKERS *In* AGARD, Vortex Flow Aerodynamics 19 p (SEE N92-12996 04-02) Jul. 1991 Sponsored in part by the Netherlands Agency for Aerospace Program (NIVR) for the Netherlands Ministry of Defence
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The flow about a sharp edged cropped delta wing is investigated experimentally. The experiment comprised detailed surface pressure measurements at low subsonic, transonic, and low supersonic freestream Mach numbers for angles of attack up to 27 deg. The major part of the measurements were carried out at a Reynolds number of 9 million, but some data was also obtained at lower and higher Reynolds numbers. The investigation included continuous schlieren flow field visualization as well as surface flow visualizations at a limited number of free stream conditions. The analysis of the measured data embraced flow field phenomena such as primary separation and the formation of the leading edge vortex, secondary separation and the formation of the secondary vortex, shock waves, and the onset of vortex breakdown. Considered are the influence of Mach number, incidence, and Reynolds number on these flow features. Author

N92-13012# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Aerothermodynamique.
CHARACTERISTICS OF A BOUNDARY LAYER IN A LEADING EDGE VORTEX [CARACTERISTIQUES D'UNE COUCHE LIMITE EN AVAL D'UN TOURBILLON DE BORD D'ATTAQUE]
G. PAILHAS and J. COUSTEIX *In* AGARD, Vortex Flow Aerodynamics 17 p (SEE N92-12996 04-02) Jul. 1991 In FRENCH; ENGLISH summary
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The boundary layer developing downstream of a leading edge vortex was investigated. This experiment is devoted to the understanding of the behavior of such a boundary layer submitted to the effects of a leading edge vortex developing on the suction side of a swept wing. The infinite swept wing considered for the present study is mounted between the top and the bottom walls of the test section at a sweep angle of 60 degrees and at an incidence of 15 degrees. The airfoil is symmetric and has a maximum thickness ratio of .1 and a chord length of 200 mm; it is an ONERA D airfoil, that is, a peaky-type airfoil. Mean and turbulent velocity profile surveys were carried out in various positions located downstream of the reattachment line, but also for a few positions in the vortex core by means of hot wire anemometry. Measurements in the vortex core and in the boundary layer were made by using respectively a four and single hot wire probe. *Author*

N92-13013# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
VORTEX FLOW ON A MISSILE BODY: EXPERIMENTAL STUDY AND MODELING [ECOULEMENT TOURBILLONNAIRE SUR FUSELAGE DE MISSILE ETUDE EXPERIMENTALE ET MODELISATION]
P. CHAMPIGNY and D. BAUDIN *In* AGARD, Vortex Flow Aerodynamics 9 p (SEE N92-12996 04-02) Jul. 1991 In FRENCH; ENGLISH summary Previously announced in IAA as A91-16738
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The vortex flowfield around a missile body was investigated in the ONERA S2MA wind tunnel in order to predict missile aerodynamic characteristics. For angles of attack up to 20 degrees and Mach numbers ranging from 0.8 to 3.0, five-hole probe measurements give the local characteristics of the flow, e.g., transverse velocity vectors, local Mach numbers, and stagnation pressures. The position, strength, and core radius of the vortices are analyzed and a modeling of the flowfield based on viscous vortices is described. Applications of this model to missile aerodynamics show the need to take the nose vortices into account in engineering methods for good performance predictions. *Author*

N92-13014# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
ASYMMETRIC VORTEX FLOW OVER CIRCULAR CONES
M. PIDD and J. H. B. SMITH *In* AGARD, Vortex Flow Aerodynamics 11 p (SEE N92-12996 04-02) Jul. 1991
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Presented here is an update on earlier Royal Aerospace Establishment (RAE) work on the formation of asymmetric vortices from slender pointed bodies at large angles of incidence. The emphasis is on theoretical and experimental work on flow over circular cones. For a single line vortex model of asymmetric conical flow over circular cones with symmetric separation lines, a thorough exploration of parameter space revealed only insignificant regions of multiple solutions and no further bifurcation locus from which asymmetric solutions could arise. An examination of the stability of solutions of this model to small spatial disturbances has shown that stable symmetric solutions are confined to a narrow band of values of the incidence parameter, but that, with insignificant exceptions, the asymmetric solutions are stable. An examination of low speed experimental data shows that asymmetric flow over a circular cone can be significantly non-conical with large variations in local side force coefficient along the length of the cone. At an angle of incidence of 35 degrees on a 10 degree cone, the approximately conical flows appear to predominate, but at 30 degrees they only occur exceptionally. *Author*

N92-13015# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF FINENESS RATIO ON LATERAL FORCE ON A POINTED SLENDER BODY OF REVOLUTION
I. R. M. MOIR *In* AGARD, Vortex Flow Aerodynamics 13 p (SEE N92-12996 04-02) Jul. 1991
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Tests were made on a slender body model in the Royal Aerospace Establishment (RAE) Farnborough 5 meter pressurized low speed wind tunnel. Measurements of side force variation with angle of incidence and with roll angle are presented, together with an examination of the angle of incidence at which side force onset occurs and how this varies with nose apex angle, overall fineness ratio, and Reynolds number. A flow visualization technique was used to study the development of vortical symmetry as angle of incidence was increased. *Author*

N92-13016# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
PHYSICS OF VORTICAL FLOW [PHYSIQUE DES ECOULEMENTS TOURBILLONNAIRES]
J. DELERY *In* AGARD, Vortex Flow Aerodynamics 32 p (SEE N92-12996 04-02) Jul. 1991 In FRENCH, ENGLISH summary
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In three dimensional flows, separation leads to the formation of vortical structures resulting from the rolling up of a sheet of viscous flow, initially contained in a thin boundary layer, which springs out from the obstacle surface into the outer perfect fluid flow. A clear physical understanding of this phenomenon must rely on a rational analysis of the flowfield, calling upon the critical points theory. With this theory, it is possible to correctly interpret the surface flow patterns which constitute the imprints of the outer flow and to give a rational description of the vortical system. This kind of analysis is applied to separated flows generated by typical bodies, the field of which has been carefully investigated by means of visualizations and surveys using multi-hole probes and laser velocimetry. The problem of vortex breakdown, so important for a large number of applications, is discussed briefly. *Author*

N92-13017*# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
BREAKING DOWN THE DELTA WING VORTEX: THE ROLE OF VORTICITY IN THE BREAKDOWN PROCESS
R. C. NELSON and KENNETH DALE VISSER *In* AGARD, Vortex Flow Aerodynamics 15 p (SEE N92-12996 04-02) Jul. 1991 Sponsored in part by Notre Dame Univ.
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Experimental x-wire measurements of the flowfield above a 70 degree and 75 degree flat plate delta wing were performed at a Reynolds number of 250,000. Grids were taken normal to the wing at various chordwise locations for angles of attack of 20 degrees and 30 degrees. Axial and azimuthal vorticity distributions were derived from the velocity fields. The dependence of circulation on distance from the vortex core and on chordwise location was also examined. The effects of nondimensionalization in comparison with other experimental data is made. The results indicate that the circulation distribution scales with the local semispan and grows in a nearly linear fashion in the chordwise direction. The spanwise distribution of axial vorticity is severely altered through the breakdown region and the amount of vorticity present appears to reach a maximum immediately preceding breakdown. The axial velocity components with a negative sense, such as that found in the secondary vortex, seem to remain unaffected by changes in wing sweep or angle of attack, in direct contrast to the visible components. In addition, the inclusion of the local wing geometry into a previously derived correlation parameter allows the circulation

of growing leading edge vortex flows to be reduced to a single curve. Author

N92-13018# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
DETERMINATION OF VORTEX-BREAKDOWN CRITERIA BY SOLVING THE EULER AND NAVIER-STOKES EQUATIONS [DETERMINATION DE CRITERES D'ECLATEMENT TOURBILLONNAIRE PAR RESOLUTION DES EQUATIONS D'EULER ET DE NAVIER STOKES]
T. H. LE, PH. MEGE, and Y. MORCHOISNE In AGARD, Vortex Flow Aerodynamics 10 p (SEE N92-12996 04-02) Jul. 1991 In FRENCH; ENGLISH summary Previously announced in IAA as A91-26081
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A parametric study based on numerical simulations which solve Euler and Navier-Stokes equations is performed on the configuration of an isolated vortex subjected to an initial perturbation. An analysis of the vortex breakdown characteristics indicates that the phenomenon appears abruptly, that it is three dimensional and unsteady by nature, and that the turbulence is characterized by small-scale structures that are established at a specified moment. This analysis permits a criterion to be specified that is based on an appropriately defined local Rossby number to determine the area where breakdown occurs. Author

N92-13019*# McDonnell Aircraft Co., Saint Louis, MO. Aerodynamics Dept.
INVESTIGATION OF VORTEX BREAKDOWN ON A DELTA WING USING EULER AND NAVIER-STOKES EQUATIONS
S. AGRAWAL, R. M. BARNETT, and B. A. ROBINSON In AGARD, Vortex Flow Aerodynamics 12 p (SEE N92-12996 04-02) Jul. 1991
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A numerical investigation of leading edge vortex breakdown in a delta wing at high angles of attack is presented. The analysis was restricted to low speed flows on a flat plate wing with sharp leading edges. Both Euler and Navier-Stokes equations were used and the results were compared with experimental data. Predictions of vortex breakdown progression with angle of attack with both Euler and Navier-Stokes equations are shown to be consistent with the experimental data. However, the Navier-Stokes predictions show significant improvements in breakdown location at angles of attack where the vortex breakdown approaches the wing apex. The predicted trajectories of the primary vortex are in very good agreement with the test data, the laminar solutions providing the overall best comparison. The Euler shows a small displacement of the primary vortex, relative to experiment, due to the lack of secondary vortices. The turbulent Navier-Stokes, in general, fall between the Euler and laminar solutions. Author

N92-13020*# Vigyan Research Associates, Inc., Hampton, VA.
VORTEX CONTROL: FURTHER ENCOUNTERS
DHANVADA M. RAO In AGARD, Vortex Flow Aerodynamics 12 p (SEE N92-12996 04-02) Jul. 1991 Sponsored in part by NASA. Langley Research Center; and by AF
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The progress of continuing investigations on vortex control techniques is updated. The following topics are briefly discussed: (1) vortex flaps adapted for high-alpha control; (2) alleviation of leading edge extension (LEX) vortex induced twin-tail buffet; (3) controlled decoupling of interactive forebody chine and wing vortices; (4) forebody vortex manipulation by mechanical and pneumatic techniques; and (5) stall-departure alleviation of high aspect-ratio wings. Salient results of exploratory low speed wind tunned experiments are presented. The investigations, primarily aimed at concept validation, were performed on generic configurations utilizing flow visualizations and pressure and balance measurements. Selected results illustrate the efficacy and potential for development of specific vortex control concepts for improved high-alpha configuration aerodynamics. Author

N92-13021# Technische Univ., Aachen (Germany, F.R.). Dept. of Aerospace Engineering.
ON AIRCRAFT WAKE PROPERTIES AND SOME METHODS FOR STIMULATING DECAY AND BREAKDOWN OF TIP VORTICES
R. STAUFENBIEL and T. VITTING In AGARD, Vortex Flow Aerodynamics 14 p (SEE N92-12996 04-02) Jul. 1991 Sponsored in part by Deutsche Forschungsgemeinschaft (DFG)
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Investigations on the formation and structure of wing tip vortices are presented. A computational method for the time-dependent roll-up process is derived, which is based on the Biot-Savart approach with a particular technique of amalgamation which preserves energy, center of vorticity, and the second moment of vorticity distribution. The results are compared with laser Doppler velocimeter (LDV) measurements performed in a water tunnel. The influence of lift distribution on maximum circumferential velocity of trailing vortices is investigated. Moreover, some special devices for vortex wake alleviation were experimentally investigated in order to reveal the potential of three methods for vortex wake alleviation: (1) artificially destabilizing the vortex; (2) inducing breakdown of the vortex core; and (3) spreading and splitting the vorticity of trailing vortices. Author

N92-13022# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
CONTROL OF FOREBODY VORTICES BY SUCTION AT THE NOSE OF THE RAE HIGH INCIDENCE RESEARCH MODEL
A. JEAN ROSS and E. B. JEFFERIES In AGARD, Vortex Flow Aerodynamics 9 p (SEE N92-12996 04-02) Jul. 1991
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The concept of applying suction at the nose of forebodies at high angle of attack to control the vortex flow was applied in static and dynamic wind tunnel tests on the RAE High Incidence Research Model. The first series of static tests showed that sideforce and yawing moment varied nearly linearly with the flow rate (or mass flow) coefficient, rather than the momentum coefficient, up to a maximum, but the maximum control powers available were small on the original drooped forebody. The results for suction on a large ogival forebody give yawing moment equivalent to about 25 degrees of rudder at an angle of attack of 30 degrees, and significantly higher for higher angles. They also show some dependence on whether separation is laminar or turbulent, and parameters defining the variation with flow rates are compared. Dynamic experiments on a free-to-yaw rig, with active control of flow rates, were inconclusive and further experiments are being conducted. Author

N92-13023# Royal Aircraft Establishment, Farnborough (England).
AN EXPERIMENTAL INVESTIGATION OF VORTEX FLAPS ON A CANARD COMBAT-AIRCRAFT CONFIGURATION
D. A. LOVELL In AGARD, Vortex Flow Aerodynamics 11 p (SEE N92-12996 04-02) Jul. 1991
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A low-speed wind tunnel investigation of two vortex-flap configurations fitted to a canard-delta combat-aircraft research model having a 53 degree sweep wing is reported. The effect of foreplane interference and vortex-flap geometry on the aerodynamic performance of the vortex flaps is determined. It is concluded that vortex flaps can generate large gains in trimmed lift and lift to drag ratio, particularly when used in conjunction with trailing-edge flaps. Author

N92-13024# General Dynamics Corp., Fort Worth, TX.
**STEADY AND UNSTEADY AERODYNAMICS OF A PITCHING
STRAKED WING MODEL AT HIGH ANGLES OF ATTACK**
A. M. CUNNINGHAM, JR. and R. G. DENBOER (National
Aerospace Lab., Amsterdam, Netherlands) *In* AGARD, Vortex
Flow Aerodynamics 10 p (SEE N92-12996 04-02) Jul. 1991
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Results are presented and discussed for the low speed test of
a straked wing model oscillating in pitch that was conducted during
1986 at the National Aerospace Laboratory of the Netherlands.
The model was oscillated about mean angles of attack ranging
from -4 to 48 degrees with amplitudes varying from 2 to 18 degrees
for a maximum incidence range of -8 to 50 degrees. It was also
oscillated in pitch at side slip angles of 5 and -5 degrees. Force,
pressure, and flow visualization data were recorded, processed,
and documented in log magnetic tapes. A description of the model,
test programs, steady aerodynamic characteristics, and unsteady
aerodynamic characteristics is presented. These results are used
to provide a better understanding of the unsteady forces
experienced by rapidly pitching wings at low speed conditions
ranging from zero incidence to fully stalled flows. Dynamic rolling
moments for the pitching model at steady side-slip are also
discussed to illustrate asymmetric aerodynamic hysteresis effects.
Finally, implications for aircraft flight dynamics modeling are
discussed with particular emphasis on nonlinear time dependency
effects. Author

N92-13025# National Research Council of Canada, Ottawa
(Ontario). Inst. for Aerospace Research.
**SOME CHARACTERISTICS AND EFFECTS OF THE F/A-18
LEX VORTICES**
D. BROWN, B. H. K. LEE, and F. C. TANG *In* AGARD, Vortex
Flow Aerodynamics 20 p (SEE N92-12996 04-02) Jul. 1991
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The first phase of a wind tunnel program to measure mean
and unsteady forces and moments and pressure distributions on
the forward fuselage, leading-edge extension (LEX), fins and in
the LEX vortex wake of a 6 percent rigid model of the F/A-18
aircraft was accomplished. The effect of compressibility up to Mach
0.8 was studied. The mean chord Reynolds number range was
1.2 to 3.8 x 10(exp 6). Mean pressures were measured at 84
orifices distributed between canopy, forward fuselage, and the LEX.
Unsteady and mean pressure measurements were made at four
points on the LEX and at 24 points on each side of the fin. The
vortex wake measurements were made with a 49 tube total
pressure rake of which 13 tubes were capable of acquiring unsteady
as well as mean pressures. The effects of the LEX fences, that
were retroactively fitted to CF-18 aircraft in service, were assessed.
The influence on aircraft lift and pitching moments is small. The
data shows their local effect on LEX pressures, reduction in fin
mean and unsteady loading that they cause, and their effect on
the stagnation pressure distribution in the vortex wake. Author

N92-13026# National Aeronautical Establishment, Ottawa
(Ontario). Inst. for Aerospace Research.
**MULTIPLE ROLL ATTRACTORS OF A DELTA WING AT HIGH
INCIDENCE**
E. S. HANFF and L. E. ERICSSON (Lockheed Missiles and Space
Co., Sunnyvale, CA.) *In* AGARD, Vortex Flow Aerodynamics 10
p (SEE N92-12996 04-02) Jul. 1991
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A comprehensive roll oscillation test program on a 65 degree
delta wing was conducted at the IAR (formerly NAE) 2 x 3 m low
speed wind tunnel. The principle objectives of the program were
to obtain a better insight of the vortex dynamics associated with
large-amplitude and high-rate roll oscillations and to validate the
hypersurface representation of aerodynamic loads as a means of
improving prediction of aircraft dynamics in the nonlinear regime.
Although some of the observed unusual roll response
characteristics can be qualitatively explained in terms of existing
knowledge regarding unsteady aerodynamic effects of separated
flow, further tests and data analyses will be needed to reach the

in-depth understanding of the flow phenomena which is required
for the successful design of future high-agility aircraft. Author

N92-13027# Technical Univ. of Istanbul (Turkey). Faculty of
Aeronautics and Astronautics.
**NUMERICAL SIMULATION OF VORTEX STREET-EDGE
INTERACTION**
M. O. KAYA, C. R. KAYKAYOGLU, K. C. BAYAR, and J. M. R.
GRAHAM (Imperial Coll. of Science and Technology, London,
England) *In* AGARD, Vortex Flow Aerodynamics 12 p (SEE
N92-12996 04-02) Jul. 1991
(AGARD-CP-494) Copyright Avail: NTIS HC/MF A23;
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Preliminary results and computational method reviews are
presented for the simulation of a vortex street impinging on three
different leading edge geometries of sharp, blunt, and elliptic type,
making use of Lagrangian and mixed Lagrangian-Eulerian vortex
methods. Two new computer codes were developed to capture
the essential features of the interaction mechanism near the edge
surface. The first method utilizes a Discrete Vorticity Method (DVM)
where a fixed Eulerian mesh system is needed to move the vortices
through the flow domain. A more advanced computer model of
the full Navier-Stokes equations of motion combines the Lagrangian
convection and Eulerian diffusion schemes and is called the Hybrid
Moving Vortex Diffusive Method (HMVDM). An unsteady shear
layer flow arising from boundary layer separation at a bluff trailing
edge creates the downstream vortex street. The models simulate
most features of the impingement including the secondary vortex
shedding as a truly self-generated phenomenon arising from
impingement of the large-scale incident disturbances. The
approaching vortex street is effected by the diverging flow around
the elliptic edge. Vortex impingement on a blunt edge causes the
most complex features of the interaction. The unsteady pressure
distributions agree with the common observations. Author

N92-13028# Politecnico di Milano (Italy). Dipt. di Ingegneria
Aerospaziale.
**NUMERICAL SIMULATION OF VORTEX FLOWS PAST
IMPULSIVELY STARTED WINGS**
A. BARON, M. BOFFADOSSI, and S. DEPONTE *In* AGARD,
Vortex Flow Aerodynamics 14 p (SEE N92-12996 04-02) Jul.
1991
(AGARD-CP-494) Copyright Avail: NTIS HC/MF A23;
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A nonlinear unsteady vortex lattice method is used to predict
the geometry of the wakes and the distribution of the aerodynamic
loads on impulsively started wings. The wings are assumed to
have negligible thickness, arbitrary aspect ratio, and planform. They
can undergo a general unsteady motion. Multi-wing configurations
can be treated. Wakes can be released in the flowfield from any
of the sharp edges of the lifting surfaces, depending on planform,
aspect ratio, and attitude of the wings. Particular emphasis is placed
on the simulation of vortex core diffusion which is regarded as a
prominent factor in a correct development of unsteady wakes. A
vortex core diffusion model is proposed which seems to be able
to deal even with the severe roll-up of the shear layers past
highly swept multi-wing configurations with leading edge separation.
The prediction capabilities of the method are verified by comparison
of the numerical results with experimental data published by various
authors. Author

N92-13269# Advisory Group for Aerospace Research and
Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
**DESIGN AND TESTING OF HIGH-PERFORMANCE
PARACHUTES**
R. C. MAYDEW, C. W. PETERSON, and K. J.
ORLIK-RUECKEMANN (Institute for Aerospace Research, Ottawa,
Ontario) Nov. 1991 302 p Original contains color
illustrations
(AGARD-AG-319; ISBN-92-835-0649-9) Copyright Avail: NTIS
HC/MF A14; Non-NATO Nationals requests available only from
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Provided here are general state-of-the-art procedures for the
design and testing of high-performance parachutes. This includes
the use of aerodynamic and structural analysis and application of
numerical codes to predict parachute inflation, deceleration forces,

payload and parachute trajectories, and canopy/suspension line stresses. Design problems such as parachute collapse, parachute line sail, parachute stability, and body-wake interaction are discussed. The use of nylon, Nomex, Kevlar, Teflon, and other materials is covered. Techniques for the design and fabrication of prototype parachutes and deployment bags are presented, and parachute packing methods are discussed. A section is included on testing of model parachutes in wind tunnels. Full-scale testing, using a sled track or aircraft drop or rocket boost to deploy the parachute at the desired Mach number and altitude, and descriptions of onboard and ground-based instrumentation are outlined. Example parachute designs are given for differing system requirements of payload weight, deployment Mach number and dynamic pressure, parachute weight/volume, etc.   Author

N92-18783# Wright Lab., Wright-Patterson AFB, OH.
NON-LINEAR AIRLOADS HYPERSURFACE
REPRESENTATION: A TIME DOMAIN PERSPECTIVE
J. E. JENKINS and E. S. HANFF (National Aeronautical Establishment, Ottawa, Ontario)   *In* AGARD, Manoeuvring Aerodynamics 9 p (SEE N92-18778 09-05) Nov. 1991 Sponsored in part by AFOSR and Dept. of National Defence
(AGARD-CP-497) Copyright Avail: NTIS HC/MF A13;
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  Representation of nonlinear and unsteady airloads by the reaction hypersurface model is shown to be a special case of the nonlinear indicial response model. The principal requirement is that the motions are analytical (in the strict mathematical sense) to ensure uniqueness. Static and roll oscillation test data for a 65 deg delta wing at an angle of attack of 30 deg were analyzed using the theoretical relationships between the two models. Analysis results indicate that the existence of singularities in the static rolling moment variation with roll angle invalidate the current model. Additional experiments are planned to resolve this issue.
                                                              Author

N92-20797#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel Working Group 13.
AIR INTAKES FOR HIGH SPEED VEHICLES
Sep. 1991   263 p
(AGARD-AR-270; ISBN-92-835-0637-5) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
  The results of a study by Working Group 13 of the AGARD Fluid Dynamics Panel are presented. The scope of the investigation included intake aerodynamics, intake/engine compatibility, and intake/airframe integration for both aircraft and missiles. The present capability of Computational Fluid Dynamics (CFD) methods was assessed through a comparative analysis of both CFD predictions and experimental data. This analysis was conducted for eight different flow field test cases designed to produce critical features of air-intake flow fields. Flow field results and comparisons are presented both in the report and in a microfiche appendix. Air-inlet wind tunnel testing techniques and limitations were also investigated and reported. Results from measurements of inlet performance from three European wind tunnels using a common axisymmetric pitot intake are also presented. The participants in Working Group 13 represented Belgium, France, Germany, Italy, the United Kingdom, and the United States.   Author

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AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

N90-13358#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
THE HUMAN FACTORS RELATING TO ESCAPE AND SURVIVAL FROM HELICOPTERS DITCHING IN WATER
C. J. BROOKS (Defence and Civil Inst. of Environmental Medicine, Downsview, Ontario) Aug. 1989 71 p
(AGARD-AG-305(E); ISBN-92-835-0522-0; AD-A215755)
Copyright Avail: NTIS HC A04/MF A01
  The worldwide incidence of military and civilian over-water helicopter accidents and the problems related to survival are described. Typical accident scenarios are reviewed from the moment the occupant steps on board a helicopter to the pre-flight briefing through to the accident itself, to the difficulties with escape (commonly from underwater and in darkness), to the rescue and return safely to dry land. Improvements to crashworthiness and life support equipment in current in-service and future helicopters are proposed. A syllabus for underwater escape training is also discussed.   Author

N90-15048# Technische Univ., Brunswick (Germany, F.R.). Inst. for Flight Guidance and Control.
INFLUENCE OF WINDSHEAR, DOWNDRAFT AND TURBULENCE ON FLIGHT SAFETY
GUNTHER SCHAENZER   *In* AGARD, Flight in Adverse Environmental Conditions 19 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03;
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  Wind shear, downdraft, and turbulence influences flight safety especially in take-off and landing approach. For a better understanding of the relevant problems, the typical aircraft response in gust and in wind shear will be pointed out and will be compared with real flight situations. In general the airspeed deviation of an aircraft in a wind shear situation is relatively small in contrast to flight path deviations and flight performance is not the limiting factor. Flight simulator studies have shown that it is difficult for the cockpit crew to identify a wind shear situation without any additional display of relevant information in order to control throttle and elevator in a correct manner. A wind shear warning display, based on energy deviation and energy rate can assist the pilot to overcome severe wind shear.   Author

N90-15062*#   National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NASA'S PROGRAM ON ICING RESEARCH AND TECHNOLOGY
JOHN J. REINMANN, ROBERT J. SHAW, and RICHARD J. RANAUDO *In* AGARD, Flight in Adverse Environmental Conditions 31 p (SEE N90-15041 07-01) Sep. 1989 Previously announced as N89-22569
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive   CSCL 01/3
  NASA's program in aircraft icing research and technology is reviewed. The program relies heavily on computer codes and modern applied physics technology in seeking icing solutions on a finer scale than those offered in earlier programs. Three major goals of this program are to offer new approaches to ice protection, to improve the ability to model the response of an aircraft to an icing encounter, and to provide improved techniques and facilities for ground and flight testing. The following program elements are reviewed: (1) new approaches to ice protection, (2) numerical codes for deicer analysis; (3) measurement and prediction of ice accretion and its effect on aircraft and aircraft components; (4) special wind tunnel test techniques for rotorcraft icing; (5) improvements in icing wind tunnels and research aircraft; (6) ground de-icing fluids used in winter operation; (7) fundamental studies in icing; and (8) droplet sizing instruments for icing clouds.   Author

N90-15065*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECTS OF LIGHTNING ON OPERATIONS OF AEROSPACE VEHICLES
BRUCE D. FISHER *In* AGARD, Flight in Adverse Environmental Conditions 14 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01/3

Traditionally, aircraft lightning strikes were a major aviation safety issue. However, the increasing use of composite materials and the use of digital avionics for flight critical systems will require that more specific lightning protection measures be incorporated in the design of such aircraft in order to maintain the excellent lightning safety record presently enjoyed by transport aircraft. In addition, several recent lightning mishaps, most notably the loss of the Atlas/Centaur-67 vehicle at Cape Canaveral Air Force Station, Florida in March 1987, have shown the susceptibility of aircraft and launch vehicles to the phenomenon of vehicle-triggered lightning. The recent findings of the NASA Storm Hazards Program were reviewed as they pertain to the atmospheric conditions conducive to aircraft lightning strikes. These data are then compared to recent summaries of lightning strikes to operational aircraft fleets. Finally, the new launch commit criteria for triggered lightning being used by NASA and the U.S. Defense Department are summarized. The NASA Research data show that the greatest probability of a direct strike in a thunderstorm occurs at ambient temperatures of about -40 C. Relative precipitation and turbulence levels were characterized as negligible to light for these conditions. However, operational fleet data have shown that most aircraft lightning strikes in routine operations occur at temperatures near the freezing level in non-cumulonimbus clouds. The non-thunderstorm environment was not the subject of dedicated airborne lightning research. Author

N90-15067# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PRINCIPAL CHARACTERISTICS OF LIGHTNING ON AIRCRAFT [PRINCIPALES CARACTERISTIQUES DES FOUDROIEMENTS SUR AVIONS]
J. L. BOULAY *In* AGARD, Flight in Adverse Environmental Conditions 10 p (SEE N90-15041 07-01) Sep. 1989 In FRENCH Previously announced in IAA as A89-48744
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The modeling and measurement of lightning on aircraft are considered. Experimental studies were conducted which are based on the launching of small rockets with conducting wires attached to the ground. The study of the lightning-aircraft interaction involves the characterization of the direct effect of lightning on the aircraft, the affect of the electromagnetic field of nearby lightning, the distribution of the electrical and magnetic field components on the aircraft exterior and interior, and the effect of perturbations on on-board equipment. Results are presented for lightning strikes observed on the Transall and CV 580 aircraft. IAA

N90-17581# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
AIRCRAFT FIRE SAFETY
Oct. 1989 408 p In ENGLISH and FRENCH Symposium held in Sintra, Portugal, 22-26 May 1989
(AGARD-CP-467; ISBN-92-835-0529-8; AD-A217575) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Symposium was arranged in the following sessions: Review of Fire-Related Aircraft Accidents; Fire Safety Standards and Research Programmes; Aircraft Internal Fires; Aircraft External Fires; Fire Safety of Military Weapon Systems; Fire Hardening by Advanced Materials and Structural Design; Passenger Behaviour in Emergy Situations; and Passenger Protective Equipment. The Technical Evaluation Report and an Addendum are included at the beginning of the Proceedings. Questions and answers of the discussions follow each paper. The purpose was a review of the present state-of-the-art and of the last improvements. Improvements are listed in the conclusions and recommendations

of the Technical Evaluation Report and in the Addendum. For individual titles, see N90-17582 through N90-17619.

N90-17582# Federal Aviation Administration, Atlantic City, NJ. Fire Safety Branch.
INVESTIGATION AND CHARACTERISTICS OF MAJOR FIRE-RELATED ACCIDENTS IN CIVIL AIR TRANSPORTS OVER THE PAST TEN YEARS
RICHARD G. HILL *In* AGARD, Aircraft Fire Safety 17 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A number of fire-related accidents and incidents that have occurred during the present decade are summarized. The selection of accidents/incidents was based on information availability and perceived importance of those chosen. A brief summary of accident data for the past ten years is presented. A methodology is shown for logically calculating the effects of cabin fire safety improvements on survivability utilizing past accidents. Eight accidents and four incidents are discussed and their link to safety improvements is described. A call for better information from accident investigations was issued. Author

N90-17583# Cranfield Inst. of Tech., Bedford (England).
AIRCRAFT FIRES: A STUDY OF TRANSPORT ACCIDENTS FROM 1975 TO THE PRESENT
A. F. TAYLOR *In* AGARD, Aircraft Fire Safety 19 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A further study is being made, on a world-wide basis, of accident summaries and reports together with recent papers on the various aspects of fire safety. The aim is to compare the period since 1974 with the first twenty years of survivable accidents to turbine powered aircraft as presented to the 1975 AGARD Symposium in Rome. While the study is still far from complete it does seem that, although some lessons were learned and improvements were made or are on the way, crashworthiness, fire, and survival remain areas of major concern. Author

N90-17584# Canadian Aviation Safety Board, Ottawa (Ontario).
AIRCRAFT FIRE SAFETY: LEARNING FROM PAST ACCIDENTS
W. T. TUCKER *In* AGARD, Aircraft Fire Safety 10 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The real value of aviation occurrence investigations lies in the lessons that can be learned from them to eliminate future accidents or reduce their severity. Past accidents are reviewed with emphasis on the Canadian experience (e.g., Pacific Western Airlines B737 at Calgary International Airport in March 1984) The determination of contributing factors and causes and the identification of safety deficiencies as practiced by the Canadian Aviation Safety Board are differentiated. Also included are areas of current concern and topics requiring further research with a view to further improving aircraft fire safety. Author

N90-17585# Federal Aviation Administration, Atlantic City, NJ. Fire Safety Branch.
DEVELOPMENT OF IMPROVED FIRE SAFETY STANDARDS ADOPTED BY THE FEDERAL AVIATION ADMINISTRATION
CONSTANTINE P. SARKOS *In* AGARD, Aircraft Fire Safety 14 p. (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A series of improved fire safety standards for transport aircraft adopted or proposed by the United States Federal Aviation Administration over the past five years are summarized and the technical development of these standards are described. Important test results and analyses employed to develop the new standards are described. Reference is made to technical publications issued by the FAA for each fire safety area. Emphasis is placed on recent and high-impact rulemaking actions such as the heat release

standard for large surface area interior panels (based on the Ohio State Rate-of-Heat-Release Apparatus). Other activities summarized include heat resistance evacuation slides, smoke detectors and fire extinguishers, cargo compartment fire protection, seat cushion fire blocking layers, floor proximity lighting, and crewmember protecting breathing equipment. Author

N90-17586# Department of Civil Aviation, An Hoofddorp (Netherlands).
FIRE SAFETY IN CIVIL AVIATION
W. KORENROMP *In* AGARD, Aircraft Fire Safety 12 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03;
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A large share of all fatalities in civil aviation are caused by fire. For a passenger who considers traveling by air as just another human activity to spend his lifetime, like walking, sporting or sleeping, the risk of flying is more relevant per time unit than per passenger-kilometer. This approach gives also a partial answer why so much should be done to improve safety in civil aviation and to harden the cabin against fire hazards, although commercial air transportation is already considered to be very safe. It is explained what relations exist between preventive measures and measures that mainly enhance survivability. An overview of types of aircraft accidents is given, which points to what types of measures are applicable and effective. The regulatory authorities should gradually develop the airworthiness requirements along these lines, in concert with technological progress and with an emphasis on quality. This will require much attention for cost-benefit analyses for new as well as old safety measures. Author

N90-17587# Civil Aviation Authority, London (England).
A REVIEW OF UK CIVIL AVIATION FIRE AND CABIN SAFETY RESEARCH
TREVOR J. GILPIN *In* AGARD, Aircraft Fire Safety 4 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03;
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A broad overview of current research in the UK into cabin safety is presented with particular emphasis on fire research. The status of passenger protection equipment is reviewed and work in the UK on cabin water sprays is reported. Work on fire blocking layers and small scale tests for the measurement of heat release from aircraft furnishing materials are discussed along with the suppression of fire in cargo compartments. Other topics include work on the mathematical modeling of aircraft cabin fires and on the human factors side, a study of the behavioral aspects of passengers evacuating an aircraft in a competitive situation. Author

N90-17588# Federal Ministry of Transport, Bonn (Germany, F.R.). Directorate General for Civil Aviation and Spaceflight.
OBJECTIVES AND RESULTS OF CABIN FIRE RESEARCH IN GERMANY
MANFRED WITTMANN *In* AGARD, Aircraft Fire Safety 6 p (SEE N90-17581 10-03) Oct. 1989
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German activities in aircraft cabin fire safety started in the early 1980's, highlighted by a full scale test in 1986, simulating an aircraft in-flight fire in a modern widebody fuselage. Beginning with a statistical analysis of in-flight fires in the period 1970 to 1982, efforts are presented from the political side to improve aircraft fire safety and outlines the philosophy why Germany concentrated on in-flight fire research. The consequences drawn out of the studies and test results for the design of aircraft cabin interiors and for post-crash fire situations are described. Finally, a view to future activities, including full scale component tests, is presented. Author

N90-17589# Air Canada, Montreal (Quebec). Materials and Processes Engineering.
NEW AIRCRAFT CABIN AND CARGO FLAMMABILITY STANDARDS FOR TRANSPORT CATEGORY AIRCRAFT
ARTHUR M. WITTENBERG *In* AGARD, Aircraft Fire Safety 9 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03;
Non-NATO Nationals requests available only from
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In transport aircraft, passenger safety is of paramount importance in establishment of criteria and requirements covering fireworthiness. Thus for cabin and cargo interiors, regulators and aircraft manufacturers have established flammability standards and/or criteria for materials used in these areas. The aircraft manufacturers in turn furnish aircraft with existing state-of-the-art materials technology which will satisfy or exceed the standards and/or criteria requirements. The evolution of these flammability standards to-date and test methods used to ascertain compliance, and an indication of the materials used to meet these standards are outlined. Author

N90-17590# Lufthansa German Airlines, Frankfurt (Germany, F.R.). Cabin, Cargo Systems.
FIRE PREVENTION IN TRANSPORT AIRPLANE PASSENGER CABINS
UDO WARGENAU *In* AGARD, Aircraft Fire Safety 6 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03;
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The most important aspect in air transportation is safety, a part of which is fire prevention. In the environment of the passenger cabin there are different ways to prevent fires. The most obvious one is to provide adequate detection and extinguishing devices. The second way is to design in a fire-preventive manner. The third and most challenging way is to be concerned with fire-resistant materials of the latest state of the art. Although airplanes are designed and built by big airframe manufacturers the airline engineers can take some influence on a fire-hard cabin. Aside from continually requesting changes from aircraft manufactuers the engineers can force the interior equipment vendors to use advanced techniques and materials. This, however, requires a certain degree of know-how and the good intention to assist these v. ... Author

N90-17591# Federal Aviation Administration, Atlantic City, NJ. Fire Safety Branch.
CHARACTERISTICS OF TRANSPORT, AIRCRAFT FIRES MEASURED BY FULL-SCALE TESTS
CONSTANTINE P. SARKOS and RICHARD G. HILL *In* AGARD, Aircraft Fire Safety 19 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03;
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AGARD/Scientific Publications Executive
Full-scale transport aircraft cabin fire tests conducted in the United States under postcrash fire conditions are discussed. The logic behind the development of fire test scenarios is described, including a comparison of fire involvement by external fuel fire penetration through an opening or by fuselage burnthrough. Early full-scale tests in the 1960's and 1970's that furnished data on the characteristics of cabin fires are briefly described. Past test activities addressing facets of the fuselage burnthrough problem are also discussed. The impact of environmental factors (such as wind, door opening configuration, and fuselage orientation) on fire penetration through openings and the resulting cabin hazards is discussed on the basis of past test activities. The majority of the data presented are from a recent full-scale test to determine fire/hazard progression in a postcrash cabin fire environment with emphasis on post-flashover conditions, to examine factors affecting occupant survivability, and to evaluate the performance of a protective breathing equipment filter. Past studies addressing important cabin fire characteristics and concepts, such as flashover, stratification, and survivability are discussed and cited. Author

N90-17592# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.

FULL SCALE STUDY OF A CABIN FIRE IN AN A300 FUSELAGE SECTION

R. DUSSA, R. FIALA, R. WAGNER, and B. ZENSES *In* AGARD, Aircraft Fire Safety 16 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Aircraft accidents involving cabin fires have shown that the burning behavior of the cabin materials plays a vital role for the survivability of the passengers. To gain more information on the complex physical and chemical processes in a cabin fire and one the validity of laboratory test methods to evaluate the burning behavior a Cabin-Fire-Safety program was set up. Besides laboratory tests a first full scale cabin fire test was carried out in the scope of this program. For this test an 18 meter long section of a wide body jet was available. Six meters of this fuselage were furnished with cabin materials fulfilling the newest safety standards. In this section gas sampling tubes, thermocouples, radiometers, and smoke density measuring devices were installed. Additionally, the fire was observed and recorded by five video cameras. The burner was situated between the side wall of the cabin and the adjacent seat of the last seat row. After a burning time of 105 seconds a self sustaining fire had developed. The burner was shut off. The fire was extinguished after 365 seconds. Halon was used as an extinguishing agent. Total halon consumption: 1.000 kg. A optical inspection of the cabin had the following result: The seat cushions showed minor to medium burns, except those in the immediate vicinity of the ignition source. The overall weight loss of the seat cushions was approximately 10 percent. The carpet was nearly undamaged. All other parts, as side wall panels, ceiling panels, insulation, air conditioning system, hatracks and so on suffered heavy damage or were destroyed. From gas concentration and temperature readings one could conclude that in the first 60 seconds after ignition survivable conditions prevailed in the cabin. In the following 60 seconds gas concentrations and temperatures reached lethal values. Oxygen concentration decreased rapidly. Visibility fell to zero. Flash-over occurred. The test will be illustrated by video film. Author

N90-17593# Civil Aviation Authority, Gatwick (England). Safety Regulation Group.

AIRCRAFT INTERNAL FIRES

REGINALD D. HALLIDAY *In* AGARD, Aircraft Fire Safety 9 p (SEE N90-17581 10-03) Oct. 1989
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With modern day appliances and equipment a well trained fire service unit should be able to effectively deal with any external fire that may occur at a survivable aircraft accident situation. Incidents that have occurred during recent years show that a positive approach is still needed to what is loosely referred to as the internal fire. New legislation does call for higher fire resistance standards but there will always be the requirement for fire service personnel to deal with this type of problem. A number of attempts were made to address this problem by using various methods to inject either water or halon gas. While these attempts are a possible way forward they have inherent problems. The fire service are faced with a situation over which they have no control and cannot alter in any way. These are: response time, the possible need to deal with an external fire first, passengers evacuating and using exits and denying access or exits that were left open by escaping passengers and will allow any exterior fire to enter. At the present time the United Kingdom is testing a system that does address these problems. It is really two systems in one: onboard water to be used through the cabin area at very low consumption rates activated immediately on impact; and the ability for external services to connect to the system without entering the fuselage and thereby maintain the water sprays while evacuation continues or rescue actions take place. Author

N90-17594# Factory Mutual Research Corp., Norwood, MA.

IGNITABILITY OF JET-A FUEL VAPORS IN AIRCRAFT FUEL TANKS

ERDEM A. URAL, ROBERT G. ZALOOSH, and FRANCO TAMANINI *In* AGARD, Aircraft Fire Safety 13 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Ignitability criteria for fuel vapors in aircraft wing tanks were analyzed. The effects of ambient temperature, tank pressurization, and ventilation on the flammability of the ullage gas mixtures were demonstrated using the ULLAGE computer code. It was shown that in the absence of tank inerting, flammable mixtures are most likely to form at some point during all transport and fighter missions considered. The relative ignitability of ullage vapor mixtures versus the propane-air mixture called for in Military Standard 1757A was analyzed for a lightning strike scenario for spark ignition and hot surface ignition modes. It was shown that the military standard is not always a conservative evaluation of the ullage ignition hazard. A procedure to determine when the ullage is more readily ignitable than the mixture specified by the Military Standard 1757A was recommended. Author

N90-17595*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

FIRE SAFETY APPLICATIONS FOR SPACECRAFT

ROBERT FRIEDMAN and SANDRA I. OLSON *In* AGARD, Aircraft Fire Safety 15 p (SEE N90-17581 10-03) Oct. 1989 Previously announced as N89-24413
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Fire safety for spacecraft is reviewed by first describing current practices, many of which are adapted directly from aircraft. Then, current analyses and experimental knowledge in low-gravity combustion, with implications for fire safety are discussed. In orbiting spacecraft, the detection and suppression of flames are strongly affected by the large reduction in buoyant flows under low gravity. Generally, combustion intensity is reduced in low gravity. There are some notable exceptions, however, one example being the strong enhancement of flames by low-velocity ventilation flows in space. Finally, the future requirements in fire safety, particularly the needs of long-duration space stations in fire prevention, detection, extinguishment, and atmospheric control are examined. The goal of spacecraft fire-safety investigations is the establishment of trade-offs that promote maximum safety without hampering the useful human and scientific activities in space. Author

N90-17596# Fire Research Station, Borehamwood (England).

FIRE SCIENCE AND AIRCRAFT SAFETY

G. COX and J. B. MOSS (Cranfield Inst. of Tech., Bedford, England) *In* AGARD, Aircraft Fire Safety 12 p (SEE N90-17581 10-03) Oct. 1989
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The increased awareness of fire hazards in both passenger transport and buildings has precipitated a reappraisal of models of fire spread embracing both empirical and more fundamentally-based computational approaches. Recent developments are described in the fire science-related aspects of such hazards, contrasting the broad strategies adopted with those applied in the more highly developed combustion technologies. It seeks to demonstrate how current capabilities and future developments, particularly in the computational modeling fire, and driven primarily by the study of fires in building enclosures, might be utilized to guide layout, design and the selection of furnishing materials in aircraft cabins. Examples of current capabilities of computational fluid dynamic models in describing such critical fire phenomena as smoke movement, fire growth, and flame spread are presented. Author

N90-17597# Thames Polytechnic, London (England). Centre for Numerical Modelling and Process Analysis.
FORCED AND NATURAL VENTING OF AIRCRAFT CABIN FIRES: A NUMERICAL SIMULATION
E. R. GALEA and N. C. MARKATOS   *In* AGARD, Aircraft Fire Safety 9 p (SEE N90-17581 10-03)   Oct. 1989   Prepared in cooperation with National Technical Univ., Athens (Greece)
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A steady-state three-dimensional mathematical field model describing aircraft cabin fires is presented. The fire is modeled by a simple heat source. The simulation is intended to represent nonspreading fires. The computer code uses a Body-Fitted Co-ordinate (BFC) formulation to model accurately the interior of the aircraft that is neither Cartesian nor polar-cylindrical. The dimensions of the fuselage are that of a BOEING-737. The effect of various openings in the fuselage on the temperature distribution within the empty aircraft cabin are investigated. With the cabin fitted with seats, ceiling panels and overhead stowage bins the effect of the aircrafts air-conditioning system on the temperature distribution within the burning fuselage is also examined. Early results suggest that a reverse flow situation (i.e., cold air injected through floor vents and hot air sucked out at ceiling vents) greatly reduces the temperature throughout the fuselage.   Author

N90-17598# New Brunswick Univ., Fredericton. Dept. of Mechanical Engineering.
TIME DEVELOPMENT OF CONVECTION FLOW PATTERNS IN AIRCRAFT CABINS UNDER POST-CRASH FIRE EXPOSURE
G. V. HADJISOPHOCLEOUS, A. C. M. SOUSA, and J. E. E. VENART   *In* AGARD, Aircraft Fire Safety 14 p (SEE N90-17581 10-03)   Oct. 1989
(AGARD-CP-467)   Copyright   Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The internal transient thermal response of an aircraft cabin to pool fires of different strengths burning outside an open door or fuselage break is simulated. The thermal processes within the cabin are modeled using the fluid flow and energy governing equations. Particular attention is given to the level and time development of the thermal stratification within the cabin over the first 90 s and the time allowed for evacuation of passengers in aircraft certification tests. The numerical simulations for a two-dimensional domain were carried out with advanced numerical techniques based on a control volume formulation combined with boundary-fitted coordinates. Assessments conducted previously on the reliability and accuracy of the algorithm are also briefly outlined.   Author

N90-17599# Societe Bertin et Cie, Les Milles (France). Electronics and Information Div.
VULCAIN: AN EXPERT SYSTEM DEDICATED TO FIRE RISK ANALYSIS WITHIN COMPLEX INDUSTRIAL ENVIRONMENTS
SERGE GALANT, PIERRE MEREAU, and N. TURIN   *In* AGARD, Aircraft Fire Safety 9 p (SEE N90-17581 10-03)   Oct. 1989
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VULCAIN is an expert system which allows rapid fire risk analysis within complex industrial environments. It works step by step as a function of the risk critically. It uses: as a first step, a risk analysis using standards; then more complete diagnosis based on various aspects which are not covered by standards (viz: fire propagation on targets, influence of both natural and forced ventilation); and finally, complete spatial and temporal numerical simulations of fire propagation where temperatures vs time diagrams are obtained to characterize fire propagation and/or extinction. VULCAIN is very convivial software tool to carry out complex sensitivity analysis concerning all critical parameters (combustible material, openings, wall thermal and chemical characteristics) and systematic studies concerning a given criterion (for instance: possibility of fire control by human means). All the knowledge base within VULCAIN was validated with respect to small and full scale experiments. Good results were obtained for such industrial sites as: nuclear power plants, storage areas, submarines. Its use can be envisaged for vulnerability studies of airplanes.   Author

N90-17600# Air Force Aero Propulsion Lab., Wright-Patterson AFB, OH.
HOT SURFACE IGNITION STUDIES OF AVIATION FLUIDS
R. G. CLODFELTER   *In* AGARD, Aircraft Fire Safety 8 p (SEE N90-17581 10-03)   Oct. 1989
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Hot surface ignition temperature testing was performed in the Aircraft Engine Nacelle Fire Test Simulator (AENFTS) located at Wright-Patterson Air Force Base, Ohio. The objective of this test program was to measure Minimum Hot Surface Ignition Temperatures (MHSIT) of five common aircraft fluids (MIL-H-5606 and MIL-H-83282 hydraulic fluids, JP-4 and JP-8 fuels and MIL-L-7808 lubricating oil) using an air-heated bleed-air duct in a high realism test article. A simulated portion of the F-16 engine compartment and F100 engine was inserted into the AENFTS and the five aircraft fluids were injected as spray or drips (streams) onto various locations on the hot bleed-air duct. Ventilation air pressure, temperature, velocity and the flammable fluid flow rate were varied to study their effect on the MHSIT of these fluids. The results show that MHSIT is dependent on both fluid application mode, spray or drip, and application location. MHSIT increased for all test conditions as ventilation air pressure decreased. Increasing ventilation air temperature tended to decrease the MHSIT. Although MHSIT increased with ventilation air velocity increases, this is not a dependable safety criteria since stagnation regions are known to exist in engine compartments. In general, due to the high level of simulation achieved in this program and the wide scope of the test conditions, the results will be of significant value in the fire safety design of future aircraft systems.   Author

N90-17601# Royal Aerospace Establishment, Farnborough (England).
THE STABILITY OF FUEL FIRES
J. R. TILSTON   *In* AGARD, Aircraft Fire Safety 11 p (SEE N90-17581 10-03)   Oct. 1989
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The mechanisms of ignition, stabilization, and propagation of aviation turbine fuel fires are examined and discussed in the context of aircraft accidents. This appraisal suggests that the crucial role of a suitably sized aerodynamic stability zone in the stabilization of fuel spray fires was not adequately recognized in the past. It also suggests that the importance of hot surfaces as sources of fuel preparation and ignition was, similarly, neglected. From considerations of the buoyancy and radiative characteristics of even moderately sized pool fires it is concluded that great care is required in the interpretation of results from smaller experimental fires.   Author

N90-17602# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
ONBOARD FIRE- AND EXPLOSION SUPPRESSION FOR FIGHTER AIRCRAFT
J. WORDEHOFF   *In* AGARD, Aircraft Fire Safety 11 p (SEE N90-17581 10-03)   Oct. 1989
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The threats to which modern fighter aircraft can be exposed and the state of the art hardware for active and passive fire and explosion suppression systems on the market to combat these threats are described. A summary of forecasted development will be given especially in the field of fire detection systems. An example is given to indicate the progress which was achieved in weight reduction and system improvement over the last 10 years. A fire and explosion suppression system layout will be given for a modern fighter aircraft including its penalty on mass and fuel denial.   Author

N90-17603# Naval Air Systems Command, Washington, DC. Subsystems Branch.
US NAVY AIRCRAFT FIRE PROTECTION TECHNOLOGY
P. WEINBERG *In* AGARD, Aircraft Fire Safety 7 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The U.S. Navy aircraft are routinely exposed to various combat and non-combat threats that could cause either a fire or fuel system explosion. An overview is provided for the design concepts to prevent, detect, and extinguish these fires and explosions. Examples are given of actual designs and equipment installed on current Navy aircraft. An assessment is included on how well these systems perform under test and operational conditions.
Author

N90-17604# National Defence Headquarters, Ottawa (Ontario). Accident Investigation Prevention.
AIRCRAFT FIRE SAFETY IN THE CANADIAN FORCES
T. A. BAILEY *In* AGARD, Aircraft Fire Safety 6 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Flight safety is a prime consideration of the Canadian Forces in its approach to air operations. The aim of the flight safety program is to prevent the accidental loss of aviation resources and this is done by investigation of occurrences, determination of cause, and implementation of preventive measures. Aircraft fire safety is a concern not only to save lives, but resources as well. An overview of aircraft fire safety in the Canadian Forces and how fire safety is approached for the various aircraft types is presented. The transport, maritime, and helicopter fleets are discussed as are procedures for the CF-18. Another aspect of fire safety is that is briefly covered is the crash, fire, and rescue capability (CFR) at military airports to handle an emergency.
Author

N90-17605# Boeing Commercial Airplane Co., Seattle, WA.
FIRE HARDENING OF AIRCRAFT THROUGH UPGRADES OF MATERIALS AND DESIGNS
J. M. PETERSON, J. C. MCMILLAN, and J. T. LIKES *In* AGARD, Aircraft Fire Safety 7 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Commercial air transportation is the safest mode of transport, because the industry and its regulators have emphasized accident avoidance along with backup fire management/control and personnel evacuation strategies when accidents do occur. Regulatory authorities set the minimum safety standards for the design, manufacture, and operation of aircraft, to which the individual manufacturers and operators add their own unilateral, self-imposed safety criteria. The evolution and status of the FAA regulatory fire safety criteria applicable to aircraft manufacturers, and the additional criteria imposed by the manufacturers on themselves such as D6-51377 for Boeing and ATS 1000.001 for AIRBUS Industries, are discussed.
Author

N90-17606# British Aerospace Public Ltd. Co., Woodford (England). Airlines Div.
FIRE HARDENING OF AN AIRCRAFT PASSENGER CABIN
G. J. TRELOAR *In* AGARD, Aircraft Fire Safety 9 p (SEE N90-17581 10-03) Oct. 1989
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The implications of fires to that part of a passenger aircraft comprising the fuselage pressure shell are discussed, with particular reference to the passenger cabin and crew areas. The history of materials utilization is reviewed, leading to an overview of the current materials scenario, with particular reference to the use of combustible materials. The particular materials related regulations, covering aspects of fire hardening appertaining to baggage holds, passenger cabin furnishings, and seats, and the additional smoke and toxicity tests introduced by constructors, are discussed. Potential developments to fire harden the fuselage shell to resist

an external fire, and cabin furnishings improvements to provide increased fire hardening are exemplified. The interaction between the design aims of the constructors, passenger acceptance, the requirements of the airlines and fire safety are presented finally.
Author

N90-17607# Royal Air Force Coll., Cranwell (England).
FIRE RESISTANCE AND BREAKDOWN OF COMPOSITE MATERIALS
K. W. SMITH *In* AGARD, Aircraft Fire Safety 4 p (SEE N90-17581 10-03) Oct. 1989
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Aspects of cabin fire safety and passenger protective breathing equipment are considered. The use of non-metallic composites in furnishings and structures is examined for advantages and future trends. Test requirements for fire resistance and breakdown are reviewed and suggestions are made in light of past accident experience.
B.G.

N90-17608# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Non-Metallic Materials and Processes.
ADVANCED MATERIALS FOR INTERIOR AND EQUIPMENT RELATED TO FIRE SAFETY IN AVIATION
HANS-DIETER BERG *In* AGARD, Aircraft Fire Safety 7 p (SEE N90-17581 10-03) Oct. 1989
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The improvements of product safety is continuously under review by aircraft manufacturers. One of the most important fields of safety for passengers and crew members relates to improvements in connection with fires inside and outside the cabin. Naturally, several paths have to be followed simultaneously to achieve the best possible effect. First and foremost there is obviously the endeavor to avoid such accidents from the start. The training of the crew, design of the aircraft and maintenance, airport safety facilities and, last not least, the introduction of improved materials are of vital importance to reduce the danger of accidents with fires. The important aspect of material development and structural design for the interior furnishings and equipment of aircraft is considered.
Author

N90-17609# Aerospatiale, Toulouse (France).
NEW MATERIALS FOR CIVIL AIRCRAFT FURNISHING
M. J. FRUSTIE and C. KURAS (Aerospatiale, Suresnes, France)
In AGARD, Aircraft Fire Safety 4 p (SEE N90-17581 10-03) Oct. 1989
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In order to improve aircraft safety with respect to fire, in the last few years the authorities have issued several regulations relative to the fire resistance of organic materials used in civil aircraft commercial furnishing, in particular FAR 25 Amendment 61 and FAR 121 Amendment 189. The purpose is to limit the heat release of the materials used for passenger cabin furnishing. These regulations to be applied on aircraft delivered as soon as August 88 are very severe as they prohibit the use of most of the materials which were used up to now. The purpose is to present the various investigations on new materials made at Aerospatiale together with the development of new technologies.
Author

N90-17610# National Research Council of Canada, Ottawa (Ontario). Inst. for Research in Construction.
HEAT RELEASE RATE MEASUREMENT FOR EVALUATING THE FLAMMABILITY OF AIRCRAFT MATERIALS
YOSHIO TSUCHIYA *In* AGARD, Aircraft Fire Safety 8 p (SEE N90-17581 10-03) Oct. 1989
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With the goal of improving fire safety in passenger aircraft, the FAA and Transport Canada have adopted a new test method to evaluate the flammability of aircraft interior materials. The method uses a modified ASTM E906 release rate test apparatus. Experiments have shown that the test is affected by small variations

in such factors as the pattern of airflow in the combustion chamber, the number and position of pilot flames and certain characteristics of the sample such as flame retardancy and physical construction. The various factors affecting the test are discussed. Of particular interest is a comparison between the thermal method and the oxygen consumption method of HRR measurement. The oxygen consumption method is recommended.   Author

N90-17611# Factory Mutual Research Corp., Norwood, MA.
FLAMMABILITY TESTING OF AIRCRAFT CABIN MATERIALS
A. TEWARSON and R. G. ZALOSH   *In* AGARD, Aircraft Fire Safety 12 p (SEE N90-17581 10-03) Oct. 1989
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    Before the new Federal Aviation Administration flammability regulations for aircraft cabin materials were announced, various laboratory flammability tests were conducted on generic aircraft panel materials. Besides convective heat release rates and smoke optical densities, which are included in the new regulations, the tests included material ignitability, fire propagation rates, chemical hea. reiease rates, and toxic gas generation rates. Data obtained using different test methods often differ significantly for the same generic panel material. For example, critical heat fluxes for ignition as measured in the NIST Ignition Apparatus are 16percent to 110 percent higher than those measured in the FMRC apparatus. In the case of fire propagation, test data are reported for electrical cables as well as panel materials. The cable fire propagation rates are correlated against a fire propagation index based on heat release rate and ignitability data. These data may be useful in assessing the in-flight fire hazard of various cabin materials. In the case of heat release rates per unit surface area, if data from different test facilities are normalized by incident heat flux and compared in terms of the ratio of chemical, and convective heats of combustion to the effective heat of gasification, there is agreement to within at least one significant figure for most materials. Aircraft panel material smoke generation potential, as measured by mass optical density, is shown to be highly dependent on the light source and the ventilation conditions in the fire test. Since these conditions differ substantially for post-crash fires and in-flight fires, flammability guidelines for smoke generation, toxicity, and corrosivity during in-flight fires may entail different test methods than currently used to screen cabin materials for post-crash fire survivability.   Author

N90-20054# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
IMPLICATIONS OF ADVANCED TECHNOLOGIES FOR AIR AND SPACECRAFT ESCAPE
Feb. 1990   108 p   in ENGLISH and FRENCH   Symposium held in Munich, Fed. Republic of Germany, 24-28 Apr. 1989
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    With reduction of escape fatalities or injuries and improvement of out-of-the envelope ejection safety as primary goals, this Symposium addressed the latest technological advances in all areas which affect overall escape system performance and capabilities. Escapes from hypersonic vehicles and spacecraft were also considered. For individual titles, see N90-20055 through N90-20066.

N90-20057#   Institute of Aviation Medicine, Farnborough (England).
DEVELOPMENT OF AN EJECTION SEAT SPECIFICATION FOR A NEW FIGHTER AIRCRAFT
D. J. ANTON   *In* AGARD, Implcations of Advanced Technologies for Air and Spacecraft Escape 7 p (SEE N90-20054 13-03) Feb. 1990
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    The development of a new aircraft brings with it the opportunity to incorporate improvements, and new features, in the design of the escape system that experience with previous systems has shown to be necessary. Just such an opportunity occurred with the announcement of the development of the European Fighter

Aircraft. The United Kingdom input to the specification of the ejection seat for this aircraft wa derived from accident experience and from analysis of ejection est data from previous marks of ejection seat. The aim is to dis the problem of impairment of consciousness on ejection, the rationale for improvements in ejection seat stability, and measures taken to improve ejection seat headbox impact attenuation.   Author

N90-20058#   Royal Aerospace Establishment, Farnborough (England).
ESCAPE SYSTEMS RESEARCH AT RAE
D. J. GILSON   *In* AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 15 p (SEE N90-20054 13-03) Feb. 1990
(AGARD-CP-472) Copyright Avail: NTIS HC A03/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    A range of recent topics in the escape systems research program at the Establishment is described. Prominent among these is the computer simulation of ejection seat dynamics which enables prediction of the behavior of escape systems in different conditions, and complements the experimental methods of investigation. Other topics described include passive methods of seat stabilization using plates to supplement a bridle-mounted drc_ o, use of a reefed drogue to improve deceleration characteristics. consideration of some methods of deceleration, and use of inflatable restraint devices. Electronic sequencer developments are described, leading to provision of a high capacity, high reliability sequencer for trials use. A Biodynamic modeling and dummy development are considered.   Author

N90-20059# Martin-Baker Aircraft Co. Ltd., Denham (England).
FIGHTER ESCAPE SYSTEM: THE NEXT STEP FORWARD
B. A. MILLER   *In* AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 6 p (SEE N90-20054 13-03) Feb. 1990
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    Ejection seats have become increasingly complex, heavier and bulkier in recent years. This growth in response to the increasing demands for greater performance, under more severe conditions. It is also due to the relocation onto the seat of equipment which was previously aircraft mounted such as anti-g valve, oxygen regulator, NBC equipment, and OBOGS auxiliary oxygen equipment. In the Tornado, the Mk10A ejection seat even gained outlets for the cabin conditioning system, becoming the world's first air conditioned ejection seat. This trend has persisted for some 15 years, but now new design derivers are becoming dominant with an increasing and urgent need for lightweight and low cost. The Martin-Baker developments of the pas 15 years are briefly reviewed and the new trends which are shaping future Fighter Escape Systems discussed.   Author

N90-20060# Douglas Aircraft Co., Inc., Long Beach, CA.
POTENTIAL ROLE OF AVIONICS IN ESCAPE SYSTEMS
JAMES J. SCHOEN   *In* AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 4 p (SEE N90-20054 13-03) Feb. 1990
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    The role of avionics in escape systems for high-performance aircraft is rapidly expanding. In the most advanced systems currently in service, an electronic controller, in conjunction with mechanical sensors, selects the recovery sequence and controls event timing. More advanced avionics systems under development feature improved microprocessors and solid-state sensors. These slightly improve performance by modifying system timing based on airspeed and altitude conditions. They also introduce desirable black-box features such as built-in-test and fault isolation. Avionics has the potential to contribute far more to escape systems based on the current development of controllable propulsion systems. Typically these systems would consist of multiple rocket engines under the command of a microprocessor/controller. The controllable propulsion system would control attitude and would also control the acceleration forces on the crew member. The avionics system would therefore include attitude and acceleration

sensors. In smarter systems,the propulsion system could be used to control the escape trajectory for ground avoidance or to reduce forces on the crew member in an escape under benign conditions. Thus, the avionics system may include ground direction and proximity sensors. Real-time control of an escape system vehicle under the dynamic conditions associated with high airspeed or rapid maneuvering requires a comprehensive avionics system with high-frequency response. However, the technology is available, and this type of system could be a basic feature of any next-generation escape system. Author

N90-20061# German Air Force, Fuerstenfeldbruk (Germany, F.R.). Inst. of Aerospace Medicine.
EJECTION SEAT TRAINING OF JET PILOTS AND WEAPON SYSTEM OFFICERS AT THE GERMAN AIR FORCE SCHOOL OF AVIATION MEDICINE
R. O. AMENDT In AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 2 p (SEE N90-20054 13-03) Feb. 1990
(AGARD-CP-472) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Ejection seat systems have been in use since World War II in most jet aircraft in Air Forces all over the world and nowadays have reached a high technical performance standard. There is no doubt that any escape system can only be as efficient as its operator and user and how he knows and correctly applies it within the system performance limits. For these reasons academic and practical training of pilots and weapon system officers in two-seater aircraft has become mandatory. The objectives of this training are as follows: inform the pilot about the physical stress on his body during ejection from aircraft in order to safe his life and avoid injuries; drill safe operating procedures of the respective escape system so they become routine and instinctive, emphasizing what can happen if the system is not used correctly or in good time; and eliminate the psychological threshold to actually get out of the protecting cockpit in case of emergency simply by having already practiced this situation in a simulator. The primary objective with this new device was to simulate ejection from the aircraft as realistic as possible under training conditions on the ground. The new training device and some first experiences with it are described. Author

N90-20063# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Systems Div.
WINDBLAST PROTECTION FOR ADVANCED EJECTION SEATS
LAWRENCE J. SPECKER and JAMES W. BRINKLEY In AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 11 p (SEE N90-20054 13-03) Feb. 1990
(AGARD-CP-472) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The United States Air Force is currently engaged in an advanced development program to demonstrate the feasibility of extending the capability of open ejection seats to 700 KEAS. The probability of injury at this airspeed is estimated to be 100 percent based on the current injury statistics. Past approaches to windblast protection have involved the use of harnesses and limb tethers which have proved to be unacceptable to pilots. Therefore, advanced unencumbering techniques are required to provide the needed protection. The USAF has developed and tested a windblast protection concept that utilizes high-strength, deployable fabric panels. The panels capture and slow the aerodynamic flow impinging on the ejection seat occupant's extremities and torso and reduce the probability of windblast induced flail injury. Wind tunnel tests were conducted in low- and high-speed wind funnels using one-half scale models of a fiftieth percentile crewman and ejection seat as well as full-scale manikins and modified ACES 2 ejection seats equipped with the flow-stagnation panels. The tests were accomplished to determine the degree of protection for the crewmember, the influence of the flow-stagnation panels on ejection seat aerodynamics, and the effects of design changes to the panel shape and material. The wind tunnel tests have demonstrated the protective potential of the flow-stagnation concept, but classical aerodynamic and windblast tests have indicated the configuration of the panels is critical to the protection of the crewmember's head. Configuration of the panels is also

critical for the reduction of the total loads acting on the crewmember and seat combination. Without passive aerodynamic reduction of the forces and moments, a larger catapult and stabilization system thrust must be used to maintain stabilized flight through the ejection sequence. An overview of the flow-stagnation windblast protection system tests, the implications of its use and required future tests are discussed. Author

N90-20064# Douglas Aircraft Co., Inc., Long Beach, CA.
CONTROLLABLE PROPULSION FOR ESCAPE SYSTEMS CONTROL
A. BLAIR MCDONALD In AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 6 p (SEE N90-20054 13-03) Feb. 1990
(AGARD-CP-472) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Current escape systems for military aircraft use solid-grain rockets for propulsion. These provide a fixed level of thrust for a fixed period of time. Since the escape system has no function over a wide range of conditions, this approach is a compromise. Significant improvements in escape capability could be achieved by introducing a propulsion system in which the thrust-time profile could be varied to suit the circumstances of each emergency. The technology now exists to introduce a fully controllable propulsion system. Such a system would not only provide a variable thrust-time profile but would also permit the propulsion system to provide stabilization, to control the forces applied to the crew member, and to control the escape trajectory. These capabilities would allow improved system operation throughout an expanded escape envelope. The technology for a fully controllable propulsion system was already demonstrated in a development program. Author

N90-20065# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
REQUIREMENTS FOR PROTECTIVE PRESSURE SUITS FOR THE HERMES SPACECREW [EXIGENCES DU SCAPHANDRE DE PROTECTION DE L'EQUIPAGE D'HERMES]
L. SIMIONESCO and C. FAGOT In AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 10 p (SEE N90-20054 13-03) Feb. 1990 In FRENCH
(AGARD-CP-472) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
In its present configuration, the Hermes space plane is equipped with a pressurized ejection capsule designed to assure crew protection during the critical phases of both launching and atmospheric reentry. The capability of operating in large areas (up to M = 7, Z = 60 km) is required of the launcher. The capsule provides the 3 man space crew the physical protection necessary during ejection in either landing or splashdown. The fear of accidental loss of pressure in the Hermes cabin requires the crew to be equipped with individual protective pressure suits. From analyses of missions and results, the functions of the pressure suits are described, and the physical limits and operating constraints are proven. The pressure suit systems can be integrated with the space plane. Of concern is the resolution of the insertion interface procedures used in mission rescue scenarios and emergencies. Author

N91-11706# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
OCCUPANT CRASH PROTECTION IN MILITARY AIR TRANSPORT
RICHARD F. CHANDLER Aug. 1990 151 p
(AGARD-AG-306; ISBN-92-835-0579-4; AD-A227647) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The progress is traced of developments in seat and restraint systems for passengers in all types of aircraft. Results of carefully directed studies from the 1940s through current times leading to today's state-of-the-art are reported as are specifications and regulations which were developed. An extensive bibliography provides the sources of reports necessary for a reader who wishes to make an indepth study of the technology. Author

N91-18067# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
PROGRESS IN MILITARY AIRLIFT
Dec. 1990 306 p In ENGLISH and FRENCH Symposium held in Lisbon, Portugal, 28-31 May 1990
(AGARD-CP-495; ISBN-92-835-0585-9; AD-A239471) Copyright
Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Although military transport aircraft and helicopters will continue to be of increasing importance in future military operations, military transport aircraft technology has not received the same level of attention that has been directed, for example, to combat aircraft. It is important and timely to review the area of military airlift and assess: the present and perceived future military roles and requirements, the required developments in technology, the extent to which civil technology applications can enhance current and Included are operational experience and requirements, cockpit design and aircrew performance, specific technologies such as fuel, powerplant and aerodynamic design, and a review of current new programs. For individual titles, see N91-18068 through N91-18093.

N91-18068# Aeronautical Systems Div., Wright-Patterson AFB, OH.
THE STUDY APPROACH AND PERCEIVED NEEDS FOR AN ADVANCED THEATER TRANSPORT
VLADIMIR VUKMIR In AGARD, Progress in Military Airlift 12 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Advanced Transport Technology Mission Analysis (ATTMA) is a broad based investigation of future tactical airlift mission requirements and of the attendant technologies necessary to satisfy those requirements. The approach taken in the study effort and the perceived needs for a 21st century Advanced Theater Transport (ATT) are considered. The descriptors theater, tactical, and intratheater are used synonymously and are to be differentiated from a strategic or intertheater airlifter. Specific military airlift tasks are defined in detail for Europe, Southwest Asia, and Central America that are representative of the kinds of missions that are believed to drive the demand for theater airlift in the 21st century. These tasks then serve as a basis for comparing the productivity/effectiveness of alternative system options. Presented are the results of conceptual STOL and VSTOL airlifters relative to the current U.S. airlift fleet in accomplishing the tasks defined above. Perceived system deficiencies and corresponding needs are identified. One such need is improved cargo handling (loading/unloading and transshipment) for future theater airlifters operating into short, austere landing sites in or near a threat environment. When the many variations in intermodel interfaces with present or future airlifters and potential increase in the need for theater airlift on an international scale are considered, the cargo handling issue may be one of several that could benefit greatly from international cooperation. Author

N91-18069# Sikorsky Aircraft, Stratford, CT. Advanced Design and Business Development.
DESIGN OF THE ADVANCED CARGO AIRCRAFT. THE US ARMY'S NEXT GENERATION TRANSPORT ROTORCRAFT: AN OVERVIEW
CHRIS JARAN In AGARD, Progress in Military Airlift 8 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A family of rotorcraft were defined to meet the projected requirements of the U.S. Army for combat airlift in the year 2000 and beyond. A detailed definition of equipment and mission load inventories was developed, and a knowledge-based simulation assessed the capability of various-size aircraft to transport these inventories in three combat theaters: Europe, Southwest Asia, and Latin America. Payload capabilities of 18, 26, 30, and 39 thousand lb with 270 nm (500 km) radius of action at Army hot day ambients were identified as potentially cost effective design points. A 9 x 9 ft (2.74 x 2.74 m) cabin cross section was required, with a cabin length of 32 to 41 ft (9.75 to 12.5 m) depending on design payload

Single and tandem rotor helicopter solutions were defined for each of the four design payloads. A tilt rotor solution was also examined. A single rotor configuration with a design gross weight of 94,000 lb (42,637 kg), a rotor diameter of 122 ft (37.2 m), and three engines served as a baseline for evaluation of the impact of various design criteria and system technology levels. Author

N91-18070# Construcciones Aeronauticas S.A., Madrid (Spain). Projects Div.
GENERAL CONFIGURATION ASPECTS ON AIRLIFTER DESIGN
J. L. LOPEZDIEZ, J. R. HERRERA, and J. L. ASENJO In AGARD, Progress in Military Airlift 14 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The history and actual process followed at CASA for the analysis of the requirements and selection of the most suitable configuration for a new Military Airlifter System are presented. The importance of an adequate initial choice of some parameters such as fuselage cross-section and length, wing area and geometry related to load and unload operations was emphasized. Peace time and war time operations must be taken into account to get a realistic view of essential factors such as fleet size and life-cycle cost for the transport system. Finally the availability of suitable powerplants is an important factor to fix the final specifications of a Military Airlifter System. Author

N91-18071# Plans du Transport Aerien Militaire, Velizy-Villacoublay (France).
LESSONS DRAWN FROM FRANCE'S RECENT OPERATIONAL EXPERIENCES REGARDING THE DESIGN OF MILITARY TRANSPORT AIRCRAFT [ENSEIGNEMENTS TIRES PAR LA FRANCE DE SES EXPERIENCES OPERATIONNELLES RECENTES EN MATIERE DE CONCEPTION D'AVIONS DE TRANSPORT MILITAIRE]
A. BEVILLARD In AGARD, Progress in Military Airlift 8 p (SEE N91-18067 10-03) Dec. 1990 In FRENCH
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Since the end of the second world war the French military has conducted operations in a number of diverse theaters including Indochina, Algeria and Chad. Lessons drawn from these operational experiences, related to the design of military transport aircraft are discussed and specific design criteria for a future fleet of transport aircraft are defined. The essential characteristics of a future military transport include: (1) a cargo bay with a minimum height and width of 4 meters (larger than the current dimensions of the C-160 and C-130); (2) good tactical capabilities combined with a significant operating range; and (3) interoperability (since the development of this aircraft will require a european, if not an american-european cooperative effort. Transl. by M.G.

N91-18072# Joint Air Transport Establishment, Brize Norton (England).
RECENT IMPROVEMENTS TO THE RAF AIR TRANSPORT FORCE
D. MACINTOSH In AGARD, Progress in Military Airlift 7 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The most significant improvement to the United Kingdom's Military Air Transport Force in recent years is described: the procurement of the Lockheed L1011 Tristar aircraft into the RAF service. The reasons behind the introduction of the Tristar, and its subsequent modifications into three very capable tanker, freighter, and passenger carrying variants are outlined. Moreover, some of the aircraft's capabilities and drawbacks are discussed. In addition, and with a view to the future, some of the cost disadvantages of an aging air transport fleet are considered. Furthermore, the RAF approach to considering a timescale for the introduction of a possible replacement transport aircraft is presented. Author

N91-18074# Aerospatiale, Toulouse (France). Div. Avions.
APPLICATION OF NEW TECHNOLOGIES IN THE DESIGN OF THE COCKPIT IN FUTURE MILITARY TRANSPORT AIRCRAFT [APPORT DES TECHNOLOGIES NOUVELLES DANS LA CONCEPTION DU POSTE DE PILOTAGE D'UN FUTUR AVION DE TRANSPORT MILITAIRE]
J. BORREL, M. DUTURC, and G. MITONNEAU   *In* AGARD, Progress in Military Airlift 20 p (SEE N91-18067 10-03)   Dec. 1990   In FRENCH
(AGARD-CP-495)   Copyright   Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Aerospatiale's experiences in the design and development of cockpits for the Airbus-series aircraft and the C-160 military transport are discussed. The evolution of cockpit display instruments, automatic flight control, and flight management systems utilized for the Airbus series is summarized. The application of new technologies in the cockpits of future military transport aircraft is discussed.   Transl. by M.G.

N91-18075# Aeritalia S.p.A., Naples (Italy). Flight Deck and Avionics Systems.
ADVANCED TECHNOLOGY APPLICATION IN THE FLIGHT DECK DESIGN FOR MILITARY TRANSPORT AIRCRAFTS
V. AFELTRA and A. LAPASTINA   *In* AGARD, Progress in Military Airlift 8 p (SEE N91-18067 10-03)   Dec. 1990
(AGARD-CP-495)   Copyright   Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The continuous growing in systems/functions installed in the modern aircraft, imposed by the more and more demanding requirements in terms of performance and safety, is leading to the development and the application of new components and systems in the area of cockpit indication and automatic controller integration. The cathode ray tube (CRT) and other multifunction display technologies are rapidly replacing many of the dials, panels, and gauges of the old cockpit. Artificial intelligence and high level automation are emerging in digital avionics. These systems would take over the crew in many cockpit management functions such as reconfiguration to compensate fault or execute emergency procedures. The design and certification aspects are analyzed which relate to the adoption of these new technologies and some aspects of human factor engineering are discussed which become an integral part for the cockpit design, for the symbology, and for the logic integration of the function within the automatic control and display systems.   Author

N91-18081# Societe Nationale d'Etudes et de Construction de Moteurs Aeronautiques, Corbeil (France). Centre d'Essais de Villaroche.
IMPROVING MILITARY TRANSPORT AIRCRAFT THROUGH HIGHLY INTEGRATED ENGINE-WING DESIGN
A. LARDELLIER   *In* AGARD, Progress in Military Airlift 15 p (SEE N91-18067 10-03)   Dec. 1990
(AGARD-CP-495)   Copyright   Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Current studies have shown the interest of very large bypass ratio (BPR) engines (10 is less than BPR is less than 14) to power Long Range Airliners, at cruise speed exceeding Mach 0.8. A further benefit in terms of installed SFC (specific fuel consumption) can be expected for Future Large Aircraft (FLA), cruising at Mach 0 75. Compared to an equivalent turbofan, a very large bypass engine can deliver a higher thrust during takeoff, thus improving the high lift capability of the aircraft. Taking into account that a conventional front fan engine is likely to show a large radar cross section (RCS), and that this problem would have to be addressed for FLA, the engine perferred concept is a ducted aft contrafan. The resulting high hub-tip ratio fan flow path, combined with slow rotating composite fan-blades is indeed a good approach toward reduction of the engine RCS. In order to minimize the extra-weight due to the long duct, a highly integrated engine-wing design is proposed, offering a reduced friction drag; particular attention is paid to the maintenance and transportation problems.   Author

N91-18083*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
APPLICATION OF ADVANCED TECHNOLOGIES TO FUTURE MILITARY TRANSPORTS
RODNEY L. CLARK, ROY H. LANGE (Lockheed Aeronautical Systems Co., Marietta, GA.), and RICHARD C WAGNER   *In* AGARD, Progress in Military Airlift 8 p (SEE N91-18067 10-03)   Dec. 1990
(AGARD-CP-495)   Copyright   Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 01/3
    Long range military transport technologies e addressed with emphasis of defining the potential benefits of the hybrid laminar flow control (HLFC) concept currently being flight tested. Results of a 1990's global range transport study are presented showing the expected payoff from application of advanced technologies. Technology forecast for military transports is also presented.   Author

N91-18086# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
APPLICATION OF CIVIL AIR TRANSPORT TECHNOLOGY TO MILITARY AIRLIFT
JOHANNES SPINTZYK   *In* AGARD, Progress in Military Airlift 14 p (SEE N91-18067 10-03)   Dec. 1990
(AGARD-CP-495)   Copyright   Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Due to a strong market demand and competition the civil passenger aircraft have improved considerably in performance and operating cost in the last 30 years. These improvements were achieved mainly by progress in technology. Comparable improvements were not achieved in military aircraft. The military transport aircraft in operation today are of older design. Civil and military transport technologies are identical to a large extent. Therefore, application of the advanced civil transport technology to a new military transport aircraft promises a leap in performance improvements and operating cost reductions. Moreover, changes in tasks and requirements can be incorporated in a new design. The example of an advanced medium transport aircraft shows promising indications of the improvements which are possible by applying civil transport technology and encourages further investigations.   Author

N91-18091# British Aerospace Aircraft Group, Woodford (England). Airlines Div.
FIMA AND EUROFLAG: PROGRESS IN MEETING MILITARY AIRLIFT AND FLA REQUIREMENTS FOR THE 21ST CENTURY
D. K. EMPSON   *In* AGARD, Progress in Military Airlift 10 p (SEE N91-18067 10-03)   Dec. 1990
(AGARD-CP-495)   Copyright   Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Progress is reviewed made initially by the Future International Military Airlifter (FIMA) Group and, since 1989, by its successor the European Future Large Aircraft Group (EUROFLAG), in studying the potential for development of a collaborative program to satisfy airlift requirements for the 21st century. EUROFLAG studies indicate that future military transport and other Future Large Aircraft (FLA) designs based on mid-1990's, modern but proven technology standards, can provide a greatly enhanced airlift capability at significantly lower fleet life cycle costs and with major manpower savings compared with aircraft in service today. Theses attributes are important in a world climate of shrinking defence budgets, growing manpower shortages and defence scenario uncertainties. European or transatlantic collaboration tc develop and manufacture such aircraft is seen as the most economical way for air forces to obtain the operational capability required at the lowest cost.   Author

N91-18092# Boeing Helicopter Co., Philadelphia, PA.
V-22 OPERATIONAL CAPABILITIES
ROBERT B. TAYLOR *In* AGARD, Progress in Military Airlift 9 p
(SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   The operational capabilities of the V-22 Osprey, the world's
first operational tilt rotor aircraft, are described. The designed-in
capabilities of the V-22, plus its performance characteristics, provide
a multi-mission aircraft that will improve the capability of all service
forces well into the 21st century. Key elements in providing a
broad operational capability are shipboard compatibility,
payload-range, maneuverability, high speed capability with an
external load, reduced vulnerability, and glass cockpit integrated
avionics for reduced pilot workload during day and night missions.
                                                                    Author

N91-18093# Westland Helicopters Ltd., Yeovil (England).
TACTICAL SUPPORT EH101
J. C. FIELDING *In* AGARD, Progress in Military Airlift 10 p (SEE
N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   The development and use of military tactical helicopters from
the early beginnings to the present day are reviewed. The
background to the EH101 is presented explaining the rationale of
its design philosophy and the application of technology and
equipments to meet the requirements of the late '90s and the
early 21st century. The operational capabilities and applications
of the EH101 related to a changing fast-moving battlefield
environment are also discussed.   Author

N91-22099# Advisory Group for Aerospace Research and
Development, Neuilly-Sur-Seine (France). Aerospace Medical
Panel.
**THE HUMAN FACTORS RELATING TO ESCAPE AND
SURVIVAL FROM HELICOPTERS DITCHING IN WATER**
C. J. BROOKS (Defence and Civil Inst. of Environmental Medicine,
Downsview, Ontario) Feb. 1991 125 p In FRENCH English
language document was announced as N90-13358
(AGARD-AG-305(F); ISBN-92-835-2116-1) Copyright Avail:
NTIS HC/MF A06; Non-NATO Nationals requests available only
from AGARD/Scientific Publications Executive
   The worldwide incidence of military and civilian over-water
helicopter accidents and the problems related to survival are
described. Typical accident scenarios are reviewed from the
moment the occupant steps onboard a helicopter to the pre-flight
briefing through to the accident itself, to the difficulties with escape
(commonly from underwater and in darkness), to the rescue and
return safely to dry land. Improvements to crashworthiness and
life support equipment in current in-service and future helicopters
are proposed. A syllabus for underwater escape training is also
discussed.   Author

N91-25119# Advisory Group for Aerospace Research and
Development, Neuilly-Sur-Seine (France). Flight Mechanics
Panel.
**TECHNICAL EVALUATION REPORT ON THE FLIGHT
MECHANICS PANEL SYMPOSIUM ON PROGRESS IN
MILITARY AIRLIFT**
F. MARY May 1991 26 p Symposium held in Lisbon, Portugal,
28-31 May 1990
(AGARD-AR-300; ISBN-92-835-0619-7; AD-A237345) Copyright
Avail: NTIS HC/MF A03; Non-NATO Nationals requests available
only from AGARD/Scientific Publications Executive
   Although military transport aircraft and helicopters continue to
be of increasing importance in future military operations, military
transport aircraft technology has not received the same level of
attention that has been directed, for example, to combat aircraft.
In-service fleets of transport aircraft are also becoming physically
old and technically outdated, and are less and less capable of
fulfilling the more demanding mission requirements. It was therefore
important and timely to review the area of military airlift and assess:
the present and perceived future military roles and requirements,
the required developments in technology, the extent to which civil
technology applications can enhance capability, technologies for

real cost reduction, and to what extent the current and future
development programs in this field embody the new technologies.
To accomplish this review and assessment, a symposium was
held that included sessions on operational experience and
requirements; cockpit design and aircrew performance; specific
technologies such as fuel, powerplant and aerodynamic design;
and a review of current and new programs.   Author

N92-18242# Advisory Group for Aerospace Research and
Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
**TECHNICAL EVALUATION REPORT ON THE FLUID
DYNAMICS PANEL SPECIALISTS' MEETING ON EFFECTS OF
ADVERSE WEATHER ON AERODYNAMICS**
JOHN J. REINMANN (NASA. Lewis Research Center) and J. W.
SLOOFF, ed. (National Aerospace Lab., Amsterdam, Netherlands)
Nov. 1991 26 p
(AGARD-AR-306; ISBN-92-835-0646-4) Copyright Avail: NTIS
HC/MF A03; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   The proceedings of the conference are summarized. The
purpose of the meeting was to provide an update of the state of
the art with respect to the prediction, simulation, and measurement
of the effects of icing, anti-icing fluids and various forms of
precipitation on the aerodynamic characteristics of flight vehicles.
Sessions were devoted to introductory and survey papers and
icing certification issues, to analytical and experimental simulation
of ice frost contamination and its effects on aerodynamics, and to
the effects of heavy rain and deicing and/or anti-icing fluids. The
19 papers announced for the meeting are published in AGARD
CP-496.   Author

N92-21679# Advisory Group for Aerospace Research and
Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
EFFECTS OF ADVERSE WEATHER ON AERODYNAMICS
Dec. 1991 287 p In ENGLISH and FRENCH Meeting held in
Toulouse, France, 29 Apr. - 1 May 1991
(AGARD-CP-496; ISBN-92-835-0644-8) Copyright Avail: NTIS
HC/MF A13; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   This meeting was organized to provide a timely review of the
progress being made in advancing the state of the art in predicting,
simulating, and measuring the effects of icing, anti-icing fluids,
and various forms of precipitation on the aerodynamic
characteristics of flight vehicles. Topics included results from both
theoretical and experimental programs and material related to
procedures and regulations for certification and operation.
International participation for the meeting included authors from
eight nations and representatives from most of the 16 NATO
nations. For individual titles, see N92-21680 through N92-21698.

N92-21680# Renaudie (J. F.), Versailles (France).
FLIGHT IN ADVERSE ENVIRONMENTAL CONDITIONS
J. F. RENAUDIE *In* AGARD, Effects of Adverse Weather on
Aerodynamics 21 p (SEE N92-21679 12-03) Dec. 1991
(AGARD-CP-496) Copyright Avail: NTIS HC/MF A13;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   Brief accounts are given of a number of papers presented at
the Flight Mechanics Panel (FMP) Symposium held in Gol, Norway
May 8 to 11, 1989. Atmospheric measurements and modeling,
the effect of disturbances on design and operations, visibility,
aircraft icing, and electromagnetic disturbances are discussed.
                                                                    Author

N92-21681# Douglas Aircraft Co., Inc., Long Beach, CA.
**THE EFFECT OF WING ICE CONTAMINATION ON ESSENTIAL
FLIGHT CHARACTERISTICS**
R. E. BRUMBY *In* AGARD, Effects of Adverse Weather on
Aerodynamics 4 p (SEE N92-21679 12-03) Dec. 1991
(AGARD-CP-496) Copyright Avail: NTIS HC/MF A13;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   Contamination of critical aerodynamic surfaces by ice, frost,
and/or snow has been identified as the probable cause of a
significant number of aircraft accidents. In most cases, the ice
contamination has not been large ice accretions on the leading
edges or thick layers of adhering snow on top of the wings. Rather,
dangerous reductions in stall margins and handling qualities can

occur because of ice related roughness equivalent to that of medium-grit sandpaper. Described here are the typical effects of such roughness on lift, drag, and pitching moment, and the corresponding effects on longitudinal and lateral control characteristics during rotation and liftoff. Of great importance is that the visual, aural, and tactical clues signaling a developing critical situation occur within a very few seconds, and usually do not correspond to any for which the flight crew has been trained or has previously experienced.　　　　　　　　　Author

N92-21682# Ecole Royale Militaire, Brussels (Belgium).
LOW TEMPERATURE ENVIRONMENT OPERATIONS OF TURBOENGINES (DESIGN AND USER'S PROBLEMS)
R. JACQUES　*In* AGARD, Effects of Adverse Weather on Aerodynamics 12 p (SEE N92-21679 12-03)　Dec. 1991
(AGARD-CP-496)　Copyright　Avail: NTIS HC/MF A13;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
The author summarizes and links together a number of papers that were presented at the Propulsion and Energetics (PEP) symposium on low temperature environment operation of turbojet engines that was held October 8 to 12, 1990. Topics covered include operational experience of ice ingestion in the turboprop engine in the 2,000 hp class, icing on helicopter turbo engines, icing test facilities, ice relevant cloud physical parameters, and low temperature and fuel problems.　　　　　　　Author

N92-21683# Centre d'Essais en Vol, Istres (France). Ingenieur Navigant d'Essais.
REGULATIONS AND THEIR CHANGES FOR CERTIFICATION OF CIVIL AIRCRAFT IN ICING CONDITIONS [EVOLUTION REGLEMENTAIRE EN MATIERE DE CERTIFICATION DES AVIONS CIVILS EN CONDITIONS GIVRANTES]
GILBERT CATTANEO　*In* AGARD, Effects of Adverse Weather on Aerodynamics 9 p (SEE N92-21679 12-03)　Dec. 1991　In FRENCH
(AGARD-CP-496)　Copyright　Avail: NTIS HC/MF A13;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
Experience acquired in the process of certifying standards and service use of civil aircraft has shown that a change of regulations is necessary. The regulatory changes in maintaining a safety level during flight in icing conditions that are comparable to flight in conditions where no icing is possible are discussed.　　　Author

N92-21684*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ICING SIMULATION: A SURVEY OF COMPUTER MODELS AND EXPERIMENTAL FACILITIES
M. G. POTAPCZUK and J. J. REINMANN　*In* AGARD, Effects of Adverse Weather on Aerodynamics 27 p (SEE N92-21679 12-03) Dec. 1991　Previously announced as N91-23087
(AGARD-CP-496)　Copyright　Avail: NTIS HC/MF A13;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive　CSCL 01/3
A survey of the current methods for simulation of the response of an aircraft or aircraft subsystem to an icing encounter is presented. The topics discussed include a computer code modeling of aircraft icing and performance degradation, an evaluation of experimental facility simulation capabilities, and ice protection system evaluation tests in simulated icing conditions. Current research focused on upgrading simulation fidelity of both experimental and computational methods is discussed. The need for the increased understanding of the physical processes governing ice accretion, ice shedding, and iced aerodynamics is examined.　　　　　　　　　　　　　Author

N92-21686*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SIMULATION OF ICED WING AERODYNAMICS
M. G. POTAPCZUK, M. B BRAGG, O. J. KWON, and L. N. SANKAR (Georgia Inst. of Tech., Atlanta.)　*In* AGARD, Effects of Adverse Weather on Aerodynamics 15 p (SEE N92-21679 12-03)　Dec. 1991　Previously announced as N91-23086
(AGARD-CP-496)　Copyright　Avail: NTIS HC/MF A13;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive　CSCL 01/3
The sectional and total aerodynamic load characteristics of moderate aspect ratio wings with and without simulated glaze leading edge ice were studied both computationally, using a three dimensional, compressible Navier-Stokes solver, and experimentally. The wing has an untwisted, untapered planform shape with NACA 0012 airfoil section. The wing has an unswept and swept configuration with aspect ratios of 4.06 and 5.0. Comparisons of computed surface pressures and sectional loads with experimental data for identical configurations are given. The abrupt decrease in stall angle of attack for the wing, as a result of the leading edge ice formation, was demonstrated numerically and experimentally.　　　　　　　　　Author

N92-21687# Carleton Univ., Ottawa (Ontario). Dept. of Mechanical and Aerospace Engineering.
EFFECTS OF FROST ON WING AERODYNAMICS AND TAKE-OFF PERFORMANCE
R. J. KIND and M. A. LAWRYSYN　*In* AGARD, Effects of Adverse Weather on Aerodynamics 11 p (SEE N92-21679 12-03)　Dec. 1991
(AGARD-CP-496)　Copyright　Avail: NTIS HC/MF A13;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
Computations were done to predict the effects of various extents of frost coverage on the airfoil, wing, and takeoff performance of two hypothetical aircraft, a small light aircraft and a large transport aircraft. Airfoil performance was computed using rough wall boundary layer calculations coupled to an inviscid vortex panel method which includes a capacity for modeling stalled flow conditions. The roughness parameters determined for one of the frost samples were used for this purpose. A lifting line analysis was used to determine wing performance from the airfoil results. The results indicate that frost having an effective height of only 0.4 mm in the leading edge region of a wing can cause serious performance degradation even for a very large aircraft. On the other hand, frost coverage beginning well down stream of the suction peak, for example at about one/quarter chord, was predicted to have little effect.　　　　　　　　Author

N92-21688*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MODEL ROTOR ICING TESTS IN THE NASA. LEWIS ICING RESEARCH TUNNEL
ROBERT J. FLEMMING, RANDALL K. BRITTON (Sverdrup Technology, Inc., Brook Park, OH.), and THOMAS H. BOND　*In* AGARD, Effects of Adverse Weather on Aerodynamics 25 p (SEE N92-21679 12-03)　Dec. 1991　Previously announced as N91-23184
(AGARD-CP-496)　Copyright　Avail: NTIS HC/MF A13;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive　CSCL 01/3
Tests of a lightly instrumented two bladed teetering rotor and a heavily instrumented subscale articulated main rotor were conducted in the NASA Lewis Icing Research Tunnel (IRT). The first was an OH-58 tail rotor which had a diameter of 1.575 m and a blade chord of 0.133 m, and was mounted on a NASA designed test rig. The second, a four bladed articulated rotor, had a diameter of 1.83 m with 0.124 m chord blades specifically fabricated for the experiment. This rotor was mounted on a Sikorsky Aircraft Powered Force Model, which enclosed a rotor balance and other measurement systems. The models were exposed to variations in temperature, liquid water content, and medium droplet diameter, and were operated over ranges of advance ratio, shaft angle, tip Mach number (rotor speed), and weight coefficient to determine the effect of these parameters on ice accretion. In addition to strain gage and balance data, the test was documented with still, video, and high speed photography, ice profile tracing, and ice molds. The sensitivity is presented of the model rotors to

the test parameter and a comparison of the results to theoretical predictions. Author

N92-21689# Royal Aerospace Establishment, Farnborough (England).
A REVIEW OF ICING RESEARCH AT THE ROYAL AEROSPACE ESTABLISHMENT
R. W. GENT   *In* AGARD, Effects of Adverse Weather on Aerodynamics 15 p (SEE N92-21679 12-03)   Dec. 1991
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A brief review of the computer models developed by the Royal Aerospace Establishment (RAE) for the analysis of natural rotor icing and rotor protection against icing is provided. Experimental results are then presented for the increase in profile drag due to rime, glaze, and beak type icing. These data, combined with other published data, were used to obtain correlations for iced profile performance which were included in a computer model of helicopter performance. This enables the prediction of the increase in rotor power required by a helicopter with unprotected rotors during flight in icing conditions. Comparisons between model prediction and both rig and flight test data are given.   K.S.

N92-21690# National Research Council of Canada, Ottawa (Ontario). Applied Aerodynamics Lab.
WIND TUNNEL INVESTIGATION OF A WING-PROPELLER MODEL PERFORMANCE DEGRADATION DUE TO DISTRIBUTED UPPER-SURFACE ROUGHNESS AND LEADING EDGE SHAPE MODIFICATION
R. H. WICKENS and V. D. NGUYEN   *In* AGARD, Effects of Adverse Weather on Aerodynamics 19 p (SEE N92-21679 12-03) Dec. 1991
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A wind tunnel investigation has assessed the effects of distributed upper surface roughness, and leading edge ice formation on a powered wing propeller model. In the unpowered state, it was found that roughness reduces the lift slope, and maximum lift by 30 to 50 percent, depending upon particle size and Reynolds number. The leading edge region is especially sensitive to these disturbances, however, removal of the toughness over a small portion of the nose restored the wing to close to its original performance. The application of power to the wing, with an increase of slipstream dynamic pressure increases the lift slope and maximum lift; however, removal of the roughness over a small portion of the nose restored the wing to close to its original performance. The application of power to the wing, with an increase of slipstream dynamic pressure increases the lift slope and maximum lift; however, this benefit is lost if the wing is roughened. Subtraction of the propeller reactions indicated that the slipstream interaction accounted for half the lift increase, and also resulted in reduced drag for the clean surface. This drag reduction was removed when the wing was roughened, indicating that the degradation of wing performance due to roughening is relatively greater when a slipstream is presented, compared to the unpowered wing. Leading edge ice accretion causes similar large losses in lift and increases of form drag although a comparison of the two types of contamination showed that leading edge ice produces a smaller reduction of lift slope prior to flow separation. In both types of contamination, Reynolds number is important, and emphasizes the necessity of testing under near full-scale conditions.   K.S.

N92-21691*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE ADVERSE AERODYNAMIC IMPACT OF VERY SMALL LEADING-EDGE ICE (ROUGHNESS) BUILDUPS ON WINGS AND TAILS
FRANK T. LYNCH, WALTER O. VALAREZO (Douglas Aircraft Co., Inc., Long Beach, CA.), and ROBERT J. MCGHEE   *In* AGARD, Effects of Adverse Weather on Aerodynamics 8 p (SEE N92-21679 12-03)   Dec. 1991
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Systematic experimental studies were performed to establish the aerodynamic impact of very small leading-edge simulated ice (roughness) formations on lifting surfaces. The geometries studied include single element configurations (airfoil and 3-D tail) as well as multi-element high-lift airfoil geometries. Emphasis in these studies was placed on obtaining results at high Reynolds numbers to insure the applicability of the findings to full-scale situations. It was found that the well-known Brumby correlation for the adverse lift impact of discrete roughness elements at the leading edge is not appropriate for cases representative of initial ice build up (i.e., distributed roughness). It was also found that allowing initial ice formations of a size required for removal by presently proposed deicing systems could lead to maximum lift losses of approximately 40 percent for single-element airfoils. Losses in angle-of-attack margin to stall are equally substantial - as high as 6 degrees. Percentage losses for multi-element airfoils are not as severe as for single-element configurations, but degradations of the angle-of-attack-to-stall margin are the same for both.   K.S.

N92-21692# Fokker B.V., Schipol-Oost (Netherlands). Aerodynamics and Aeroelasticity Dept.
THE EFFECT OF HOAR-FROSTED WINGS ON THE FOKKER 50 TAKE-OFF CHARACTERISTICS
J. VANHENGST and J. N. BOER   *In* AGARD, Effects of Adverse Weather an Aerodynamics 9 p (SEE N92-21679 12-03)   Dec. 1991
(AGARD-CP-496)   Copyright   Avail: NTIS HC/MF A13;
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Reviewed here is how contamination resulting from ice, snow, or frost accumulated during ground icing degrades the Fokker 50 aircraft aerodynamics and leads to reduced flight safety during takeoff. From simulation tests it was concluded that wing contamination due to ground frost seriously deteriorates the aircraft behavior in takeoff, leading to reduced flight safety. A large increase in takeoff distance is experienced. No improvement was found from cleaning the wing leading edge only or by increasing rotation speed. The results clearly demonstrate the importance of Advisory Circular AC 20-117 emphasizing the 'clean aircraft concept' under adverse weather conditions before takeoff.   Author

N92-21693# Dornier Luftfahrt G.m.b.H., Friedrichshafen (Germany, F.R.).
PREPARATION OF THE ICE CERTIFICATION OF THE DORNIER 328 REGIONAL AIRLINER BY NUMERICAL SIMULATION AND BY GROUND TEST
D. WELTE, W. WOHLRATH, R. SEUBERT, W. DIBARTOLOMEO, and R. D. TOOGOOD (Pratt and Whitney Aircraft of Canada Ltd., Longueuil, Quebec)   *In* AGARD, Effects of Adverse Weather on Aerodynamics 14 p (SEE N92-21679 12-03)   Dec. 1991
(AGARD-CP-496)   Copyright   Avail: NTIS HC/MF A13;
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The Dornier 328, a new regional airliner, is to be qualified to FAR25/JAR25 requirements for operation into known icing conditions. All lifting surfaces are pneumatically deiced. Impingement limits were determined using a validated computational fluid dynamic (CFD) code. Wind tunnel tests with a model of the whole aircraft and the isolated empennage equipped with artificial ice shapes showed a degradation of handling characteristics due to ice accretion. Extensive two and three dimensional CFD calculations evaluated ice accretion at the deflection elevator horn. Icing tunnel tests were performed with a model of the horizontal tail with icing similitude fulfilled. The Dornier Do328 powerplant air induction system has successfully completed a program of icing tests in support of aircraft certification for

operation into known icing conditions. Potential flight icing conditions were extensively analyzed using a CFD potential flow code and 3-D particle tracking routine to identify critical flight icing conditions. The tunnel test program verified the analytically predicted critical ice accretion surfaces of the air induction system, the adequacy of the ice protection provisions and demonstrated compliance with the applicable (JAR25) regulatory material.

Author

N92-21694*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A SUMMARY OF NASA RESEARCH ON EFFECTS OF HEAVY RAIN ON AIRFOILS
DANA J. DUNHAM, R. EARL DUNHAM, JR., and GAUDY M. BEZOS *In* AGARD, Effects of Adverse Weather on Aerodynamics 14 p (SEE N92-21679 12-03) Dec. 1991
(AGARD-CP-496) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01/3

Results from a broad NASA research program are presented. The intention of the program was to obtain fundamental aerodynamic information regarding the effect of heavy rain on airplane performance. The take-off and landing characteristics are of particular concern, and the aim of the program is to understand the physical phenomena associated with any aerodynamic performance penalty that may occur during a rain encounter. This overview includes results of recent attempts to measure high-intensity, short-duration rainfall, a discussion of some of the earlier analytical investigations of rain effects on airfoils, a review of some promising experimental methods for evaluating rain effects, and some important scaling considerations for extrapolating model data. D.R.D.

N92-21695# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain). Experimental Aerodynamics Lab.
THE MEASUREMENT OF WATER FILM THICKNESS ON AIRFOILS IN HEAVY RAIN CONDITIONS USING CONDUCTANCE SENSORS
A. FEO, F. ROGLES, and M. URDIALES *In* AGARD, Effects of Adverse Weather on Aerodynamics 14 p (SEE N92-21679 12-03) Dec. 1991
(AGARD-CP-496) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Calibration results of liquid film thickness using electric conductance sensors are presented. Two sensor types are analyzed. First, a double electrode sensor whose calibrations compensate liquid conductivity and secondly, a triple electrode sensor that, when properly calibrated, also compensates capacitive effects. For this second type, the electrolytic effects can also be corrected without excessive errors. Tests conducted on a large-scale airfoil under simulated heavy rain conditions, at NASA Langley Research Center are described, and the film thickness that develop, measured. Author

N92-21696# National Research Council of Canada, Ottawa (Ontario). Inst. for Aerospace Research.
EXPERIMENTAL INVESTIGATION OF HEAVY RAINFALL EFFECT ON A 2-D HIGH LIFT AIRFOIL
F. C. TANG *In* AGARD, Effects of Adverse Weather on Aerodynamics 10 p (SEE N92-21679 12-03) Dec. 1991
(AGARD-CP-496) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The effects of simulated heavy rainfall on a 2D high lift airfoil were studied in a wind tunnel program. The experiment was carried out in the 2D test section of the 1.5 m x 1.5 m blowdown wind tunnel of the High Speed Aerodynamics Laboratory. The model used in the investigation was a modified NACA 85(sub 2)215 multi-element airfoil with a basic chord of 254 mm. The Mach number was fixed at M = 0.2, typical of the landing speed of transport type aircraft. The chord Reynolds number range was 1.7 to 8.8 x 10(exp 6). Measurements included lift, drag, and pitching moment of the airfoil obtained by side wall balances and the flow rate from a water spray manifold. The effects of the simulated rainfall to the airfoil performances are very significant. The loss in maximum lift coefficient ranged from 6 percent to a high of 16 percent. The drag levels at constant lift are up to 43

percent higher under wet conditions. A smaller performance degradation was noted when the model was stripped of the smooth epoxy paint with which it was originally finished. D.R.D.

N92-21697# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). Aeronautics/Aerospace Dept.
AERODYNAMIC EFFECTS OF DE/ANTI-ICING FLUIDS AND DESCRIPTION OF A FACILITY AND TEST TECHNIQUE FOR THEIR ASSESSMENT
MARIO CARBONARO *In* AGARD, Effects of Adverse Weather on Aerodynamics 20 p (SEE N92-21679 12-03) Dec. 1991
(AGARD-CP-496) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Research carried out at the von Karman Institute, from 1984 to the present, on the subject of flow-off of aircraft de-icing and anti-icing fluids is presented. Additionally, a test methodology for the acceptance of anti- and de-icing fluids is described. D.R.D.

N92-21698# Boeing Commercial Airplane Co., Seattle, WA. Aerodynamics Div.
WIND TUNNEL INVESTIGATION OF THE AERODYNAMIC EFFECTS OF AIRCRAFT GROUND DEICING/ANTI-ICING FLUIDS AND CRITERIA FOR AERODYNAMIC ACCEPTANCE
THOMAS A. ZIERTEN and EUGENE G. HILL *In* AGARD, Effects of Adverse Weather on Aerodynamics 8 p (SEE N92-21679 12-03) Dec. 1991
(AGARD-CP-496) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A follow-on wind tunnel investigation of the aerodynamic effects of aircraft ground deicing/anti-icing fluids was performed to supplement earlier reported flight and wind tunnel tests and support the development of aerodynamic acceptance criteria for aircraft ground deicing/anti-icing fluids. The test was conducted at the NASA Lewis Research Center Icing Research Tunnel using both a 2D model and a 3D half model of the 737-200ADV airplane. The fluids that were tested included the following: three Type I Newtonian fluids, which use ethylene, diethylene, and propylene glycol as the freezing point depressant; four Type II non-Newtonian fluids, which are currently in production; eight developmental fluids; and a Mil Spec fluid to be used as a reference fluid in the aerodynamic acceptance test. The Type I and current Type II fluids were tested neat and diluted to determine basic aerodynamic effects. Dilution of the Type II fluids did not significantly alter the aerodynamic effects of the fluids. Diluting the Type I fluids did result in a significant reduction in the adverse aerodynamic effects of these fluids, especially at temperatures of -10 C and colder. Boundary layer displacement thickness, delta*, measurements made with the fluids on the 2D model show excellent correlation with lift loss due to the fluids at maximum lift and at operating angles of attack and with the boundary layer displacement thickness measured on a flat plate in the small von Karman Institute wind tunnel. This correlation validated the future use of flat plate boundary layer displacement thickness measurement as the criterion for the aerodynamic acceptability of a fluid. The limiting boundary layer displacement thickness, which identifies a fluid as being aerodynamically acceptable, is correlated with a loss in maximum lift that results in an allowed specific reduction in aerodynamic performance margins. D.R.D.

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

N90-10847# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
KALMAN FILTER INTEGRATION OF MODERN GUIDANCE AND NAVIGATION SYSTEMS
Jun. 1989 181 p In ENGLISH and FRENCH Lecture series held in Delft, Netherlands, 26-27 Jun. 1989, in Neubiberg, Fed. Republic of Germany, 29-30 Jun. 1989, and in London, England, 3-4 Jul. 1989
(AGARD-LS-166; ISBN-92-835-0514-X; AD-A214284) Copyright Avail: NTIS HC A09/MF A01
The integration of modern guidance and navigation systems is usually performed with a suboptimal implementation of the Kalman filter. The most difficult problem is how to develop that suboptimal implementation when considering system modeling, algorithm design, and real hardware nonlinearities. This lecture series brings together a group of speakers with outstanding practical experience in the design of integrated systems, providing the audience with the principles, insights, and mechanisms of real, current-day system synthesis approaches, and giving the overall background necessary for synthesizing future practical guidance and navigation systems. Two of the lectures deal with the synthesis of solutions to tracking problems. The remainder of the lectures deal with the integrations of avionics systems. For individual titles, see N90-10848 through N90-10854.

N90-10848# Norwegian Defence Research Establishment, Kjeller.
DESIGN OF A KALMAN FILTER FOR TRANSFER ALIGNMENT
ODDVAR HALLINGSTAD In AGARD, Kalman Filter Integration of Modern Guidance and Navigation Systems, 14 p (SEE N90-10847 02-04) Jun. 1989
(AGARD-LS-166) Copyright Avail: NTIS HC A09/MF A01
The design philosophy used in the development of the alignment subsystem of the inertial midcourse navigation system for the air launched Penguin antiship missile adopted for the F-16 fighter aircraft is described. The desired performance was achieved through a three level Kalman filter (KF) design process. On the first level it was assumed that the system is linear and then the KF was designed. On the second level the design of the preprocessor which makes the linear assumptions on level one valid, was presented. The last level deals with the field testing of the missile navigation system which is the final test of the validity of the design procedure. Author

N90-10849# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
DEVELOPMENT OF THE INTEGRATED ALL-WEATHER NAVIGATION SYSTEM FOR TORNADO
FRANK HUPKE and FLORIAN SCHWEGLER In AGARD, Kalman Filter Integration of Modern Guidance and Navigation Systems 15 p (SEE N90-10847 02-04) Jun. 1989
(AGARD LS 166) Copyright Avail: NTIS HC A09/MF A01
The integrated navigation system for the Tornado weapon system was now in service for almost 10 years. A detailed presentation will be given on the following topics: primary development approach, problems encountered in development and solutions, side developments that were not implemented for various reasons, methods used for optimization, and modifications of the filter as revisions of the Tornado navigation system were performed. Author

N90-10850# Ferranti Defence Systems Ltd., Edinburgh (Scotland). Dept. of Navigation Systems.
A HIGH PERFORMANCE AIRBORNE INS/GPS INTEGRATED NAVIGATION SYSTEM
DAVID I. CALLENDER In AGARD, Kalman Filter Integration of Modern Guidance and Navigation Systems 15 p (SEE N90-10847 02-04) Jun. 1989
(AGARD-LS-166) Copyright Avail: NTIS HC A09/MF A01
The system architecture and the trade-offs that drive its evolution are examined for a practical high-performance Integrated System designed for a number of current requirements. The system incorporates a 4 gimbal inertial navigator of inherently high stand-alone performance, integrated with a state-of-the-art 5 channel F-code GPS receiver. The system partitioning and interfacing are configured to optimize system accuracy during potentially lengthy periods when a full GPS solution may be unavailable, while providing satisfactory integrity under reversionary conditions. The main Kalman Filter takes pseudo-range and range rate measurements from the GPS rather than position and velocity and in the primary navigation mode models INS and GPS error parameters. The Kalman Filter in the GPS receiver operates independently to provide the desired reversionary capability. The system architecture, both in hardware and software, allows a high degree of inherent flexibility which is required to tailor the Integrated Navigation System to a wide variety of specific applications.
Author

N90-10851# Defence Research Establishment, Ottawa (Ontario). Electromagnetics Section.
THE DEVELOPMENT OF MISSION-SPECIFIC ADVANCED INERTIALLY-BASED AVIONICS SYSTEM
D. F. LIANG and D. J. DIFILIPPO In AGARD, Kalman Filter Integration of Modern Guidance and Navigation Systems 25 p (SEE N90-10847 02-04) Jun. 1989
(AGARD-LS-166) Copyright Avail: NTIS HC A09/MF A01
The Defence Research Establishment Ottawa (DREO) was involved in the development of several mission-specific airborne inertially based multi-sensor integrated avionics systems. More specifically, DREO has successfully completed the Phase 2 development and flight trial evaluation of an airborne Synthetic Aperture Radar Motion Compensation System (SARMCS). To achieve high resolution, high contrast and low geometric distortion in synthetic aperture radar imagery, it is necessary to apply accurate motion compensation to the radar returns. The hardware configuration consists of a ring laser gyro inertial navigation system, a Doppler radar, a baroaltimeter and a specially designed strapped-down Motion Compensation Inertial Measurement Subsystem (MCIMS). The Department of National Defence is also undertaking a program to develop and flight test a Helicopter Integrated Navigation System (HINS) which can satisfy the operational requirements of Canadian New Shipborne Aircraft (NSA). The roles of this maritime helicopter include search and rescue, Anti-Surface Surveillance and Targeting (ASST), Anti-Submarine Warfare (ASW), and Anti-Ship Missile Defence (ASMD). The development of appropriate Kalman filters to integrate the selected avionics configurations is described. Design objectives, configuration definition, simulation analysis and some flight test data are presented. Author

N90-10852# Defence Research Establishment, Ottawa (Ontario). Electromagnetics Section.
DEVELOPMENT OF A MARINE INTEGRATED NAVIGATION SYSTEM
D. F. LIANG and J. C. MCMILLAN In AGARD, Kalman Filter Integration of Modern Guidance and Navigation Systems 23 p (SEE N90-10847 02-04) Jun. 1989
(AGARD-LS-166) Copyright Avail: NTIS HC A09/MF A01
Startling advances in electronics and computer technologies over the last two decades have significantly altered the scope of military operations, weapon systems and some of the required supporting services. The increased range, speed and accuracy of modern weapon systems impose stringent accuracy and reliability requirements upon the navigation systems of military platforms. Over the last few years, DREO was involved in the development of a microprocessor-based Marine Integrated Navigation System (MINS). The present version of the MINS can work with a variety of types and brands of navigation sensors such as Omega, Transit, GPS, Loran C, speedlog and gyrocompass as well as

operator-entered position or sextant measurements. It has been successfully tested on both Canadian and U.S. Navy vessels and it is due to be installed on almost all of Her Majesty's Canadian ships in 1988. The application of Kalman filter design to optimally and synergistically combine the diverse types of navigation sensor information is described. Technical problems, design objectives and some design features unique to this application are highlighted. Results of sea trial evaluations are compared to simulation results. Integrated system design guidelines and road maps derived from the Canadian experience are also presented.   Author

N90-10854#   Centre d'Etudes et de Recherches, Toulouse (France).
PASSIVE TRAJECTOGRAPHY BY AZIMUTH: IMPROVEMENT OF ESTIMATION QUALITY [TRAJECTOGRAPHIE PASSIVE PAR AZIMUT: AMELIORATION DE LA QUALITE D'ESTIMATION]
PIERRE VACHER, MICHEL GAUVRIT, GUY MAYNARD-DELAVALETTE, and PHILIPPE MENNECIER (CAPCA, Le Pradet, France) In AGARD, Kalman Filter Integration of Modern Guidance and Navigation Systems 30 p (SEE N90-10847 02-04) Jun. 1989 In FRENCH
(AGARD-LS-166) Copyright Avail: NTIS HC A09/MF A01
  Many of the difficulties are described for target tracking such as nonlinearities and maneuvers when using bearings-only tracking whose characteristic feature is poorness of information in terms of observability. Investigations are described for recursive and global algorithms as well as leg by leg estimation techniques. Conditioning of the computations, the implementation of the algorithms, and the accuracy of the estimators are presented.
                                                                Author

N90-15061#   Royal Aircraft Establishment, Bedford (England). Flight Management Dept.
THE ASSESSMENT OF VISIBILITY FROM AUTOMATIC CONTRAST MEASUREMENTS
A. W. PUFFETT   In AGARD, Flight in Adverse Environmental Conditions 14 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
  Visibility and hence runway visual range through the passive and automatic measurement of contrast reduction in a dark target are assessed. Though limited to use from dawn through to dusk the method offers significant advantages over the more usual transmission, or scattering approaches. The advantages arise not only from the measurement process which is intrinsically more robust than that of the transmissometer, but also from the ratiometric manner in which it can be implemented. The result is a self-compensating system which virtually abolishes any requirement for temperature and long term stability in the instrument. Unlike conventional scatter-meters the method may be used under a wide range of obscuring conditions without doubts in respect of its constancy of sensitivity. Initial comparisons with a human observer have both produced good agreement and confirmed theoretical expectations of behavior. To overcome the night-time deficiency, suggestions are made for ways in which conventional measurements might be integrated into the system. The relaxation in design that would result from night-time only operation show this to be both a practical and economic alternative.   Author

N90-15899#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
ADVANCES IN TECHNIQUES AND TECHNOLOGIES FOR AIR VEHICLE NAVIGATION AND GUIDANCE
WALTER M. HOLLISTER (Massachusetts Inst. of Tech., Cambridge.) 1990 13 p Presented at the 48th Guidance and Control Panel Symposium, Lisbon, Portugal, 9-12 May 1989
(AGARD-AR-276; ISBN-92-835-0528-X) Copyright Avail: NTIS HC A03/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
  Papers were presented covering the following topics: terrain reference navigation methods; positioning by image processing or Global Positioning System (GPS); mission and sensor management; new techniques and algorithms; sensor technology; and systems applications.   Author

N90-15927#   Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
NAVIGATION OF AUTONOMOUS AIR VEHICLES BY PASSIVE IMAGING SENSORS
H. ZINNER, R. SCHMIDT, and D. WOLF   In AGARD, Guidance and Control of Unmanned Air Vehicles 14 p (SEE N90-15924 08-08) Aug. 1989 Sponsored in part by German Ministry of Defence
(AGARD-CP-436) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
  Navigation systems of autonomous vehicles must provide information that enables the control of flight and information about the environment that allows for the perception of the 3-D scene. Passive imaging sensors with the appropriate algorithms can supply both types of information. A concept is presented that evaluates the optical flow field across the image plane in order to derive the quantities necessary for the guidance and control of the vehicle. The quality of information processing is improved by incorporating knowledge of the environment and the dynamics of the vehicle. In various computer simulations, the performance of an observer is compared with an Extended Kalman Filter. The concept is applied to two kinds of unmanned vehicles: to an autonomous unpropelled submunition, which has to detect, to classify, and to track ground vehicles, and to the fiber-optic guided missile that serves as a testbed towards systems of higher autonomy.   Author

N90-15928#   Aerospatiale, Paris (France).   Div. Engins Tactiques.
NAVIGATION UP-DATE USING RADAR MAPPING: ASSESSMENT AND OPTIMISATION SIMULATION TOOL
J. P. GUYVARCH   In AGARD, Guidance and Control of Unmanned Air Vehicles 11 p (SEE N90-15924 08-08) Aug. 1989 In FRENCH
(AGARD-CP-436) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
  The idea of an air-to-ground missile, fired from a safe distance and having all-weather capabilities, is a suitable strategy for the aerial attack of terrestrial targets. The guidance precision required exceeds the capabilities of an inertial system alone. The missile would also be equipped with a millimeter-wave radar sensor that permits localization through cartography. This principle implies that trajectory selection be made at the time of mission preparation and provisional maps be incorporated into the memory of the missile before firing. In order to estimate the probability of mission success and aid in the making of provisional maps, a method for the numerical simulation of the entire system was developed. The simulation is validated and progressively enhanced with actual data obtained in the course of sensor experimentation.
                                                        Transl. by M.G.

N90-15935#   Lockheed Missiles and Space Co., Austin, TX.
NAVIGATION AND GUIDANCE TESTING OF THE LOCKHEED/US ARMY AQUILA REMOTELY PILOTED VEHICLE
STEVEN L. FERGUSON   In AGARD, Guidance and Control of Unmanned Air Vehicles 13 p (SEE N90-15924 08-08) Aug. 1989
(AGARD-CP-436) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
  The Lockheed/U.S. Army Aquila Remotely Piloted Vehicle test program is described. The Aquila system is described, the data collection system discussed, and then particular tests required for testing the various navigation and guidance functions of the Aquila are described.   Author

N90-16731# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
ADVANCES IN TECHNIQUES AND TECHNOLOGIES FOR AIR VEHICLE NAVIGATION AND GUIDANCE
Dec. 1989 200 p In ENGLISH and FRENCH Symposium held in Lisbon, Portugal, 9-12 May 1989
(AGARD-CP-455; ISBN-92-835-0535-2; AD-A217512) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The following topics are addressed: terrain reference navigation methods; positioning by image processing or Global Positioning System; mission and sensor management; new techniques and algorithms; sensor technology; and systems applications. For individual titles, see N90-16732 through N90-16747.

N90-16732# British Aerospace Public Ltd. Co., Bracknell (England).
RECENT DEVELOPMENTS IN TERPROM
DENIS M. GREY and ROBERT S. DALE In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 15 p (SEE N90-16731 09-04) Dec. 1989
(AGARD-CP-455) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Terrain Reference Navigation Systems (TRANs) began developemt some 30 years ago but since then their appeal has broadened considerably. The British Aerospace (BAe) Terrain Matching Profile system (TERPROM) is one of the most mature. It has three basic modes of operation and a number of features which navigation is but one. Terrain Following (TF) and intelligent ground proximity warning are just two of several benefits which result from TERPROM's ability to interpret the digital map data base. These features were all tested in a variety of fast-jet aircraft. Recent developments include TERPROM's integration with other systems such as Doppler, Scene Matching Area Correlation (SMAC), and Global Positioning System (GPS) to improve navigation performance even further and moreover, a redesign of the system architecture was proposed which enables the best information from a range of sensors to be used both for navigation and weapon aiming. Author

N90-16733# Technische Univ., Clausthal-Zellerfeld (Germany, F.R.). Inst. fuer Elektr. Informationstechnik.
POSITION FIXING BY DETECTION OF ROADS AND RIVERS
E. MUEHLENFELD In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 8 p (SEE N90-16731 09-04) Dec. 1989
(AGARD-CP-455) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An image sensor, looking straight downward from an aircraft, detects line-shaped patterns of roads, rivers, or railroads with a detection rate of 75 percent. Combining these measurement with stored map data on these traffic routes and with INS data yields reliable position estimates within + or - 8 meters. Author

N90-16734# Hochschule der Bundeswehr, Munich (Germany, F.R.). Dept. of Aerospace Technology.
AUTONOMOUS AUTOMATIC LANDING THROUGH COMPUTER VISION
R. SCHELL and E. D. DICKMANNS In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 9 p (SEE N90-16731 09-04) Dec. 1989
(AGARD-CP-455) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The automatic autonomous landing approach through computer vision was investigated in a simulation loop with real image sequence processing hardware and software. The use of integral spatio-temporal world models is the presupposition to achieve real time performance with the microprocessors currently available. Results achieved for a business-jet aircraft demonstrate that this set up is powerful enough to solve the problem of autonomous unmanned landing approach. Author

N90-16735# Technische Univ., Brunswick (Germany, F.R.). Inst. of Guidance and Control.
INTEGRATED FLIGHT GUIDANCE SYSTEM USING DIFFERENTIAL-GPS FOR LANDING APPROACH GUIDANCE
THOMAS JACOB and G. SCHAENZER In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 10 p (SEE N90-16731 09-04) Dec. 1989
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Using the satellite based Global Positioning System (GPS) for precision flight guidance, accuracy problems arise due to the influence of dynamic maneuvers on GPS receivers. The error behavior in stationary as well as in dynamic applications is explained. From the error behavior a system concept of an Integrated Flight Guidance System is derived. Different concepts of system integration are explained. The results of a closed loop mechanization of a Kalman filter coupling GPS and INS implemented in the Integrated Flight Guidance System were checked by simulation and flight test results in approach and landings up to CAT 2. Author

N90-16736# Defense Advanced Research Projects Agency, Arlington, VA.
MINIATURE GPS-BASED GUIDANCE PACKAGE
L. STOTTS, J. AEIN, and N. DOHERTY (Mitre Corp., Bedford, MA.) In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 18 p (SEE N90-16731 09-04) Dec. 1989
(AGARD-CP-455) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The technical goals, issues, and status of the Global Positioning System (GPS) based Guidance Package (GGP) effort within the Aerospace and Strategic Technology Office of DARPA are presented. The GGP exploits the synergisms achieved by combining inertially sensed (IMU) movement with externally sensed GPS reference signals. The goal is to produce a combined GPS/IMU navigation grade system which will be miniaturized for easy insertion to any host vehicle and inexpensive for use by expendable vehicles (weapons and platforms). Efforts already under way within the DoD community based on integrating conventional navigation technologies result in systems on the order of 65 lbs, 160 watts, 1800 cu. in., and $15 K per unit. The GGP builds upon the integrated circuit technology from the preexisting DARPA mini GPS receiver (MGR) program combined with the following: solid state linear accelerometers and fiber optic rotation rate sensors (gyros) for three axes inertial sensing, and a data processor and associated software to implement a Kalman filter to integrate the sensor outputs and provide the navigation solution as well as any filtered velocity, acceleration, and orientation data needed by the host vehicle. Major cost reduction breakthroughs are offered by FOG sensors which employ integrated optic chips for light wave processing along with the polarization preserving fiber optic rotation sensing coil and laser diode optical source. GGP host vehicle insertion is also facilitated by its packing/customizing achieved through modularity of MGR, IMU, and navigation microprocessor subsystems. Modularity is achieved with standardization of the Kalman filter architecture in the navigation processor and data transfer points (ports) interfacing the MGR and IMU sensors to the navigation processor. Technical detail is provided on the following topics: functional architecture, technology, and status of the MGR chip set; desired performance, approach, status, and technology issues for a FOG sensor, and system level integration and performance issues. Author

N90-16737# Centre d'Enseignement et de Recherches de Medecine Aeronautique, Paris (France). Dept. d'Ergonomie Aerospatiale.
ADVANCES IN NAVIGATION SUPPORT SYSTEMS BASED ON OPERATIONAL PILOT'S HEURISTICS
F. DEBLON, A. GUENGANT (Dassault-Breguet Aviation, Saint Cloud, France), C. VALOT, and R. AMALBERTI In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 12 p (SEE N90-16731 09-04) Dec. 1989 In FRENCH; ENGLISH summary
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The conjecture of the future battlefield (many threats, single seat combat aircraft) will impose the development of onboard decision support systems. The concept of pilot's assistant fits this need in assistance. While this concept covers different classes of aids, the focus is on the development of a navigation support system. Special attention was pa the quality of man-machine coupling of such a real-time aid. It is evidenced that, because the quality of the coupling is a vital goal, the best solution consists in computerizing the navigation expertise with the greatest proximity of human being (and not with optimal multi-expert and/or multi-constraint software). Thus, pilot expertise elicitation was closely conducted during 4 years in nap of the earth penetration mission. A AI computer model of navigation is derived from this cognitive model with respect to the use of actors language. Extended description of this program is given in the paper, including direct connections with the future of the French's pilot assistant.
Author

N90-16738*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NASA/RAE COOPERATION ON A KNOWLEDE BASED FLIGHT STATUS MONITOR
G. F. BUTLER (Royal Aircraft Establishment, Farnborough, England) and E. L. DUKE In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 9 p (SEE N90-16731 09-04) Dec. 1989
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As part of a US/UK cooperative aeronautical research pragram, a joint activity between the Dryden Flight Research Facility of the NASA Ames Research Center (Ames-Dryden) and the Royal Aerospace Establishment (RAE) on Knowledge Based Systems was established. Under the agreement, a Flight Status Monitor Knowledge base developed at Ames-Dryden was implemented using the real-time IKBS toolkit, MUSE, which was developed in the UK under RAE sponsorship. The Flight Status Monitor is designed to provide on-line aid to the flight test engineer in the interpretation of system health and status by storing expert knowledge of system behavior in an easily accessible form. The background to the cooperation is described and the details of the Flight Status Monitor, the MUSE implementation are presented.
Author

N90-16739# Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France). Missile and Space Guidance Systems Unit.
EXPERT SYSTEM FOR KALMAN FILTER SUPERVISION: APPLICATION TO AUTONOMOUS SATELLITE NAVI \TION
DOMINIQUE BERTON, T. CODRON, R. HORAK, and S. SAILE (Grenoble-1 Univ., Saint Martin d'Heres, France) In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 12 p (SEE N90-16731 09-04) Dec. 1989
(Contract DRET-87-464)
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The realization of a rule based supervisor which ensures the good performance and the robust behavior of a non-liner Kalman filter is presented. Together with the description of the functional architecture of this supervisor, the different sources of knowledge are explained and how they are used to program the rule. The typical characteristics of the Real Time Expert System which is the heart of the supervisor is analyzed, and also how the emission of actions in real time led to selection of an original tool to generate the Expert System. Rules and results are presented, they are applied in the case of a navigation filter for satellites and show considerable improvements in performances of the Kalman filter once coupled with the Expert System.
Author

N90-16740# Air Force Wright Research and Development Center, Wright-Patterson AFB, OH.
APPLICATION OF MULTIFUNCTION INERTIAL REFERENCE SYSTEMS TO FIGHTER AIRCRAFT
JOHN M. PERDZOCK, JACK JANKOVITZ, and CARLOS A. BEDOYA (McDonnell Aircraft Co., Saint Louis, MO.) In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 19 p (SEE N90-16731 09-04) Dec. 1989
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Advanced high performance fighter and transport aircraft depend on reliable, accurate, inertially derived data to perform such subsystem functions as fly-by-wire automatic flight control, fire control, weapon delivery, navigation, guidance, and cockpit displays. These data are currently obtained from inertial reference sensors which are essentially dedicated for each major functional application. Future inertial reference systems must meet the requirements of the functional users and have lower life cycle cost, increased survivability to combat damage, and improve reliability and accuracy. One way to meet these requirements is to use the same sensors to provide kinematic data to all applications. The feasibility of such a system was investigated in the Multifunction Inertial Reference Assembly (MIRA) study. The MIRA is defined by combined inertial requirements for flight control, cockpit display, weapon delivery, and navigation resulting in a common reference package for multiple users. A history of development activity is shown.
Author

N90-16741# Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France). Div. Missiles/Espace.
INTELLIGENT LANDMARKS RECOGNITION IN SATELLITES IMAGES
OLIVIER REICHERT and DOMINIQUE BERTON In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 13 p (SEE N90-16731 09-04) Dec. 1989 In FRENCH; ENGLISH summary
(Contract DRET-97-464)
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The determination of the position of a known landmark within a ground image allows, among other things, an update on on-board satellite navigation filter. In the application described, the landmark recognition process uses image correlation techniques and is supervised by a real-time expert system. The system controls a library of algorithms by dynamically selecting the most appropriate algorithms considering the features of the landmark, the likely perturbations in the search area and the time constraints, then by interpreting the results through a multicriteria analysis. Several processings are successively triggered and the fusion of their results provide a better confidence on the final update decision. The performances on SPOT multispectral images show the superiority of this approach with respect to more classical recognition techniques, especially in terms of robustness and autonomy.
Author

N90-16742# Naval Weapons Center, China Lake, CA.
REUSABLE NAVIGATION MODULE
C. W. HALL and K. A. KOHOUT In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 4 p (SEE N90-16731 09-04) Dec. 1989
(AGARD-CP-455) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The principal objective of the reusable software task is to determine if missile software that is mission specific can be made reusable, and if so, how best to identify and create the reusable parts. A baseline was established from an Independent Exploratory Development (IED) project. The baseline consisted of many packages, procedures, subprograms, and functions, but rather than

attempt to make the entire package reusable, attention was focused on the navigation portion. From this navigation portion evolved the common metaparts into a reusable navigation module that could be used either intact or modified in other missile systems. This reuseable navigation module was implemented in the MIL-STD-1815A (Ada) language, mandated by Directives 3405.1 and 3405.2 for computers integral to weapon systems. Methodologies were explored for identifying, developing, and verifying a reusable navigation module. Currently, several navigational metaparts, were identified and developed. The remainder of the project will be devoted to porting the software to a multiprocessor system, upon which it will be further tested and evaluated for reusability on another typical missile application.   Author

N90-16743#   University Coll. of North Wales, Bangor.
PARALLEL PROCESSING IMPLEMENTATION OF A FLIGHT CONTROLLER
P. J. FLEMING, F. GARCIA NOCETTI, C. M. JONES, H. A. THOMPSON, G. INGLE, and E. BALLEY (Royal Aircraft Establishment, Farnborough, England)   In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 11 p (SEE N90-16731 09-04)   Dec. 1989
(AGARD-CP-455)   Copyright   Avail: NTIS HC A09/MF A02;
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    The feasibility of using a parallel processing transputer-based network, programmed in occam, for the implementation of an aircraft flight control law is investigated. Three techniques to generate the concurrent realization of this control law are described and illustrated together with some indications of their strengths and weaknesses. Software tools were used and developed to automate the mapping of the control law on the transputer system. Integration of the existing control hardware on-board the aircraft and the parrallel processing hardware was also addressed.
                                                        Author

N90-16744#   Societe de Fabrication d'Instruments de Mesure, Massy (France). Recherches et Developpements/Navigation-Guidage.
LOW AIR SPEED COMPUTATION FOR HELICOPTERS: A NEW AFPROACH [ANNEMOMETRIE BASSE VITESSE: UNE NOUVELLE APPROCHE]
YVES PATUREL   In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 19 p (SEE N90-16731 09-04)   Dec 1989   In FRENCH
(AGARD-CP-455)   Copyright   Avail: NTIS HC A09/MF A02;
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    In both military and civilian helicopters, it is necessary to monitor airspeed throughout the entire flight envelope. The determination of low airspeeds (less than 25 m/s) is a critical problem because of the limitations of classical anemometric sensors. A solution is proposed based on the derivation of longitudinal and transverse airspeeds from information already available aboard the helicopter: accelerations and attitude control information. The derivation algorithm, called MEDIA, is described along with the results of flight tests.   Transl. by M.G.

N90-16745#   Defence Research Establishment, Ottawa (Ontario).
THE DEVELOPMENT OF AN AIRBORNE SYNTHETIC APERTURE RADAR MOTION COMPENSATION SYSTEM
D. F. LIANG and D. J. DIFILIPPO   In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 13 p (SEE N90-16731 09-04)   Dec. 1989
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    The Canadian Department of National Defence has developed an airborne Synthetic Aperture Radar Motion Compensation System (SARMCS) for the AN/APS-506 Maritime Search Radar. To attain high quality airborne SAR imagery, the SARMCS must provide accurate information on spurious motion of the antenna phase centre during a SAR scene. This information is used to compensate the radar returns, thereby enhancing the SAR image quality. The SARMCS is effectively an integrated navigation system consisting of a ring laser gyro inertial navigation system (LTN-91), a Decca

Doppler radar, a baro-altimeter, and a motion compensation inertial measurement subsystem (MCIMS). The hardware and software configurations of the SARMCS implemented on board a Convair 580 research aircraft are described. In addition, the flight testing approach and some of the simulation and flight test results are presented.   Author

N90-16746#   Defence Research Establishment Suffield, Ralston (Alberta).
GUIDANCE AND CONTROL CONSIDERATIONS FOR A MANEUVERING AERIAL TARGET SYSTEM
ALEX B. MARKOV, ROBERT W. HERRING, and ERIC N. SOLOWKA (Atlantis Flight Research, Inc., Brampton, Ontario)   In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 16 p (SEE N90-16731 09-04)   Dec. 1989
(AGARD-CP-455)   Copyright   Avail: NTIS HC A09/MF A02;
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    In 1981 the Defence Research Establishment Suffield (DRES) initiated proof-of-concept (POC) development of a high subsonic, maneuvering fire-and-forget aerial target system named ROBOT-X. This effort was in response to a Canadian Navy requirement for aerial targets simulating low flying aircraft or anti-ship missiles, but has resulted in a target system that is also useful in many army low level air defence training scenarios. The POC development, recently completed, included seventeen POC test flights conducted at DRES. Of critical importance for ROBOT-X to meet its performance objectives is a programmable, cost-effective flight control system. The system that was developed, which was called MicroPilot, incorporates a number of software and hardware features that allow it to fulfill ROBOT-X guidance and control sensor suite, and facilitate implementation of algorithmic changes. This modularity has resulted in a flight control system that can also be used in other unmanned flight vehicles. A description is included of the ROBOT-X aerial target system. Guidance and control aspects are emphasized, and the methodology adopted in the flight control system design and prototyping is reviewed. MicroPilot algorithmic, software, and hardware features are described as they evolved in POC ROBOT-X development. Highlights of results from simulation, testbed aircraft trials and POC ROBOT-X flight trials are given.
                                                        Author

N90-16747#   Harris Corp., Melbourne, FL   Government Aerospace Systems Div.
TERRAIN-AIDED NAVIGATION AND TARGET ACQUISITION ON THE AFTI/F-16
CHARLES A. BAIRD, NOEL COLLINS, and MYRES DREW   In AGARD, Advances in Techniques and Technologies for Air Vehicle Navigation and Guidance 12 p (SEE N90-16731 09-04)   Dec. 1989
(AGARD-CP-455)   Copyright   Avail: NTIS HC A09/MF A02;
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    The Advanced Fighter Technology Integration/F-16 (AFTI/F-16) aircraft is currently involved in flight testing aimed at developing technologies and capabilities to support the close air support (CAS) and battlefield air interdiction (BAI) missions The major features of CAS missions are illustrated. The CAS/BAI problem is described from a pilot's mission performance perspective. The integration of the aircraft system to utilize the terrain-aided navigation is described and passive ranging functions are provided by the Digital Terrain Management and Display Systems (DTMDS) to support the target acquisition and weapon delivery aspects of the CAS mission. Detailed presentation of the terrain-aided navigation flight test results and the analytical work supporting the passive ranging functions are then presented. This is followed by a description of the three phase CAS flight test program. The recently completed phase one is described, culminating in the flight demonstrations featured in the video presentation. The future program goals to be addressed in phases two and three of the CAS program are described.   Author

N90-27446# Air Force Systems Command, Norton AFB, CA.
GLOBAL POSITIONING SYSTEM OVERVIEW/STATUS
M. T. RUNKLE and B. SIEGEL (Aerospace Corp., Los Angeles,
CA.) *In* AGARD, Tactical Applications of Space Systems 7 p
(SEE N90-27438 21-65) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   The Global Positioning System (GPS) program status is
summarized and a review of the system concept and several
applications are provided. Author

N90-27447# Air Force Systems Command, Eglin AFB, FL.
Munitions Systems Div.
**FUTURE APPLICATIONS OF GPS TO CONVENTIONAL
WEAPONS**
STEPHEN M. MCELROY and LOUIS R. CERRATO *In* AGARD,
Tactical Applications of Space Systems 13 p (SEE N90-27438
21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   The potential role of Global Positioning System (GPS) in future
conventional weapon applications are discussed. Short range
weapons can benefit from accurate GPS initialization, while medium
and long range standoff weapons could incorporate GPS in their
navigation systems. The problem of jamming and design techniques
to improve the capabilities of GPS will be discussed. Several
important integration issues will also be highlighted. Author

N90-27449# Aerospace Corp., Los Angeles, CA.
**POTENTIAL NEW TACTICAL APPLICATIONS OF THE
GLOBAL POSITIONING SYSTEM (GPS)**
MOHAN P. ANANDA and JOHN E. CLARK *In* AGARD, Tactical
Applications of Space Systems 9 p (SEE N90-27438 21-66) May
1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
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   The Global Positioning System (GPS) is an all weather global
navigation satellite system deployed by the United States
Department of Defense primarily for achieving force enhancements
for the United States and NATO military forces. The major objective
of the GPS is to provide highly accurate positioning capability to
tactical weapon platforms. The GPS will eventually have 21 to 24
operational satellites continuously transmitting navigation signals
to users around the globe. Possibilities of using GPS to disseminate
critical information in time of conflict to tactical forces are
investigated. This type of information distribution can be
accomplished without any space vehicle hardware modifications
on the GPS Block 2 vehicles by the use of spare bits in the
navigation message data frames. With minimum hardware changes
on the next generation GPS Block 2R space vehicles, a continuous
communication channel can be made available. Various system
engineering issues and applications related to the communication
capability of GPS are provided. Author

N90-29338# Advisory Group for Aerospace Research and
Development, Neuilly-Sur-Seine (France). Guidance and Control
Panel.
**ANALYSIS, DESIGN AND SYNTHESIS METHODS FOR
GUIDANCE AND CONTROL SYSTEMS**
C. T. LEONDES, ed. (California Univ., Los Angeles.) Jun. 1990
489 p Original contains color illustrations
(AGARD-AG-314; ISBN-92-835-0566-2; AD-A225966) Copyright
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   The field of modern guidance and control systems has been
raised to a very high level of capability because of the powerful
high technology advances of the past several decades. This NATO
AGARDograph captures the spirit of these powerful capabilities.
Topics include integrated guidance and control systems;
NAVSTAR/GPS Systems; optical gyroscope and control systems;
integrated communication and navigation systems; integrated
navigation flight control systems; civil aircraft navigation and traffic
control; and land navigation systems. For individual titles, see
N90-29339 through N90-29377.

N90-29339# Navstar Systems Development, Monument, CO.
**GPS INTEGRITY REQUIREMENTS FOR USE BY CIVIL
AVIATION**
ALISON K. BROWN *In* AGARD, Analysis, Design and Synthesis
Methods for Guidance and Control Systems 12 p (SEE N90-29338
24-04) Jun. 1990
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03;
Non-NATO Nationals requests available only from
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   At the request of the Federal Aviation Administration (FAA),
the Radio Technical Commission for Aeronautics (RTCA)
established the Special Committee 159 on September 20, 1985.
The purpose of SC-159 was to prepare a Minimum Aviation System
Performance Standard (MASPS) for the operation and use of the
evolving Global Positioning System (GPS) in civil air navigation.
To assist in preparing the MASPS, SC-159 formed an Integrity
Working Group to investigate and report on civil integrity problems
relating to GPS. The purpose was to establish GPS integrity
monitoring requirements and to discuss suitable integrity monitoring
techniques for civil aviation. The Integrity Working Group
recommendations to SC-159 are summarized. Author

N90-29340# Northrop Corp., Norwood, MA. Precision Products
Div.
**INTEGRATION OF GPS AND STRAPDOWN INERTIAL
SUBSYSTEMS INTO A SINGLE UNIT**
DAVID BUECHLER and MICHAEL FOSS *In* AGARD, Analysis,
Design and Synthesis Methods for Guidance and Control Systems
13 p (SEE N90-29338 24-04) Jun. 1990 Previously announced
in IAA as A88-17329
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03;
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   Most Global Positioning System (GPS) receivers are designed
for stand-alone operation. Single-channel, slow-sequencing
receivers are recognized to be the lowest cost, but lack dynamic
capability, while multiplexed and multichannel designs allow
operation during acceleration, but add cost, weight and power. It
is also well recognized that a marriage of GPS data with strapdown
inertial data enhances the quality of both, and many people are
looking at integration of available GPS receivers with various
available inertial systems. However, direct design at the outset of
a tightly integrated GPS and strapdown INS allows optimization of
both for performance and cost. Using this approach, a properly
designed slow-sequencing, single-channel receiver, married to a
low-cost strapdown inertial unit, provides satellite tracking during
10-g acceleration, very high jamming suppression, improved
strapdown inertial outputs, and improved GPS navigation accuracy.
Packaging this GPS/I in a single unit reduces software and
hardware redundancies, and results in a very low-cost design.
Author

N90-29341# McDonnell Aircraft Co., Saint Louis, MO.
**APPLICATION OF MULTIFUNCTION INERTIAL REFERENCE
SYSTEMS TO FIGHTER AIRCRAFT**
CARLOS A. BEDOYA and JOHN M. PERDZOCK (Air Force Wright
Aeronautical Labs., Wright-Patterson AFB, OH.) *In* AGARD,
Analysis, Design and Synthesis Methods for Guidance and Control
Systems 33 p (SEE N90-29338 24-04) Jun. 1990
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AGARD/Scientific Publications Executive
   As requirements for Flight Control, Fire Control, Propulsion
Control and Navigation Systems are developed for future fighter
aircraft, reliability, maintainability, availability, redundancy, and
survivability become key issues. These systems require dependable
and accurate sources of inertial measurement data. The
Multifunction Flight Control Reference System (MFCRS) was
developed to demonstrate the use of a minimum number of inertial
sensors. The MFCRS Program used two extensively modified Ring
Laser Gyro (RLG) navigation units to perform the flight control
reference and navigation functions on board an F-15 fighter aircraft.
An overview is given of the various stages of development that
were completed on this program, the lessons learned to date,
and what is planned for the future. Evaluation of MFCRS was
undertaken to evaluate performance at the system level and
evaluate flight control outputs, redundancy management, electronic
MRU to MRU alignment, reaction time, navigation performance,

performance under vibration, temperature, EMI environments, and operation when integrated with the F-15 Flight Control System. Following the MFCRS laboratory evaluation a ground structural mode interaction test and a two phase flight test program was performed. Subsequent to the successful completion of the phase two flight test evaluation, changes to the MFCRS hardware and software structure, which would improve system performance and expand the MFCRS flight envelope, were identified. Following the laboratory evaluation additional flight testing was planned to verify that the EMFCRS configuration would result in level 1 handling qualities in both supersonic and subsonic flight was well as in tracking of target aircraft. Unfortunately, during ground testing prior to flight, a 22 Hz structural mode interaction was found in the control system pitch channel. The system changes developed during the EMFCRS studies, the laboratory test results, and the aircraft testing are discussed, as well as the follow on development of multifunction system now in process under the name of Ada Based Integrated Controls System (ABICS) Phase 3.   Author

N90-29342# California Univ., San Diego, La Jolla. Dept. of Applied Mechanics and Engineering Sciences.
KALMAN FILTER FORMULATIONS FOR TRANSFER ALIGNMENT OF STRAPDOWN INERTIAL UNITS
ALAN M. SCHNEIDER   *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 11 p (SEE N90-29338 24-04)   Jun. 1990
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
     Formulations of Kalman filters are presented which are capable of aligning one strapdown inertial sensor assembly with another by estimating the misalignment angle between them. One formulation treats the case of a fixed misalignment. Another treats the case of a dynamic misalignment, caused, for example, by bending of the common supporting body. Measurements can be made by gyros only, or by gyros plus accelerometers. Filters which estimate inertial sensor error parameters are also discussed.
                                                                                Author

N90-29343# Trimble Navigation, Sunnyvale, CA.
COMBINING LORAN AND GPS: THE BEST OF BOTH WORLDS
PAUL BRAISTED, RALPH ESCHENBACK, and ANIL TIWARI   *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 4 p (SEE N90-29338 24-04)   Jun. 1990
Previously announced in IAA as A07-13544
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
     The use of the current Loran-C network and the future GPS for marine navigation is described, and their use in combination (now planned for the period before GPS becomes fully operational in 1988) is shown to offer significant advantages over either system alone. Loran provides GPS initialization and continuous coastal coverage when GPS is out of sight, while GPS improves Loran by aiding cycle selection, ambiquity treatment, and ASF-factor calibration. Graphs and diagrams are included.   Author

N90-29344# Singer Co., Wayne, NJ. Electronic Systems Div.
THE INTEGRATION OF MULTIPLE AVIONIC SENSORS AND TECHNOLOGIES FOR FUTURE MILITARY HELICOPTERS
ALBERT J. SHAPIRO   *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 20 p (SEE N90-29338 24-04)   Jun. 1990   Previously announced in IAA as A83-40301
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     The expanding role of the helicopter in the battlefield environment has burdened the pilot with missions of greater complexity and risk with a concomitant increase in pilot workload. Navigation of the helicopter is an essential supportive element to the prime mission and has been until recent years, a significant contributor to the workload. Technological advances in navigational electronics such as Doppler navigation radar, computers, integrated avionic control and display systems, etc., now can provide automated navigation with vital benefits in cost, size, weight and power, which permit incorporation of these advances into the helicopter. Cost reductions are particularly important since helicopters are used in large quantities in modern military forces

Multisensor navigation systems already available and in use in helicopters are discussed, followed by a review of the system trade-offs and considerations leading to new systems that use more advanced digital electronic techniques to achieve the goals of reduced pilot workload and improved performance with minimum size, weight, and cost. The beneficial impact of ongoing technological advances in improving the operating capabilities of future avionics systems is indicated.   Author

N90-29345# Stanford Univ., CA.
TECHNIQUES FOR AUTONOMOUS GPS INTEGRITY MONITORING
BRADFORD W. PARKINSON and PENINA AXELRAD   *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 18 p (SEE N90-29338 24-04)   Jun. 1990
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     The use of GPS for navigation critical applications such as aircraft non-precision approach or harbor and river crossings requires the navigation data to be both extremely accurate and extremely reliable. Various approaches to GPS integrity checking, are outlined, and a method is described for user autonomous satellite failure detection and isolation (D/I). The test statistic for the D/I algorithm is the range residual parameter based on six or more satellite in view. The nominal pseudo range measurement errors are modeled as normally distributed with mean in the range of -5m to +5m and standard deviation of 0.4 m based on experiments conducted at Stanford. The theoretical statistical distribution of the range residual is given. Monte Carlo simulations present results of applying the algorithm to measurement sets containing a biased measurement. With a 100 m biased measurement present successful detection is achieved 99.9 percent of the time. and successful detection and isolation is achieved 72.2 percent of the time. The user is always aware when isolation is not possible. User positioning errors resulting from application of the algorithm are always the same or better than the all in view solution.   Author

N90-29346# Interstate Electronics Corp., Anaheim, CA.
MODULAR DIGITAL GPS RECEIVERS
J. SCOTT GRAHAM, PETER C. OULD, and ROBERT J. VANWECHEL   *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 12 p (SEE N90-29338 24-04) Jun. 1990
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
     The modular digital approach to GPS receiver design being implemented at Interstate Electronics Corporation (IEC) for various range instrumentation and military P-code applications are described. The receiver consists of a preamplifier, RF downconverter that converts the GPS signal spectrum to baseband and digitizes it; single or multiple digital tracking processors for carrier and code tracking; a receiver control and navigation processor; and various types of flexible modular interface (FMI) boards. This receiver is IEC's third generation P-code design and has been achieved by a graceful miniaturization process that utilizes currently available low risk technology to reduce size, power consumption, and cost. Recent anti-jamming test results are presented.   Author

N90-29347# Diesel Computing Systems, Inc., Woodland Hills, CA.
INTEGRATION OF GPS/INS WITH PARTITIONED FILTERS
JOHN W. DIESEL   *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 15 p (SEE N90-29338 24-04)   Jun. 1990
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
     The optimal integration of a strapdown Inertial Navigation System (INS) with a Global Positioning System (GPS) in a maneuvering vehicle is considered, assuming the GPS will eventually be jammed. To achieve optimal performance after jamming, many inertial instrument errors should be calibrated by the GPS. Instead of using a single, high order Kalman filter a more effective solution is obtained by using several partitioned,

low order filters. This solution is also applicable to other GPS/INS integration problems. The observation information used in these filters comes from the phase-locked GPS carrier tracking loops. Inertial rate-aiding of these loops to delay loss of lock due to jamming is investigated. This is a more difficult problem than early investigators anticipated. It is solved by partitioning each tracking loop into a high bandwidth extrapolator for upgrading the inertial aiding information and an aided low bandwidth tracking loop for tracking the GPS phase. To gain insight into these partitioned filters, a general class of Kalman filtering problems is investigated. In most cases, an analytic solution to both the transient and steady-state Kalman filter gains is obtained. These solutions can be implemented directly in the partitioned filters, rather than using real-time Kalman filters.   Author

N90-29348#   Aerospace Corp., El Segundo, CA.
THE 2-D AND 3-D CHARACTERIZATIONS OF GPS NAVIGATION SERVICE
P. MASSATT, W. RHODUS, and K. RUDNICK   In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 15 p (SEE N90-29338 24-04)   Jun. 1990   Previously announced in IAA as A87-41401   Original contains color illustrations
(AGARD-AG-314)   Copyright   Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The quality of world-wide GPS navigation service is frequently described by plotting on a world map background 2-dimensional regions (latitude, longitude) on the Earth's surface where navigation is degraded for some period of time, over the span of a day. Such depictions provide little information concerning when such navigation degradations occur or their duration. Computationally efficient algorithms are presented for computing the locations in space and time of these navigation degradations. Quick geometric formulas are presented for calculating the dilutions of precision. A data base is generated with this approach on a mainframe computer and then post-processed on a high resolution color graphics workstation to produce 3-dimensional plots (latitude, longitude, and time) which insightfully characterize GPS navigation service and its evolution in time. Degradation regions are readily isolated with their time of occurrence, duration, and location clearly defined. Also given are 2-dimensional plots which display location and time of poor coverage permitting an analysis of the quality of coverage from another perspective. Results are provided for the current 7 operational Block 1 satellites, a 9 satellite constellation projected for 1989 when 4 Block 2 SVs will have been added, the GPS baseline 21 SV constellation, and a revised 21 SV constellation under consideration.   Author

N90-29349#   Kongsberg Vapenfabrikk A/S (Norway)
APPLICATIONS OF DIFFERENTIAL GPS
KJELL HERVIG and HERMOD FJAEREIDE   In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 6 p (SEE N90-29338 24-04)   Jun. 1990
(AGARD-AG-314)   Copyright   Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Kongsberg Navigation has developed a system for use of differential Global Positioning System (GPS) for the Norwegian offshore industry. The principles of operation and the service offered to customers of Differential GPS are described. It also describes some of the experiences with the introduction of the service, and prospects foreseen when the system is fully operational.   Author

N90-29350#   Naval Air Development Center, Warminster, PA.
AN ANALYSIS OF GPS AS THE SOLE MEANS NAVIGATION SYSTEM IN US NAVY AIRCRAFT
GEORGE LOEWENSTEIN, JOHN PHANOS, and EDWARD C. RISH (Synetics Corp., Vienna, VA.)   In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 8 p (SEE N90-29338 24-04)   Jun. 1990
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    The Department of Defense (DOD) is developing the Global Positioning System (GPS) to acquire a worldwide navigation capability. This satellite based system provides appropriately equipped users with precision three dimensional position and

velocity, and precise time. The current edition of the U.S. Federal Radionavigation Plan, issued in 1984, presents a consolidated Federal plan on the management of those Radionavigation systems which are used by both the civilian and military sectors. It states the DOD goal to phase out the use of TACAN, VOR/DME, OMEGA, Loran C and TRANSIT in military platforms and for GPS to become the standard radionavigation system for DOD. This would eliminate all the current sole means air navigation systems (TACAN and VOR/DME) aboard military aircraft. Instrument Flight Rule (IFR) operations within controlled airspace requires an operating sole means air navigation system to be aboard the aircraft. The requirements are investigated for GPS certification as a sole means air navigation system in the U.S. National Airspace System (NAS), the implication are discussed for GPS User Equipment (UE) hardware and software, the actual UE implementation and approaches for UE integration with flight instruments on Navy aircraft are described.   Author

N90-29351#   Phillips (Alan H.), Syosset, NY.
THE DETERMINATION OF PDOP (POSITION DILUTION OF PRECISION) IN GPS
ALAN H. PHILLIPS   In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 4 p (SEE N90-29338 24-04)   Jun. 1990
(AGARD-AG-314)   Copyright   Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    PDOP (Position Dilution of Precision) is defined, and equations are given to calculate it. Equations are given for 3-dimensional Global Positioning System (GPS) fixes, 2-dimensional GPS fixes, 2-dimensional hyperbolic fixes (Loran), and 2-dimensional range-range fixes. A method is given for geometrical determination of PDOP. The method gives an insight, which is lacking in the purely mathematical determination. Practical examples are given, and the results of the geometric determination are shown to agree with the purely mathematical determination. An equation is given for a dilution factor which applies to determination of velocity; it is not the same as PDOP.   Author

N90-29352#   Litton Guidance and Control Systems, Woodland Hills, CA.   Optical Technology Div.
RING LASER GYRO PRINCIPLES AND TECHNIQUES
GRAHAM J. MARTIN   In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 13 p (SEE N90-29338 24-04)   Jun. 1990
(AGARD-AG-314)   Copyright   Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The ring laser gyroscope (RLG) represents a departure from the mechanically based inertial rotation sensor used since the turn of the century. Since their use in the first crude gyroscopes manufactured for gun platforms at sea before the first World War, these systems have been highly refined to give the compact, accurate and relatively cost effective systems of today. The RLG offers true strapdown capability and has no known sensitivity to high g fields. Other attractive features include almost instant turn-on performance and a very linear scale factor over a very large dynamic range. Development of the RLG started in the early 1960's with the first flight tests being performed in the early 1970's. Commercial RLG-based inertial guidance systems have been available for about a decade, however the device has perhaps yet to reach its full potential. The ring laser gyro is one configuration in a class of optical gyroscopes, all of which are based on a relativistic principle known as the Sagnac Effect. The Sagnac Effect is described briefly and how it may be used to build optical rotation sensors is outlined. The RLG is placed in perspective with other forms of optical gyroscope and the basic layout is described. Details are given of the more serious error sources, such as frequency locking, and the most common means for minimizing them. In particular the lockin reduction scheme known as mechanical dither is explained. Finally an alternative form of the RLG known as the multioscillator is outlined as a possible configuration for systems where the mechanical dither approach may have shortcomings
                                    Author

N90-29353# Litton Guidance and Control Systems, Woodland Hills, CA.
INERTIAL GRADE FIBER GYROS
G. A. PAVLATH *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 12 p (SEE N90-29338 24-04) Jun. 1990 Previously announced in IAA as A88-51709
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Fiber gyros are being developed for numerous applications by many people around the world. These applications include smart munitions, tactical missiles, attitude and heading reference systems (AHRS), inertial navigation, and tracking and pointing. Existing methods which were developed for achieving inertial navigation grade performance in fiber gyros are reviewed. Recent data obtained at Litton on an engineering development model of an inertial grade fiber gyro will also be presented. Author

N90-29354# Singer Co., Little Falls, NJ. Guidance and Navigation Div.
USE OF A THREE-AXIS MONOLITHIC RING LASER GYRO AND DIGITAL SIGNAL PROCESSOR IN AN INERTIAL SENSOR ELEMENT
DONALD J. WEBER *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 6 p (SEE N90-29338 24-04) Jun. 1990
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03;
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A configuration based upon a 24-cm path length TRILAG gyro, three miniature single-axis force rebalance accelerometers, and a digital signal processor is presented. The resulting inertial sensor element provides navigation performance equal to a conventional medium-accuracy navigation system (0.4 to 1 nmi/h) with half the weight and volume of a traditional Ring Laser Gyro (RLG) configuration. Its application as a stand-alone inertial subsystem or as an integral part of a full inertial navigation system is discussed and performance data presented. Companion development utilizing down-sized TRILAG gyros for tactical missile or sensor stabilization applications is also reviewed. Author

N90-29355# Litton Guidance and Control Systems, Woodland Hills, CA.
RING LASER GYRO MARINE INERTIAL NAVIGATION SYSTEMS
CLINTON C. REMUZZI *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 8 p (SEE N90-29338 24-04) Jun. 1990
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The NATO navies currently use gimbaled spinning wheel gyros to support their inertial navigation system requirements. Ring Laser Gyros (RLGs) are now being considered for the next generation of marine inertial navigators. RLGs are expected to provide better performance (longer extrapolation intervals between resets), higher reliability, and lower cost-of-ownership. The performance improvement expected from RLGs was already demonstrated at sea during prototype system tests conducted by the U.S. Navy. The final production design of an RLG marine inertial navigation system (INS) required that tradeoffs be made among the sometimes conflicting factors of performance, reliability, and environmental isolation. Some of the considerations and tradeoffs involved in the design of the Litton marine RLG INS are described. Author

N90-29356# TRW Defense and Space Systems Group, San Diego, CA. Military Electronics and Avionics Div.
DISTRIBUTED CONTROL ARCHITECTURE FOR CNI PREPROCESSORS
V. R. SUBRAMANYAN and L. R. STINE *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 5 p (SEE N90-29338 24-04) Jun. 1990 Previously announced in IAA as A88-34056
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Next-generation avionics systems need to incorporate extensive integration, including the Communication, Navigation, and Identification (CNI) functions. An important element in such a highly integrated CNI system is a set of programmable preprocessors, each of which can process baseband outputs from a receiver to perform real-time signal dependent processing, such as matched filtering, PN despreading, code and carrier tracking, phase rotation, correlation, convolution, pulse shape discrimination, threshold crossing, time-of-arrival detection, demodulation message formatting, and on-line status reporting. Control of the total integrated CNI system is characterized by a distributed-control architecture, wherein the execution times range from seconds at the data processor level down to a few nanoseconds at the preprocessor level. Any candidate control architecture for the preprocessor must support reprogrammability, flexibility in event scheduling, and testability, while fully meeting the requirements of each CNI function. A distributed-control architecture is described for a generic CNI preprocessor that meets the above requirements. Author

N90-29357# Hughes Aircraft Co., Fullerton, CA.
JTIDS RELATIVE NAVIGATION: PRINCIPLES, ARCHITECTURE, AND INERTIAL MIXING
W. R. FRIED *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 11 p (SEE N90-29338 24-04) Jun. 1990
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The time-synchronous nature and excellent time-of-arrival (TOA) measurement accuracy of the Joint Tactical Information Distribution System (JTIDS) gives rise to its inherent capability to provide high accuracy relative and absolute navigation information to vehicles carrying JTIDS terminals. This is accomplished through the inclusion of the Relative Navigation (RELNAV) software in the terminal's operational computer program. This function has been called relative navigation because it is based on passive and active ranging to the other terminals in the net. If some of these terminals have knowledge of their geodetic position (which may be true for both stationary or moving terminals), the user can determine the absolute position in standard geodetic coordinates, as well as the relative position in an arbitrarily established grid In order to provide the highest possible accuracy for high dynamic users, the JTIDS RELNAV function is typically interconnected with a dead reckoning system on the vehicle, such as an inertial navigation system. The dead reckoning data is mixed with the JTIDS TOA data in a recursive (e.g., Kalman) filter mechanization to determine the user's position, velocity, and time bias. The principles of operation and architecture of the JTIDS RELNAV function and the system configuration for a particular inertial interconnection are described. The RELNAV observation model, and coordinate systems are discussed. Finally, some simulation results of the system are presented. Author

N90-29358# Hughes Aircraft Co., Fullerton, CA. Communications Systems Div.
PLRS: A NEW SPREAD SPECTRUM POSITION LOCATION REPORTING SYSTEM
JAMES A. KIVETT and U. S. OKAWA *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 9 p (SEE N90-29338 24-04) Jun. 1990
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The Position Location Reporting System (PLRS) provides position location, tracking, and reporting for communities of hundreds of cooperative users in a tactical environment. PLRS uses time-of-arrival (TOA) measurements aided by barometric pressure measurements to establish position tracking of these large communities of user terminals. The system uses the positions of a few user terminals as grid references so that all positions are available both to the cooperating users and to command centers. All control, measurement reporting, and data exchange are cryptographically secured in a synchronous anti-jam communications network. Author

N90-29359# Hughes Aircraft Co., Fullerton, CA. Ground Systems Group.
ENHANCING PLRS WITH USER-TO-USER DATA CAPABILITY
J. A. KIVETT and R. E. COOK *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 8 p (SEE N90-29338 24-04)   Jun. 1990   Previously announced in IAA as A87-41372
(Contract DAAB07-82-C-J096)
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The Enhanced Position Location Reporting System (EPLRS) maintains all of the basic PLRS capabilities while greatly increasing the user-to-user data capability. The EPLRS utilizes the proven PLRS control network for monitoring and controlling large communities of user terminals including the positioning, position reporting, navigation aid, cryptographic key distribution, and status reporting functions. In addition, the control network is utilized for distributing communications circuit assignments and monitoring user-to-user communications performances. Both duplex (point-to-point) and group addressed (broadcast) types of service are available via the same user terminal. Each terminal can support many user circuits (needlines) simultaneously with a composite (receive plus transmit) information rate in excess of three kilobits per second. The primary user interface is via the PLRS/JTIDS Hybrid Interface (PJHI), which uses CCITT x.25 protocols, but an FSK interface is also available for backward compatibility with existing systems such as TACFIRE. The EPLRS concepts were proven through live testing using prototype terminals, including interfacing with six military host systems. In addition, extensive computer modeling and large scale user community simulation have been used to confirm extension of performance to full scale operation with up to one thousand user terminals in a division area. Limited production of over two hundred terminals is underway, with development and operational testing scheduled to begin early in 1988.   Author

N90-29360# California Univ., San Diego, La Jolla. Dept. of Applied Mechanics and Engineering Sciences.
OBSERVABILITY OF RELATIVE NAVIGATION USING RANGE-ONLY MEASUREMENTS
ALAN M. SCHNEIDER *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 13 p (SEE N90-29338 24-04)   Jun. 1990   Previously announced in IAA as A85-42399   Prepared in cooperation with Naval Ocean Systems Center, San Diego, CA
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A simulation tool is described which is capable of determining the observability of various fleet configurations and maneuvers in a relative navigation environment. The motion of the relative grid established by the navigation controller is explicitly modeled as a function of the errors in his dead-reckoning sensors. The simulation uses centralized, optimal processing of an extended Kalman filter. Results show observability on a good geometry, with some degradation in performance when dead-reckoning sensor errors change rapidly.   Author

N90-29361# Singer Co., Little Falls, NJ.
INTEGRATED STRAPDOWN AVIONICS FOR PRECISION GUIDED VEHICLES
JACK RICHMAN, DAVID HAESSIG, JR., and BERNARD FRIEDLAND *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 5 p (SEE N90-29338 24-04)   Jun. 1990   Previously announced in IAA as A86-35348
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Conventional avionic configurations for precision guided weapons are often unnecessarily costly and inefficient because of built-in (but unused) redundancy in instrumentation attributed to the present day independent systems design approach. Described in this paper is an integrated design approach using strapdown avionic components that has the potential for lowering cost, increasing reliability and improving overall performance as a result of using fewer and less costly instruments in an optimum manner.   Author

N90-29362# Litton Guidance and Control Systems, Woodland Hills, CA.
INTEGRATED NAVIGATION/FLIGHT CONTROL FOR FUTURE HIGH PERFORMANCE AIRCRAFT
ROBERT E. EBNER and A. DAVID KLEIN *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 8 p (SEE N90-29338 24-04)   Jun. 1990   Previously announced in IAA as A88-35560
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Litton has delivered an Advanced Development Model (ADM) of an Integrated Inertial Sensor Assembly (IISA) on contract to the U.S. Naval Air Development Center. IISA is designed to provide all inertial sensor needs for modern military aircraft, including flight control and navigation, with reduced avionics cost through the use of redundant skewed inertial navigation sensors. Various design aspects of using six ring-laser gyros and six inertial-grade accelerometers in two, separated clusters are described. The redundancy management mechanization and the system design features for maximum flight safety are given. Navigation performance limits of strapdown INS, including the effects of skewed sensors, are presented. Laboratory testing will be performed by the Navy and flight testing will be conducted on an F-15 as part of a joint Navy/Air Force program.   Author

N90-29363# McDonnell Aircraft Co., Saint Louis, MO.
SURVIVABLE PENETRATION
CARLOS A. BEDOYA, GARY N. MAROON, WILLIAM J. MURPHY, and CHARLES W. CHAPOTON (Texas Instruments, Inc., McKinney.) *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 34 p (SEE N90-29338 24-04) Jun. 1990
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Threat densities expected on a modern battlefield do not allow penetrating tactical aircraft the option of simply flying around individual threats. As the threat becomes even more sophisticated in the 1990s new aircraft avionic systems will need to be fielded that will enable survivable penetration of tactical aircraft in an even more lethal threat environment. Recent advances in onboard mission planning, navigation, and terrain following/terrain avoidance/threat avoidance (TF/TA/TA) technologies and the onboard availability of stored digital terrain data enable the mechanization of such a survivable penetration capability. Onboard mission planning constructs a survivable penetration reference corridor which takes into account terrain data, the location of known threats, the expected densities of unknown and mobile threats, and mission goals. An advanced aided navigation capability, using information from the global positioning system, aiding sensors such as radar, and terrain navigation features, is necessary to make maximum use of the onboard terrain data. The TF/TA/TA function computes flyable three-dimensional paths within the reference corridor accounting for aircraft performance limits, knowledge of the surrounding terrain, and information about the threat. All three technologies use the Defense Mapping Agency's Digital Land Mass System (DLMS) terrain to provide look-ahead terrain masking and aided navigation. Through this survivable penetration methodology, advanced tactical aircraft can have enhanced aircraft survivability.
                                                        Author

N90-29364# Mitre Corp., McLean, VA.
INDEPENDENT GROUND MONITOR COVERAGE OF GLOBAL POSITIONING SYSTEM (GPS) SATELLITES FOR USE BY CIVIL AVIATION
KAREN J. VIETS *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 8 p (SEE N90-29338 24-04)   Jun. 1990
(Contract DTFA01-84-C-00001)
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The Federal Aviation Administration plans to independently monitor signals-in-space from the Global Positioning System (GPS) for the purpose of providing immediate awareness to civil aviation users of the operational status of GPS when it is used in the National Airspace System. The operational status will be

disseminated to Air Traffic Control and will possibly be broadcast from ground monitoring stations to GPS aviation users via a dedicated integrity channel. An algorithm is described that measures the coverage of a configuration of ground monitoring station locations, and applies the algorithm to several different configurations of ground monitoring stations to compare the coverage provided. Also included are the resulting ground monitoring station configurations that provide the best coverage of GPS signals for several specific geographical areas, the conterminous United States (CONUS), Canada, and Alaska.
Author

N90-29365# Mitre Corp., McLean, VA. Metrek Div.
ANALYSIS OF THE INTEGRITY OF THE MICROWAVE LANDING SYSTEM (MLS) DATA FUNCTIONS
M. B. EL-ARINI and M. J. ZELTSER In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 14 p (SEE N90-29338 24-04) Jun. 1990 Previously announced in IAA as A87-41388
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The Microwave Landing System (MLS) transmits angle, data, and range information for use by airborne receivers. The integrity of the data functions is analyzed in terms of the probability of undetected errors remaining in the data. The data format and integrity requirements were derived from the MLS standards and guidance material defined by the International Civil Aviation Organization (ICAO). Results show that the performance requirements can be met by: (1) averaging the received data bits of several samples of the same word using a majority voting; (2) reducing the bit error rate at the output of the receiver's decoder; and (3) a combination of the above techniques. Author

N90-29366# Litton Guidance and Control Systems, Woodland Hills. CA.
FAULT DETECTION AND ISOLATION (FDI) TECHNIQUES FOR GUIDANCE AND CONTROL SYSTEMS
MARK A. STURZA In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 13 p (SEE N90-29338 24-04) Jun. 1990
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Fault Detection and Isolation (FDI) techniques are described with particular emphasis on strapdown inertial system and Global Positioning System (GPS) applications. A generalized measurement model is considered with a single fault, step bias shift fault model. The parity vector is developed and analyzed. Equivalence is established between the parity and innovations approachs to FDI. A fault detection technique based on the parity vector is presented and analyzed. The Probabilities of False Alarm (P sub FA) and Missed Detection (P sub MD) are derived. The Detector Operating Characteristic (DOC) relating these probabilities is constructed. DOCs are presented for several inertial sensor and GPS satellite configurations. A maximum likelihood fault identification technique is described. A nonparity approach to FDI analysis is presented. The final section lists areas for future work. Author

N90-29367# Northrop Corp., Hawthorne, CA. Electronics Div.
CONTROL AND ESTIMATION FOR AEROSPACE APPLICATIONS WITH SYSTEM TIME DELAYS
EDWARD J. KNOBBE In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 5 p (SEE N90-29338 24-04) Jun. 1990
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In many pi   - space applications, guidance and control accuracy   graded as a result of system transport lags (or '   orically, solutions to problems of this type v   gnificant digital computer data delays were   1   human operators (e.g., aircraft pilots) becal   , closed-loop operation. More recently, this   countered in current SDI (Strategic Defe   oblems such as laser beam pointing and   aric laser beam wavefront correction. The ,   g a linear discrete-time system where

both the measured output and the process evolution are functions of time-delayed states is assessed. The optimal control solution is developed by re-casting the original system representation, with explicit time-delayed states, into a standard regulator form using state vector augmentation. Practical considerations are discussed regarding the implementation of this control law. This solution should prove useful in this and other advanced aerospace applications where system time delays are present and where precision guidance and control is required. Author

N90-29368# Analytic Sciences Corp., Reading, MA.
OVERVIEW OF OMEGA SIGNAL COVERAGE
RADHA R. GUPTA and PETER B. MORRIS (Omega Navigation System Center, Alexandria, VA.) In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 18 p (SEE N90-29338 24-04) Jun. 1990
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Successful use of the Omega Navigation System requires external information on the system coverage (i.e., spatial and temporal accessibility of usable signals from the Omega system) in selecting Omega signals for position fix computations. The published Omega signal coverage information is reviewed and the type (and basis) of the coverage information currently disseminated by the U.S. Coast Guard Omega Navigation System Center described. Assessments of the worldwide coverage provided by the system, and the impact of Omega transmitting station outages on the system coverage are also given. Author

N90-29369# Omega Navigation System Center, Alexandria, VA.
OMEGA NAVIGATION SIGNAL CHARACTERISTICS
PETER B. MORRIS and RADHA R. GUPTA (Analytic Sciences Corp., Reading, MA.) In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 14 p (SEE N90-29338 24-04) Jun. 1990
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A description of Omega/VLF signal propagation is given. Particular emphasis is given to nonstandard signal propagation scenarios including propagation over regions of low ground conductivity, signal spreading and converging, antipodal effects and long-path reception, modal interference (including fast terminator transit and off-path effects), and temporal anomalies (SIDs, PCAs, and magnetic storms). These elements of signal behavior are described qualitatively to aid in understanding the basis for signal selection algorithms employed in conventional Omega/VLF receiving systems. Equipped with this knowledge, the user may invoke manual deselection procedures when the receiver is suspected of processing an undesirable signal, i.e., likely to produce significant navigational error. As further guidance, a table of recommended signal deselections is given for approximately 80 geographic locations around the Earth. Signals are recommended for deselection on the basis of modal interference, long-path reception, and solar proton activity. Author

N90-29370# Aerospace Corp., Los Angeles, CA.
POINTING CONTROL SYSTEM FOR THE TEAL RUBY EXPERIMENT
RON ROGERS and MONTE SCHLESSINGER In AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 9 p (SEE N90-29338 24-04) Jun. 1990
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Teal Ruby is an advanced Earth-orbiting sensor that was developed to demonstrate the ability to detect airborne vehicles from space by use of infrared mosaic technology. The pointing system, which is able to direct the sensor at any designated target within the pointing envelope constraints and hold it steady with very low drift and jitter, represents a substantial increase in capability over earlier spaceborne systems. This pointing system, and the approach objectives, are examined. Author

N90-29371# GEC Avionics Ltd., Rochester (England). Guidance Systems Div.
THE POTENTIAL FOR DIGITAL DATABASES IN FLIGHT PLANNING AND FLIGHT AIDING FOR COMBAT AIRCRAFT
J. STONE *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 10 p (SEE N90-29338 24-04) Jun. 1990
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The forces opposing the NATO alliance are constantly improving their capability in the detection, location and interception of attacking aircraft. The ground attack pilot's survival depends upon his ability to conceal his approach by minimizing his aircraft signature in all visual, thermal, acoustic and electronic aspects. In attempting to achieve this, the pilot is forced to fly at altitudes and periods of the day which make the very essence of his mission most difficult to accomplish. From this background has emerged the general concept of stealth. The introduction of passive electro optical sensors in the form of FLIR and NVGs has been a significant step forward in aiding the combat pilot in this hostile environment. TF radars enable low level flight in all weathers. However, the FLIR/NVG combination is not all weather and TF radars are not stealthy. Recent developments in data storage, advanced processing techniques and highly efficient display presentation have been instrumental in enabling covert operations to take place in all weathers. Precise autonomous navigation and terrain following, with the threat of detection minimized, is now available to the modern combat pilot, freeing him to concentrate on successfully achieving the aims of his mission. The potential for digital databases in Flight Planning and Flight Aiding for Combat Aircraft is recognized and equipments are now being procured for military use. The capabilities described in this paper are all feasible, and are being integrated into GEC Avionics' system of Total Terrain Avionics (T sup 2A). Author

N90-29372# Westinghouse Defense and Electronic Systems Center, Baltimore, MD.
GUIDANCE AND CONTROL TECHNIQUES FOR AIRBORNE TRANSFER ALIGNMENT AND SAR MOTION COMPENSATION
JAMES L. FARRELL *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 6 p (SEE N90-29338 24-04) Jun. 1990 Previously announced in IAA as A88-35556
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A synthetic aperture radar employing an electronically steerable array antenna is simulated for the case of an existent master inertial measuring unit (IMU) in a remote location. To obtain reliable motion compensation data a strapdown IMU is mounted within about a foot of the antenna. Ramifications include (1) the approach to transfer alignment, (2) nav update for the master IMU, and (3) effects of motion-sensitive strapdown inertial instrument degradations on synthetic aperture radar (SAR) mode performance. These ramifications are addressed; although results are presented for simulation under simplified conditions only, the path was prepared for full operational validation as discussed. Author

N90-29373# Massachusetts Univ., Amherst.
STATE ESTIMATION FOR SYSTEMS MOVING THROUGH RANDOM FIELDS
DONALD E. CATLIN and ROBERT L. GEDDES (Analytic Sciences Corp., Reading, MA.) *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 16 p (SEE N90-29338 24-04) Jun. 1990
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A growing memory discrete dynamic model for performing temporal extrapolations along a predetermined path in a random field is presented. This dynamic model is used to drive a linear system that is itself driven by discrete white noise. The coupled system is used to derive a state estimation scheme that recursively processes noisy measurements of the system. In addition, using the aforementioned dynamic model as a reference (truth) model, a covariance analysis was developed to measure the estimation errors that occur when the dynamics along the path through the field are modeled as a Markov linear model and state estimation

is performed using discrete Kalman filtering. The performance evaluation of an inertial navigation system influenced by the Earth's gravity field aboard a maneuvering ship is provided as a specific illustrative example. Author

N90-29374# GEC Avionics Ltd., Rochester (England). Guidance Systems Div.
A LOW COST INERTIAL/GPS INTEGRATED APPROACH TO LAND NAVIGATION
C. G. HARRIS *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 7 p (SEE N90-29338 24-04) Jun. 1990
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The positional accuracy obtainable from the Global Positioning System (GPS) is much better than any preceding system and at a comparatively modest cost. This enables vehicles fitted with GPS receivers to be much more effective in operation and deployment. But to take full advantage of this accuracy, it is necessary that the navigation data is continuously available to the vehicle crew. While GPS is designed to be resistant to jamming it would be imprudent to assume that no significant periods of jamming will occur on the battlefield. One solution which provides continuous data is to use a hybrid system combining GPS and a low performance Inertial Navigation System (INS). Data from these systems is combined in a statistical (Kalman type) filter. This arrangement provides continuous data with no discontinuity of values, and redundancy to mitigate the effects of equipment failure. The likely accuracy requirements for land navigation systems and ways in which these can be met with a low cost hybrid system are reviewed. The results of the analysis of such a system, using test data from a low cost INS are included, demonstrating the effect of various GPS jamming patterns. Author

N90-29375# Sandia National Labs., Albuquerque, NM.
A LAND NAVIGATION DEMONSTRATION VEHICLE WITH A COLOR MAP DISPLAY FOR TACTICAL USE
E. J. NAVA, E. E. CREEL, J. R. FELLERHOFF, and S. D. MARTINEZ *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 9 p (SEE N90-29338 24-04) Jun. 1990 Sponsored in part by Army Avionics Research and Development Activity, Fort Monmouth, NJ
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A Land navigation Demonstration Vehicle (LDV) was assembled which fully automates the navigation task and provides the operator with a color map display derived from Digital Terrain Elevation Data (DTED). The system relieves the operator of the burdens associated with the tactical use of paper maps by providing accurate 3-dimensional position information using a strapdown inertial navigation platform aided by the Sandia Inertial Terrain Aided Navigation algorithm (SITAN). The map display and navigation instruments consist of a multi-processor SANDia Aerospace Computer (SANDAC) and a commercial Image Processing System (IPS). These interactive devices allow real-time map annotation and corrections of vehicle position errors. Author

N90-29376# General Motors Technical Center, Warren, MI. Advanced Engineering Staff.
SATELLITE NAVIGATION SYSTEMS FOR LAND VEHICLES
RONALD A. DORK and OLIVER T. MCCARTER *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 7 p (SEE N90-29338 24-04) Jun. 1990
(AGARD-AG-314) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Today's motorists often must confirm their route by referring to a roadmap. Looking at a map while driving creates a poor traffic situation, one even more acute for drivers of emergency service vehicles. To address this problem, development engineers at the General Motors Technical Center and Delco Electronics integrated an experimental GPS receiver into a GM Buick Park Avenue. The receiver is designed to acquire and sequentially track signals from four satellites. The vehicle's precise latitude, longitude,

and altitude are determined and presented on a color cathode ray tube (CRT) map display in the car's instrument panel.   Author

N90-29377#   Defence Research Establishment, Ottawa (Ontario).
AN INTEGRATED SYSTEM FOR LAND NAVIGATION
J. C. MCMILLAN   *In* AGARD, Analysis, Design and Synthesis Methods for Guidance and Control Systems 20 p (SEE N90-29338 24-04)   Jun. 1990
(AGARD-AG-314)   Copyright   Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Conditions for land navigation are among the most severe in the arctic, where until Global Positioning Systems (GPS) becomes fully operational, there will be no single system capable of continuously providing the necessary position and heading accuracy. Even when GPS is available reliability considerations will dictate that a self contained or autonomous backup be available, certainly for the military user. The Defence Research Establishment Ottawa (DREO) has therefore developed a multi-sensor optimally integrated navigation system to satisfy the present operational requirements of the Canadian land forces. This system, called PLANS (Primary Land Arctic Navigation System) was designed and built to be a highly reliable, moderately accurate and moderately priced, nonradiating, automatic navigation system for all weather off the road use. Although designed primarily to meet an arctic requirement, PLANS would of course be just as applicable for desert navigation, or for any application in which reliability and accuracy are a priority, or where simpler and less costly methods are ineffective. PLANS combines several self contained sensors with two satellite receivers, using an 8 state Kalman filter on a 68000 based microcomputer, to provide a continuous optimal estimate of position, height and heading. The self contained sensors consist of a strapdown gyrocompass/directional gyro unit, an odometer pickoff for speed, a magnetic fluxgate sensor (with a detailed geomagnetic field model in the software) and a baroaltimeter (with a digital terrain elevation map providing assistance). The satellite receivers are a single channel C/A code GPS and dual channel Transit. This section will describe the requirement, the difficulties in meeting this requirement, the design of a multi-sensor integrated system solution, some simulation results and some field trial results.   Author

N91-10967#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
AIRCRAFT TRAJECTORIES: COMPUTATION, PREDICTION, CONTROL, VOLUME 1. PART 1: FUNDAMENTALS. PART 2: FLIGHT IN CRITICAL ATMOSPHERIC CONDITIONS. PART 3: IMPACT OF NEW ON-BOARD TECHNOLOGIES ON AIRCRAFT OPERATION
ANDRE BENOIT, ed.   Mar. 1990   267 p   In ENGLISH and FRENCH
(AGARD-AG-301-VOL-1-PT-1-3; ISBN-92-835-0547-6; AD-A223568)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
This volume (part of a set of three) is composed of a preface and 11 papers covering respectively: fundamentals - general outline, optimal trajectories, and nonlinear models of aircraft; flight in critical atmospheric conditions - genesis of wind and influence on airplane trajectories, flight control in windshear, and flight simulation; and impact of new on-board technologies on aircraft operation - flight management in air transport, and crew/automation interface. For individual titles, see N91-10968 through N91-10977.

N91-10968*#   Rice Univ., Houston, TX.   Aero-Astronautics Group.
OPTIMAL TRAJECTORIES OF AIRCRAFT AND SPACECRAFT
A. MIELE   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3: Impact of New On-Board Technologies on Aircraft Operation 56 p (SEE N91-10967 02-04)   Mar. 1990   Sponsored in part by Boeing Commercial Airplane Co.; Air Line Pilots Association, International; United States Aviation Underwriters; and Boeing Military Airplane Development
(Contract NAG1-516; JPL-956415)
(AGARD-AG-301-VOL-1-PT-1-3)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 17/7
Work done on algorithms for the numerical solutions of optimal control problems and their application to the computation of optimal flight trajectories of aircraft and spacecraft is summarized. General considerations on calculus of variations, optimal control, numerical algorithms, and applications of these algorithms to real-world problems are presented. The sequential gradient-restoration algorithm (SGRA) is examined for the numerical solution of optimal control problems of the Bolza type. Both the primal formulation and the dual formulation are discussed. Aircraft trajectories, in particular, the application of the dual sequential gradient-restoration algorithm (DSGRA) to the determination of optimal flight trajectories in the presence of windshear are described. Both take-off trajectories and abort landing trajectories are discussed. Take-off trajectories are optimized by minimizing the peak deviation of the absolute path inclination from a reference value. Abort landing trajectories are optimized by minimizing the peak drop of altitude from a reference value. Abort landing trajectories are optimized by minimizing the peak drop of altitude from a reference value. The survival capability of an aircraft in a severe windshear is discussed, and the optimal trajectories are found to be superior to both constant pitch trajectories and maximum angle of attack trajectories. Spacecraft trajectories, in particular, the application of the primal sequential gradient-restoration algorithm (PSGRA) to the determination of optimal flight trajectories for aeroassisted orbital transfer are examined. Both the coplanar case and the noncoplanar case are discussed within the frame of three problems: minimization of the total characteristic velocity; minimization of the time integral of the square of the path inclination; and minimization of the peak heating rate. The solution of the second problem is called nearly-grazing solution, and its merits are pointed out as a useful engineering compromise between energy requirements and aerodynamics heating requirements.   Author

N91-10970#   Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
COMPUTATION OF SUB-OPTIMAL REAL-TIME GUIDANCE LAWS FOR COMBAT AIRCRAFT TRAJECTORIES
HUU THANH HUYNH   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3: Impact of New On-Board Technologies on Aircraft Operation 29 p (SEE N91-10967 02-04)   Mar. 1990   In FRENCH, ENGLISH summary
(AGARD-AG-301-VOL-1-PT-1-3)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An application of singular perturbation theory (SPT) for the computation of real-time control laws for Combat Aircraft trajectories is presented. The principle of SPT is first briefly reviewed for solving a multiple-time scale differential equations, then its application to optimization of nonlinear systems is presented. The main drawbacks and difficulties which were encountered in the computation of real-time control laws for Aircraft trajectories are described, then various techniques are also pointed out in order to overcome with these problems. Basing of this SPT, real-time guidance law, of closed-loop type, was developed for minimum time to climb in a vertical plane and three-dimensional interception for a combat Aircraft. The performances of these suboptimal guidance laws were then compared, in numerical simulation using a typical Aircraft model, with optimal control laws, of open-loop type, provided by an iterative numerical algorithm, using a generalized projected gradient technique. A better than 1 percent accuracy was obtained for the performance index (time-to-climb) for vertical climb trajectories The real-time guidance

laws are slightly less accurate for interception trajectories. The suboptimal guidance laws can fulfill final conditions on altitude or/and flight path angle and remain valid for a large flight envelope domain. Their computation times are very small and are compatible with real-time an board computer applications.   Author

N91-10978#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Guidance and Control Panel.
AIRCRAFT TRAJECTORIES: COMPUTATION, PREDICTION, · CONTROL, VOLUME 3. PART 9: BOOK OF ABSTRACTS. PART 10: BIBLIOGRAPHY. PART 11: LIST OF CONTRIBUTORS
ANDRE BENOIT, ed.   May 1990   155 p   In ENGLISH and FRENCH
(AGARD-AG-301-VOL-3-PT-9-11; ISBN-92-835-0563-8; AD-A225266)   Copyright   Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
This volume (part of a set of three) is composed of a short Introduction, a Book of Abstracts of 39 papers included in the overall work, and extensive Bibliography which incorporates, in particular, most of the references cited by the 56 authors and co-authors, and a List of Contributors ordered by countries, alphabetically. Both the Bibliography and the List of Contributors are each completed by an adequate index.   Author

N91-10982#   European Organization for the Safety of Air Navigation, Brussells (Belgium).   Engineering Directorate.
OPTIMUM ON-LINE HANDLING OF AIR TRAFFIC OVER WESTERN EUROPE
ANDRE BENOIT and SIP SWIERSTRA   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 6 p (SEE N91-10981 02-05)   May 1990   Presented at the International Seminar ATC 2000, Luxembourg, 23-25 Feb. 1988
(AGARD-AG-301-VOL-2-PT-4-8)   Copyright   Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
For today's airlines, Western Europe is not very large and the flights they make within it do not last very long. Consequently it should be possible within such an area as Western Europe to arrange Air Traffic Control (ATC) clearances and instructions so that any flight will, from departure clearance to touch-down be conducted in accordance with airline policy and without the changes to route and profile due to short term planning which are so disruptive to air traffic. An approach is recommended for the on-line handling of air traffic over such an area, covering in particular the integration of control phases from departure to destination. This leads to a central on-line optimal definition of departure/arrival sequences and essential characteristics of all flights, and a series of regional units to implement the relevant proposals/directives. This should provide the optimum integration of adjacent Zones of Convergence in which the time and altitude at which aircraft enter and leave each Zone are precisely controlled and are affected by the traffic conditions in their corresponding space/time sphere of influence. As a prerequisite to the above, a system is proposed for the purpose of accurately predicting and controlling the 4-D trajectory of an aircraft over any part of a flight, and in particular that part which extends from entry into until exit from the airspace of a given control center.   Author

N91-10983#   European Organization for the Safety of Air Navigation, Brussells (Belgium).   Engineering Directorate.
THE EUROCONTROL FUTURE ATS SYSTEM CONCEPT AND THE PROGRAMME OF STUDIES, TESTS, AND TRIALS
V. VACHIERY   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 11 p (SEE N91-10981 02-05)   May 1990
(AGARD-AG-301-VOL-2-PT-4-8)   Copyright   Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The era of parallel, uncoordinated development of ground systems and guidance, navigation and communications avionics is at an end. The pursuit of optimum economic operating conditions, coupled with the need to handle an increasing volume of traffic, demand that those responsible for Air Traffic Management apply solutions that easily combine available ground and air technologies. Cooperation between pilot and controller actions constitutes one of the keystones of the future systems. It is possible to increase the capacity and efficiency of air traffic management, while at the same time maintaining essential safety requirements, only by making more use of automation for control planning functions. It is considered that increased automation cannot provide real advantages, however, unless the accuracy of aircraft trajectory prediction is greatly improved. This was made clear in the description of the Future ATS Concept drawn up by EUROCONTROL. The Concept is presented in broad outline. Its implementation will call for a number of studies and trials, and a rundown is given of EUROCONTROL's program. The program places great emphasis on analysis of the conditions that need to be met to enable ground systems in future to have available facilities for the acquisition and exploitation of aircraft state vector parameters. The key aspects of the program are: (1) Improvement of the surveillance system; (2) Improvement of Air/Ground communications (Automatic data link); (3) Increased automation; and (4) Improvement of evaluation methods by using a realistic representation of the airborne side.   Author

N91-10988#   Consiglio Nazionale delle Ricerche, Rome (Italy). Progetto Finalizzato Trasporti and Ist. di Analisi dei Sistemi ed Informatica.
OPTIMIZATION MODELS AND TECHNIQUES TO IMPROVE AIR TRAFFIC MANAGEMENT
LUCIO BIANCO   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 22 p (SEE N91-10981 02-05)   May 1990
(AGARD-AG-301-VOL-2-PT-4-8)   Copyright   Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A survey of earlier works is given with particular emphasis on optimization models and solution techniques. First, a multilevel model of the different ATC functions is proposed. Then, attention is devoted to the on-line control functions (flow control, on-line strategic control of flights and aircraft sequencing in the terminal area); for each problem, an optimization model is established and a solution technique is illustrated. The numerical behavior is also discussed.   Author

N91-10989# European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
THE HIGH-RESOLUTION GRAPHIC DISPLAY: A POSSIBLE MAN/MACHINE INTERFACE FOR A COMPUTER ASSISTED ATC MANAGEMENT SYSTEM
CARLOS GARCIA AVELLO   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 6 p (SEE N91-10981 02-05) May 1990
(AGARD-AG-301-VOL-2-PT-4-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

An application is described of high resolution graphic display in the field of management and control of air traffic in an extended area including a major terminal, the radius of the area being liable to vary from 150 to 300 nm. Reference is made to air traffic management and 4-D guidance techniques for individual aircraft in a Zone of Convergence (ZOC) in the knowledge that the graphic display techniques are applicable virtually to all systems affording the controller assistance at the decision making level. For the purpose of presenting data to the controller, a graphic rectangular display is employed having a resolution of 1280 x 1024 points, capable of displaying 16 colors. A circular display similar to most existing radar scopes could of course be used if it had equivalent resolution and color characteristics. The management directives and orders for guidance are presented to the operator, area manager or controller of an individual sector as part of the set of data displayed on the radar surveillance and control scope without the use of additional special tabular displays.   Author

N91-10990# European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
THE 4-D CONTROL OF CURRENT AIR CARRIERS IN THE PRESENT ENVIRONMENT: OBJECTIVES, STATUS, AND PLANS
ANDRE BENOIT   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 7 p (SEE N91-10981 02-05) May 1990
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The accurate control of the time of arrival of aircraft will play an essential role in the efficient conduct of air traffic in terms of both economy and capacity. A technique was developed to select efficiently and control accurately each aircraft trajectory inbound to medium to high density traffic airports. The selection is made in terms of the overall traffic on the basis of the airline or pilot-preferred criterion, either cost, consumption or time, and the subsequent control is made in a ground/air co-operative manner, using whenever applicable speed and/or track corrections. The 4-D control is studied along with individual trajectories as applicable to current air carriers in the present environment directly adaptable to future automated air/ground digital communications. The overall control loop was simulated in an environment representing in particular the Belgian airspace configuration, using various flight simulators in conjunction with airline pilots and air traffic controllers. The results obtained to date make it possible to envisage on-line tests in the near future, aiming at a 10-second accuracy at the runway threshold for current commercial aircraft.   Author

N91-10991# Centre d'Etudes et de Recherches, Toulouse (France).
FOUR DIMENSIONAL NAVIGATION IN AIR TRAFFIC WITH 4-D NAVIGATION AIRCRAFT [NAVIGATION 4-D EN CIRCULATION AERIENNE AIRCRAFT 4-D NAVIGATION]
NICOLE IMBERT and MARC J. PELEGRIN   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 16 p (SEE N91-10981 02-05) May 1990 In FRENCH; ENGLISH summary
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Bearing in mind that the waiting times before landing are always increasing while the maximum landing rates are not reached, the monitoring of one more parameter during the approach is suggested. This is, in fact, two speed corrections and one heading correction (Nav. 4D, 3 space dimension + time). The first problem to be solved is the choice of the mathematical model to be used to simulate a plane. A model as complete as possible (in fact of the 18th order) was the starting point and it was degraded until a criterion was no longer satisfied. This criterion was a measurement of the error between the complete model and the degraded model along a reference trajectory (Roissy approach) of 54 km extension. It was assumed that the error due to the use of a simpler model should not reach + or - 320 m at the ILS entry beacon. A 6th order model was declared acceptable. After a number of simulations it was shown that corrections must arise after the entrance in the zone of convergence (ZOC) during the flight at constant level (speed correction) in the middle of the descent flown at constant indicated speed, (speed correction) and during the last leg before the ILS capture (heading correction). By a management method using a mathematical model on a fast time basis, an optimal time of arrival at the ILS entrance beacon can be determined, corresponding to an easy to fly trajectory. A model of the atmosphere must be used and it was checked that the robustness of the method (3 corrections) with regard to this model is correct. It was also checked that the time when the final beacon is reached is not sensitive to the mass of the plane at the entrance point.   Author

N91-10992# European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
THE CONTROL OF INBOUND FLIGHTS
ANDRE BENOIT and SIP SWIERSTRA   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 10 p (SEE N91-10981 02-05) May 1990
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The basic principles are described of the method to guide aircraft accurately down to the runway in a time-of-arrival constrained environment. The method is designed to be used in a Zone of Convergence context or in any similar advanced Air Traffic Control (ATC) system characterized by the integration of control phases over an extended area on the one hand and true computer assistance to the air traffic controller on the other, i.e., assistance provided at the decision making level through the automatic generation of guidance advisories. The method includes two closely coupled basic components, namely, a predictor, which computes a trajectory once initial conditions and plans are known, and a profile manager, which adapts the plans to meet the time constraint and generates the guidance directives on the basis of present position, actual surveillance information, aircraft operation and route constraints.   Author

N91-10993*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GUIDANCE CONCEPTS FOR TIME-BASED FLIGHT OPERATIONS
DAN D. VICROY *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 12 p (SEE N91-10981 02-05) May 1990
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Airport congestion and the associated delays are severe in today's airspace system and are expected to increase. NASA and the FAA is investigating various methods of alleviating this problem through new technology and operational procedures. One concept for improving airspace productivity is time-based control of aircraft. Research to date has focused primarily on the development of time-based flight management systems and Air Traffic Control operational procedures. Flight operations may, however, require special onboard guidance in order to satisfy the Air Traffic Control imposed time constraints. The results are presented of a simulation study aimed at evaluating several time-based guidance concepts in terms of tracking performance, pilot workload, and subjective preference. The guidance concepts tested varied in complexity from simple digital time-error feedback to an advanced time-referenced-energy guidance scheme. Author

N91-10994*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE 4-D DESCENT TRAJECTORY GENERATION TECHNIQUES UNDER REALISTIC OPERATING CONDITIONS
DAVID H. WILLIAMS and CHARLES E. KNOX *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 22 p (SEE N91-10981 02-05) May 1990
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NASA-Langley has been conducting and sponsoring research in airborne energy management for a number of years. During the course of this research, two fundamental techniques for the generation of 4D (fixed time) descent trajectories have emerged as viable candidates for advanced flight management systems. The first technique utilizes speed schedules of constant Mach number transitioning to constant calibrated airspeed chosen empirically to produce minimum fuel usage. The second technique computes cost optimized speed schedules of variable airspeed developed through application of optimal control theory. Both techniques have been found to produce reasonable and flyable descent trajectories. The formulation of the algorithms for each technique is evaluated and their suitability for operations in realistic conditions is discussed. Operational factors considered include: airplane speed, thrust, and altitude rate constaints; wind, temperature, and pressure variations; Air Traffic Control altitude, speed, and time constaints; and pilot interface and guidance considerations. Time flexibility, fuel usage, and airborne computational requirements were the primary performance measures. Author

N91-10995# Massachusetts Inst. of Tech., Cambridge. Flight Transportation Lab.
EXPERT SYSTEMS FOR THE GENERATION OF THERMAL AREA ARRIVAL PATHS FOR CIVIL TRANSPORT
ROBERT W. SIMPSON *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 14 p (SEE N91-10981 02-05) May 1990
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Efficiencies can be gained from dynamic scheduling of the takeoff and landing operations for the system of runways at a major civil airport. It is then necessary to be able to generate a conflict-free set of flight paths which implements this schedule, and which can be easily changed. For landing arrival aircraft, these flight paths start at a known time, point and speed in the descent towards the airport, and end at a reduced speed and time at the outer marker of the final approach to the assigned runway where desired in-trail separations must be achieved. To generate sets of conflict-free arrival paths, an expert systems computer program finds and selects a path feasible within the performance limits of each aircraft from a set of patterns which are easily understandable by the human controller. This technique is easily adaptable to the geometric characteristics of different terminal areas and runway configurations, and easily accepts rules and procedural limitations which can be specified and implemented by ATC controllers themselves, as desired. Author

N91-10996*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A DESCRIPTION AND EVALUATION OF TIMER: A TIME-BASED TERMINAL FLOW-CONTROL CONCEPT
LEONARD CREDEUR and WILLIAM R. CAPRON (PRC Kentron, Inc., Hampton, VA.) *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 42 p (SEE N91-10981 02-05) May 1990
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A description of a time-based ATC concept called TIMER (Traffic Intelligence for the Management of Efficient Runway-scheduling) and the results of a fast time and real time computer evaluation are presented. The concept was designed to improve the efficiency of extended terminal area operations (en route approach, transition, and terminal flight to the runway). TIMER integrates en route metering, fuel efficient cruise and profile descents, terminal sequencing and spacing together with computer-generated controller aids, in order to fully use runway capacity and improve efficiency of delay absorption. The concept, by using simplified aircraft models, accommodates both 4-D and non 4-D equipped aircraft and is designed for integration into the manual, voice linked ATC system in an evolutionary manner and still be able to accommodate proposed system upgrade features such as data link and further ground automation. Fast time and real time computer simulation results identify and show the effects and interactions of such key variables as horizon of control, metering fix and final approach delivery time errors, aircraft separation requirements, delay discounting, wind, flight technical error, and knowledge of aircraft final approach speed. The current ATC system has a runway interarrival-error standard deviation of approx. 26 seconds. Simulation results indicate that, with computer aiding, the runway interarrival-error standard deviation for non 4-D equipped traffic can be reduced to the region of 8 to 12 seconds if expected final approach speed is known; however, the reduction is only in the region of 16 to 20 seconds if expected final approach speed is unknown. Another major finding is that en route metering fix delivery-error standard deviation should be kept to less than a number somewhere between 35 to 45 seconds to achieve full runway capacity. This requirement implies the need for either

airborne automation or assistance to the controller since the current manual performance in today's en route metering environment is in the order of 1.5 minutes. Author

N91-10997# Boeing Commercial Airplane Co., Seattle, WA.
USE OF 4-D RNAV IN TIME-BASED EN ROUTE ARRIVAL METERING
R. L. ERWIN and K. H. IZUMI *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 19 p (SEE N91-10981 02-05) May 1990
(AGARD-AG-301-VOL-2-PT-4-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Arrival metering in en route airspace can match the demand rate to the airport acceptance rate. Air traffic control (ATC) is evolving time-based control techniques to facilitate en route arrival metering. This allows fuel savings by using speed reduction to absorb delay. The logic for en route arrival metering: (1) estimates the undelayed landing time of each arrival; (2) assigns the earliest available landing time; and (3) controls each arrival to its terminal area arrival (feeder) fix according to the common schedule developed for all arrivals. The airplane flight management system (FMS), used along with the ATC computer as part of a distributed data processing system, can define a minimum fuel cruise and descent flight profile which is consistent with ATC constraints. A study of four-dimensional area navigation (4D RNAV) operational requirements for use in en route arrival metering has determined the functions and time-guidance accuracies needed for ATC compatible operations. A 4D RNAV capability is most easily achieved by wrapping a time navigation capability around a 3D FMS. Concepts for controlling a mix of 4D RNAV equipped and unequipped aircraft in a time-based en route arrival metering system have been the subject of on-going analyses and simulations by NASA-Ames. The use of 4D RNAV in en route arrival metering operations can save the operator fuel, reduce both pilot and controller workload, and reduce terminal airspace congestion.
Author

N91-10998# European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
AIR TRAFFIC MANAGEMENT AND AIRCRAFT GUIDANCE IN A ZONE OF CONVERGENCE
ANDRE BENOIT and SIP SWIERSTRA *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 4 p (SEE N91-10981 02-05) May 1990
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The basic principles of air traffic management and guidance of individual aircraft in a Zone of Convergence (ZOC) have been presented in previous papers at successive stages in the development of the project. These principles are summarized as is their applicability to the actual operational environment, compatibility with present technology and direct adaptability to future developments, the quality of the interfaces involving the air traffic controller and the aircraft crew and the resultant benefits to the community in terms of economy, use of available capacity and safety. Author

N91-10999# European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
GROUND-BASED 4-D GUIDANCE OF FLIGHTS IN STRONG WIND
ANDRE BENOIT and SIP SWIERSTRA *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 13 p (SEE N91-10981 02-05) May 1990
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In strong wind, groundspeed may vary appreciably during a turn, just as for example in the case of a landing after a U-turn preceding the localizer intercept. Such conditions are critical for maximum use of the runway, and render human estimation of aircraft motion extremely difficult. The tests are summarized which were conducted using a ground-based 4D guidance program, developed to assist the air traffic controller in maintaining the predicted landing time sequence with an accuracy better than 10 seconds for each arrival. Author

N91-11000*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A PILOTED SIMULATOR EVALUATION OF A GROUND-BASED 4-D DESCENT ADVISOR ALGORITHM
THOMAS J. DAVIS, STEVEN M. GREEN, and HEINZ ERZBERGER *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 10 p (SEE N91-10981 02-05) May 1990 Previously announced in IAA as A87-50525
(AGARD-AG-301-VOL-2-PT-4-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 17/7

A ground-based, four dimensional (4D) descent-advisor algorithm is under development at NASA-Ames. The algorithm combines detailed aerodynamic, propulsive, and atmospheric models with an efficient numerical integration scheme to generate 4D descent advisories. The ability is investigated of the 4D descent advisor algorithm to provide adequate control of arrival time for aircraft not equipped with on-board 4D guidance systems. A piloted simulation was conducted to determine the precision with which the descent advisor could predict the 4D trajectories of typical straight-in descents flown by airline pilots under different wind conditions. The effects of errors in the estimation of wind and initial aircraft weight were also studied. A description of the descent advisor as well as the result of the simulation studies are presented. Author

N91-11001# European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
THE AIR TRAFFIC CONTROLLER FACING AUTOMATION: CONFLICT OR COOPERATION
ANDRE BENOIT, SIP SWIERSTRA, and RENE DEWISPELAERE (Eurocontrol Agency, Brussels, Belgium) *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 7 p (SEE N91-10981 02-05) May 1990 Presented at the International Conference NAV 1987, London, England, 29 Sep. - 1 Oct. 1987
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Today, developments in ground-based and on-board computers, navigation and digital air/ground/air communications make it possible to envision, for tomorrow, extensive automation of the overall air traffic control process, always provided that reliability, safety and responsibilities can be absolutely covered in all possible eventualities, however remote. Accordingly, before tomorrow, an appreciable amount of traffic will cross our skies

and be handled by air traffic controllers without the support of advanced automated tools. Nevertheless, at the same time, the potential of automation will continue to increase. This subject is discussed in the light of the experience gained during the development of an approach to the definition, assessment and testing in an operational environment of a procedure suitable for guiding aircraft along 4-D trajectories illustrative of the next system generation of ATC. The essential aspects are examined of the computer/controller/pilot/aircraft chain of dialogues, placing the emphasis on the interface between the computer and the controller, the intelligent interpretation of the surveillance information by the computer, the definition, generation, and relay of guidance directives to the pilot and finally, the use of navigation aids. The integration of the ground-based 4-D guidance and control system messages on a standard ATC radar display is shown, illustrating this for the guidance of flights conducted by SABENA crews operating B-737 and DC-10 aircraft.   Author

N91-11002#   European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
AIRCRAFT TRAJECTORY RECONSTITUTION ON THE BASIS OF MULTI-RADAR PLOT INFORMATION
P. VANDERKRAAN In AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 2 p (SEE N91-10981 02-05) May 1990
(AGARD-AG-301-VOL-2-PT-4-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A short description of the various techniques in use for the establishment of aircraft reference trajectories is presented. Then a description of the principles and operation of the EUROCONTROL program MURATREC (Multi-Radar Trajectory Reconstitution) follows, covering in particular: (1) estimation of systematic radar errors; (2) curve fitting by the use of B-splines and dynamically adaptable spline steps; (3) accuracy of the reconstructed positional information; and (4) reconstitution of altitude, accelerations and speed. Applications of the MURATREC program are outlined, including application for the analysis of radar plot and track accuracy (examples) and possible applications for incident investigations, on-line alignment of multi-radar information and simulation of aircraft trajectories in a given radar environment.
                Author

N91-11003#   National Aerospace Lab., Amsterdam (Netherlands).
BAYESIAN MULTI-SENSOR TRACKING FOR ADVANCED AIR TRAFFIC CONTROL SYSTEMS
H. A. P. BLOM, R. A. HOGENDOORN, and F. J. VANSCHAIK In AGARD, Aircraft Trajectories. Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 8 p (SEE N91-10981 02-05) May 1990
Sponsored by Dutch Civil Aviation Board
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An overview is given of a Bayesian tracking system for a multi-sensor environment. The main modules perform track initiation, track continuation and systematic error estimation, respectively. The track continuation module plays for Air Traffic Control the most important role. It consists of a combination of those approximate Bayesian methods that proved to be the most efficient for the main problems of track continuation: Extended-Kalman filtering for nonlinear dynamics, Probabilistic Data Association for unassociated measurements and Interacting-Multiple-Model filtering or sudden maneuvers. Comparisons of this new tracking system with alpha-beta Kalman based and state-of-the-art tracking systems show its superiority for application to Air Traffic Control surveillance. It provides better track continuity, more accurate expectations of position and velocity and more complete additional information in the form of probabilities of modes of flight (turning, accelerating and straight modes) and

consistent estimates of its own accuracy. With this track information, advanced Air Traffic Control systems may better cope with the many uncertainties that are inherent to air traffic.
                Author

N91-11004#   Technical Univ. of Crete, Athens (Greece).
THE USE OF DOWNLINKED MEASUREMENTS TO TRACK CIVIL AIRCRAFT
C. C. LEFAS   In AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 21 p (SEE N91-10981 02-05) May 1990
(AGARD-AG-301-VOL-2-PT-4-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The use is described of measurements made on board civil aircraft to improve tracking accuracy in air traffic control (ATC) systems. The measurements are transmitted to the ground station via the Secondary Surveillance Radar (SSR) mode S data link. First the widely used alpha-beta filter and the first order Kalman filter are reviewed. Next the problem of maneuver handling is described and it is established that significant improvements, in terms of tracking accuracy, are expected when tracking maneuvering aircraft. The shape of maneuvers is examined using recordings made on board civil aircraft during normal scheduled services. The on-board measurements considered are roll angle, heading, and true air speed (TAS). Roll angle and the rate of change of heading are theoretically equivalent, since they are related though aircraft velocity. Maneuver tracking filters using either roll angle or heading are described and compared. It is shown that the filter using heading provides a better performance in the event of missing replies, since changes of heading are eventually detected. Both filters cannot track longitudinally accelerating targets. Next the use of velocity measurements, derived from TAS and heading, is considered. A filter is described that is capable of estimating the wind speed in the vicinity of the aircraft. The same filter provides satisfactory tracking accuracy during maneuvers and can handle longitudinal accelerations. Under monoradar coverage, where the data rate and accuracy are fairly constant, the filters reduce to a particularly simple form, that may be regarded as an enhanced alpha-beta filter. The performance of the filters is evaluated using data recorded during normal scheduled services.   Author

N91-11005#   Service Technique de la Navigation Aerienne, Paris (France). Dept. Radiocommunication et Radioguidage.
CONTRIBUTION OF THE SATELLITE TECHNIQUES TO THE SURVEILLANCE OF AIR TRAFFIC [L'APPORT DES TECHNIQUES SATELLITAIRES A LA SURVEILLANCE DE LA NAVIGATION AERIENNE]
OLIVIER CAREL   In AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 13 p (SEE N91-10981 02-05) May 1990 In FRENCH; ENGLISH summary
(AGARD-AG-301-VOL-2-PT-4-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The International Civil Aviation Organization asked a special committee FANS (Future Air Navigation Systems) to study satellite system implementation for communication navigation and surveillance applications. This committee recently issued its final report. FANS work is presented and the consequences are analyzed of satellite system implementation in case of the surveillance of air traffic. The most important element will be Automatic Dependent Surveillance (ADS) which implies the automatic air to ground return transmission of various airborne measured parameters, i.e., mainly aircraft position as supplied by the aircraft navigation equipments. This concept allows a much more efficient air traffic control in every area lacking a ground infrastructure. In continents areas with heavy air traffic, satellites will not substitute the secondary surveillance radar. The new

techniques however will allow a flexible design of the ground infrastructure. Author

N91-11007# European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
INTEGRATION OF AIRCRAFT CAPABILITY IN AIR TRAFFIC HANDLING SIMULATIONS
ANDRE BENOIT, SIP SWIERSTRA, and YVES DELNATTE (Belgian World Airlines, Brussels.) *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 7 p (SEE N91-10981 02-05) May 1990
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The incorporation of airline/aircrew/aircraft specific procedures and performances into simulations and air traffic handling operations is a prerequisite for the next g eneration of management and control techniques. This matter is analyzed in the light of the shortcomings inherent in the present situation, in order to meet operators' demands in terms of capacity and efficiency. A practical approach is then proposed which includes the operators (aircrew/aircraft/avionics) in the overall ground/air/ground control loop at development, assessment, validation, and real time simulation levels. As an illustration of the potential offered, this approach is used to assess a ground/air coordinated 4-D guidance technique, and the results are summarized. Author

N91-11008# Technische Univ., Brunswick (Germany, F.R.). Inst. of Aeronautics and Astronautics.
SIMULATION OF AUTOMATED APPROACH PROCEDURES CONSIDERING DYNAMIC FLIGHT OPERATIONS
MANFRED FRICKE and ANDREAS HOERMANN *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 16 p (SEE N91-10981 02-05) May 1990
(AGARD-AG-301-VOL-2-PT-4-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

During peak hours almost all major commercial airports operate close to their capacity limits. Moreover, the traffic demand often exceeds the offered capacities leading to more or less stringent restrictions in slot allocation. The purpose of the fast-time air traffic simulations, was to analyze and assess the performance and the practicability of automated time-based approach concepts, currently developed to optimize the terminal area air traffic process with respect to safety, capacity and economy. The developed program system TASIMD (Terminal Area SIMulation considering the aircraft Dynamics) simulates flight operations of arriving aircraft within a terminal area during a specific time interval. TASIMD models all major elements of a TMA scenario related to the control and operations of automated approach procedures on the ground and in the air (e.g., surveillance, control procedures, aircraft dynamics, flight guidance). The aircraft fly along 4D-trajectories, described by a horizontal profile, an altitude profile and a speed profile to integrate the time element, considering influences on the ; at following accuracy in space and time. Sources of error impact are: entry fix time deviation, navigation, wind, airspeed error and profile management algorithm error. Errors are modeled in Monte-Carlo technique. Two types of automated approach procedures were developed and analyzed: a variable path speed control concept (VPSC) and a fixed path speed control concept (FPSC). Both concepts presume a shared air/ground responsibility for profile control. Author

N91-12701*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLIGHT TEST RESULTS OF FAILURE DETECTION AND ISOLATION ALGORITHMS FOR A REDUNDANT STRAPDOWN INERTIAL MEASUREMENT UNIT
F. R. MORRELL, P. R. MOTYKA, and M. L. BAILEY (PRC Kentron, Inc., Hampton, VA.) *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 13 p (SEE N91-12682 04-08) Apr. 1990
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Flight test results for two sensor fault-tolerant algorithms developed for a redundant strapdown inertial measurement unit are presented. The inertial measurement unit (IMU) consists of four two-degrees-of-freedom gyros and accelerometers mounted on the faces of a semi-octahedron. Fault tolerance is provided by edge vector test and generalized likelihood test algorithms, each of which can provide dual fail-operational capability for the IMU. To detect the wide range of failure magnitudes in inertial sensors, which provide flight crucial information for flight control and navigation, failure detection and isolation are developed in terms of a multi level structure. Threshold compensation techniques, developed to enhance the sensitivity of the failure detection process to navigation level failures, are presented. Four flight tests were conducted in a commercial transport-type environment to compare and determine the performance of the failure detection and isolation methods. Dual flight processors enabled concurrent tests for the algorithms. Failure signals such as hard-over, null, or bias shift, were added to the sensor outputs as simple or multiple failures during the flights. Both algorithms provided timely detection and isolation of flight control level failures. The generalized likelihood test algorithm provided more timely detection of low-level sensor failures, but it produced one false isolation. Both algorithms demonstrated the capability to provide dual fail-operational performance for the skewed array of inertial sensors. Author

N91-12704# Crouzet Aerospace and Systems, Valence (France).
A HIGH INTEGRITY FLIGHT DATA SYSTEM
J. L. ROCH and J. CONTET *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 10 p (SEE N91-12682 04-08) Apr. 1990 In FRENCH
(AGARD-CP-456) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Solutions are described for the design of a modern flight data system to be used for piloting and navigation of helicopters. The critical flight system is used in the aircraft safety cable and responds to a certain number of specific limits. First, the problems which cause the limits are examined; next, the methods and technologies are described for reaching satisfaction. Transl. by E.R.

N91-23150# Honeywell, Inc., Minneapolis, MN. Systems and Research Center.
NAVIGATION, GUIDANCE, AND TRAJECTORY OPTIMIZATION FOR HYPERSONIC VEHICLES
R. L. SCHULTZ, M. J. HOFFMAN, A. M. CASE, and S. I. SHEIKH *In* AGARD, Hypersonic Combined Cycle Propulsion 22 p (SEE N91-23147 15-07) Dec. 1990 Sponsored in part by AF
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A computationally efficient, real time trajectory optimization and guidance approach for hypersonic aircraft is described. The optimization algorithms compute, in-flight, minimum fuel trajectories within constraints from the current aircraft position to its final destination. In-flight trajectory computation can provide a high degree of vehicle autonomy which could greatly reduce aircraft ground support costs. The optimization approach is based on Euler-Lagrange theory and energy state approximations. A 3-D, spherical earth, aircraft motion model, with constraints on temperature, dynamic pressure and stall, is used. An exact optimal iterative solution and an approx. closed form feedback solution method are developed. In the exact approach, solutions are computed by iteration on adjoint constants. Each iteration requires a complete forward trajectory integration. In the approx. closed form feedback approach, the adjoint constants are expressed in

terms of the states. No forward trajectory calculations are required, thus, the computations are minimal. Minimum fuel climb to orbit, powered abort, and unpowered abort trajectories are computed with both methods. The approx. closed form feedback solution closely matches the optimal iterative solution. A computationally efficient method for generating unpowered descent footprints is also described. Footprints are used to identify candidate landing sites under an engine failure or other emergency conditions, and to initiate final descent. A hypersonic vehicle guidance, navigation, and control configuration using the optimal closed form feedback guidance and the footprint generator is described.   Author

N91-25121#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
KNOWLEDGE BASED SYSTEM APPLICATIONS FOR GUIDANCE AND CONTROL
Apr. 1991   259 p   In ENGLISH and FRENCH   The 51st symposium was held in Madrid, Spain, 18-21 Sep. 1990
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   The overall state-of-the-art of AI applications in the guidance and control area were assessed. The papers were presented covering the following headings: representative applications, design concepts and synthesis techniques, related methods and techniques, information processing and system architecture, and mechanization and integration issues. For individual titles, see N91-25122 through N91-25140.

N91-25123#   Societe d'Applications Generales d'Electricite et de Mecanique, Cergy-Pontoise (France).   Div. Recherche en Automatique.
SCIE: A KNOWLEDGE BASED SYSTEM FOR ON-BOARD ASSISTANCE WITH THE INTERPRETATION OF INFRA-RED IMAGES
D. MORILLON, T. CONTER, M. DECREMIERS, L. LEFORT, and F. GERMAIN (ITMI, Meylan, France)   In AGARD, Knowledge Based System Applications for Guidance and Control 17 p (SEE N91-25121 17-04)   Apr. 1991
(AGARD-CP-474)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   Infrared sensors are becoming more and more essential on all military vehicles: aircraft, RPVs, boats, tanks, and land robots, because of the extra information they provide, day and night, in all weather conditions and with absolute discretion. A system designed to help in the interpretation of infrared images is presented. Navigation, infrared sensing, and image processing knowledge are used to make interpretation easier, allowing optimal use of onboard data: digital maps, inertial navigation systems, and weather information. This work was validated on a lab prototype.   Author

N91-25124#   Aeritalia S.p.A., Turin (Italy). Artificial Intelligence Lab.
PATH GENERATION AND EVALUATION FOR A MISSION PLANNING EXPERT SYSTEM
FEDERICA LUISE and DANILO DABBENE   In AGARD, Knowledge Based System Applications for Guidance and Control 14 p (SEE N91-25121 17-04)   Apr. 1991
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   Aeritalia's (Defense Aircraft Group) experience with the problem of path generation and evaluation for a multitarget air to ground planning system working in a limited geographic scenario are described. Since in the same planning operation many goals (each goal is a mission target) must be satisfied, techniques of splitting problems into simpler ones were used as it is not possible to use satisfactory heuristic guided search (like A*). Although these algorithms give an optimal solution for each goal, this doesn't ensure that the union of the solutions that are optimal will be the best for the whole set of goals. The mission is decomposed into submissions, and each one of them is solved finding all the solutions satisfying the forced constraints (e.g., maximum leg length, maximum turn number). All the solutions so generated become a new search space to be used to find out the final best

solution. Every submission is represented by a task (a process) that generates all the partial solutions (partial paths) that will be combined in an upper stage by a higher level task (mission task) in order to generate the whole set of global solutions. Currently all the tasks are independent and are managed by a task-scheduler which simulates the behavior of a multiprocessor architecture carrying out the task synchronization by an event generation and waiting mechanism. A few simple primitives allow tasks to generate events and wait for them. Every submission task built each path as a collection of atomic paths (point-to-point) which may be shared by different solutions of the task. The mission tasks will combine the subtask results, generating a graph whose roots are all possible paths and whose leaves are the atomic paths. The evaluator is a graph which has path feature evaluation nodes and Bayesian combination nodes whose function is to combine evaluations in one single value. The developed prototype was tested by the pilots and the results are described. The system was developed on a Lisp machine Explorer 2 using Lisp and Flavors and later ported on a Symbolics 3630.   Author

N91-25125#   Universitaet der Bundeswehr Muenchen, Neubiberg (Germany, F.R.). Inst. fuer Systemdynamik und Flugmechanik.
KNOWLEDGE-BASED COCKPIT ASSISTANT FOR IFR OPERATIONS
R. ONKEN   In AGARD, Knowledge Based System Applications for Guidance and Control 9 p (SEE N91-25121 17-04)   Apr. 1991
(AGARD-CP-474)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   A knowledge-based cockpit assistant for IFR (Instrument Flight Rules) operation is presented, aimed at improvement of situation assessment and performance increase by computer aids for flight planning and plan execution. Here, situation assessment also includes monitoring of the pilot's own activities. The modular system structure is described as well as the individual system modules. The cockpit assistant was tested in a flight simulator by professional pilots under realistic IFR-scenarios. The concept of the test design as well as test results are presented. The system design goals are mainly confirmed by these results.   Author

N91-25126#   Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugfuhrung.
CONSTRAINT MANAGEMENT REQUIREMENTS FOR ON-LINE AIRCRAFT ROUTE PLANNING
UWE TEEGEN   In AGARD, Knowledge Based System Applications for Guidance and Control 9 p (SEE N91-25121 17-04)   Apr. 1991
(AGARD-CP-474)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   In the future, the cooperation of pilot and controller will change. Technical advances contributing to this change are a more intelligent airborne Flight Management System (FMS) and a datalink connecting the FMS and Air Traffic Control (ATC). Against this background, concepts for an Experimental Flight Management System and its human-centered system design approach are described. Combined with a basic scenario of future Air Traffic Management (ATM) the requirements for an airborne constraint management subsystem are developed. The fundamentals of aircraft route planning and system operation including considerations on the interaction between constraint management and man-machine interface are discussed and an on-line algorithm for aircraft route planning is presented. The present state of a software prototype and the software and hardware employed are also described.   Author

N91-25127#   Draper (Charles Stark) Lab., Inc., Cambridge, MA.
PLANNING AND PLANNING MANAGEMENT FOR AUTONOMOUS AND SEMI-AUTONOMOUS VEHICLES
MILTON B. ADAMS and ROBERT M. BEATON   In AGARD, Knowledge Based System Applications for Guidance and Control 13 p (SEE N91-25121 17-04)   Apr. 1991
(AGARD-CP-474)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   Planning systems for autonomous and semi-autonomous vehicles can be reviewed as performing very high level guidance

and control functions. The structure of hierarchical planning systems parallels that of the management and decision-making structure of many organizations where long-term, less detailed skeletal plans are developed at the highest levels of the hierarchy, and near-term, fully detailed plans are developed and then implemented by the lower levels. Mission planning systems can be decomposed into planning algorithms and planning management functions. Together, they provide the onboard, intelligent decision-making required to plan and execute the nominal mission and modify mission activities in response to unforeseen events, with little or no reliance on human intervention. Planning Algorithms produce plans of actions that best achieve stated mission objectives within specified mission constraints for a given mission environment. Planning Management Functions control the execution of plans, monitor the progress of the plans currently being executed, decide if replanning is necessary and, if so, define the revised planning problem to be solved by the planning algorithms. An architecture for a mission planning system is presented with descriptions of the associated planning algorithms and planning management functions. Implementation considerations for architectures in that class are discussed, and an approach to stochastic modeling of the planning process implied by such architectures is proposed.   Author

N91-25128#   Boeing Military Airplane Development, Seattle, WA.
INTELLIGENT REAL-TIME KNOWLEDGE BASED INFLIGHT MISSION MANAGEMENT
GEORGE F. WILBER   *In* AGARD, Knowledge Based System Applications for Guidance and Control 9 p (SEE N91-25121 17-04)   Apr. 1991
(AGARD-CP-474)   Copyright   Avail: NTIS HC/MF A12;
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     The problems and issues of developing a tactical mission manager are described. Development aspects of intelligent real-time avionics are discussed and an efficient real-time AI methodology and implementation for the development of the intelligent systems are outlined. Advanced software development techniques are also outlined and an overview of related Boeing research efforts provided.   Author

N91-25135#   Fabrica Italiana Apparecchiature Radioelettriche S.p.A., Milan
EVALUATION OF THE OPTIMAL HOMING POINT FOR MISSILE GUIDANCE
B. MIDOLLINI, P. L. TORELLI, and G. BALZAROTTI   *In* AGARD, Knowledge Based System Applications for Guidance and Control 11 p (SEE N91-25121 17-04)   Apr. 1991
(AGARD-CP-474)   Copyright   Avail: NTIS HC/MF A12;
Non-NATO Nationals requests available only from
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     One of the main problems arising in the field of missile guidance is the automatic search and detection of targets, in order to gather the necessary information for the correct homing of the missile. This problem is commonly approached by mounting a seeker (infrared) with an image and data processor on board the missile. The ground scene will present isolated targets and target formations, together with a high level of clutter which produces a number of false alarms. Thus, it is necessary to provide the image and data processor of the missile with algorithms which can automatically eliminate the clutter and the false alarms and detect the true targets. In order for accuracy, only one formation among the various ones in the scene must be cued to the navigation and the weapons systems of the missile: the choice depending on the shape, the disposition, and the distance between targets of the formation. An algorithm developed to evaluate the optimal point for releasing the ammunition is presented. The algorithm is further illustrated by applying it to a practical case and showing the results of this simulation.   Author

N91-25137#   Societe d'Applications Generales d'Electricite et de Mecanique, Cergy-Pontoise (France).
SEAN: A NAVIGATION AID EXPERT SYSTEM FOR COMBAT AIRCRAFT
D. MORILLON, T. CONTER, and M. DECREMIEHS   *In* AGARD, Knowledge Based System Applications for Guidance and Control 13 p (SEE N91-25121 17-04)   Apr. 1991   In FRENCH; ENGLISH summary
(AGARD-CP-474)   Copyright   Avail: NTIS HC/MF A12;
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     Technology of fighter aircraft equipment is in constant evolution. Increases in precision of navigation equipment, in number of available means of navigation updating and in onboard computer performance, has increased aircraft capabilities to satisfy modern mission requirements but also has complicated the copilot's tasks. SEAN (Expert System for Navigation Aiding) aboard fighters was designed to assist copilots in their choices and supervise the inertial hybrid navigation system. Use of KOD (Knowledge Oriented Design), a powerful cognitive methodology, associated with robust knowledge validation principles, has allowed development of a prototype of the expert system working with a realistic complete simulation of its onboard environment.   Author

N91-25140#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
A STUDY OF AN INTEGRATED IMAGE AND INERTIAL SENSOR SYSTEM
R. KOCH, R. BADER, and W. HINDING   *In its* Knowledge Based System Applications for Guidance and Control 6 p (SEE N91-25121 17-04)   Apr. 1991
(AGARD-CP-474)   Copyright   Avail: NTIS HC/MF A12;
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     The target approach over large distances of a cruise missile type vehicle, which is equipped with an imaging infrared sensor aided inertial navigation system, is examined in simulation. The study is based on the idea of using the same image sensor for navigation update and target recognition with subsequent tracking. Knowledge based methods are found to play a key role in solving the difficult image interpretation task for real world scenery. The final extraction of navigation data from the processed and interpreted IR image information, and their combination with the inertial sensor data is based on conventional optimization and filtering techniques. The study shows that the combined information leads to an improvement of navigation data. Filtering techniques are found to be capable of quantitatively estimating major error sources inherent to the gyros and accelerometers.   Author

N92-12529#   Wright Lab., Wright-Patterson AFB, OH.
ADAPTIVE TACTICAL NAVIGATION PROGRAM
SANDRA L. BERNING and DOUGLAS P. GLASSON (Analytic Sciences Corp., Reading, MA.)   *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 15 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499)   Copyright   Avail: NTIS HC/MF A14;
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     The Adaptive Tactical Navigation (ATN) system is a lab prototype which incorporates knowledge based software designed to perform navigation system management and decision aiding for the next generation of combat aircraft. The purpose of the ATN system is to manage a future multisensor navigation suite, dynamically selecting the most appropriate navigation equipment to use in accordance with mission goals, mission phase, threat environment, equipment health, equipment availability, and battle damage. The ATN system encompasses functions as diverse as sensor data interpretation, diagnosis, and navigation resource planning.   Author

N92-12530#   Dayton Univ., OH.
LOCALLY LINEAR NEURAL NETWORKS FOR AEROSPACE NAVIGATION SYSTEMS
STEVEN C. GUSTAFSON and GORDON R. LITTLE   *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 8 p (SEE N92-12517 03-63)   Sep. 1991
(AGARD-CP-499)   Copyright   Avail: NTIS HC/MF A14;
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    Neural network software simulations for the representation and prediction of aircraft inertial navigation system (INS) data were developed. These simulations were evaluated using flight test data that sampled INS outputs at a standard rate for neural network testing and at half this rate for neural network training. The simulations used both locally linear neural networks and backpropagation trained neural networks. Locally linear neural networks have several desirable properties for this application, including interpolation of the training data and representation of linear relationships. For the flight test data, two milliradian testing accuracy was generally achieved with five successive and prior INS heading, pitch, and roll increments as inputs.   Author

N92-21957#   Naval Air Test Center, Patuxent River, MD.
ENHANCED DISPLAYS, FLIGHT CONTROLS, AND GUIDANCE SYSTEMS FOR APPROACH AND LANDING
R. W. HUFF and G. K. KESSLER   *In* AGARD, Aircraft Ship Operations 22 p (SEE N92-21951 12-05)   Nov. 1991
(AGARD-CP-509)   Copyright   Avail: NTIS HC/MF A15;
Non-NATO Nationals requests available only from
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    The Navy has had an ongoing objective to provide a safe and reliable approach and landing capability with minimum interference from severe weather and sea state, and no limitation due to low ceiling and visibility. An overview is presented of the present and future Navy displays, flight controls, and guidance systems for approach and landing. The results of simulation studies and flight tests concerning enhancement to aircraft displays and flight controls are discussed. The various tradeoffs and issues that must be considered are also discussed. Tradeoffs in landing system accuracy requirements versus integration of aircraft and shipboard data are explored.   Author

N92-21958#   Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
INTEGRATION OF FLIGHT AND CARRIER LANDING AID SYSTEMS FOR SHIPBOARD OPERATIONS
B. DANG VU, T. LEMOING, and P. COSTES   *In* AGARD, Aircraft Ship Operations 15 p (SEE N92-21951 12-05)   Nov. 1991
(AGARD-CP-509)   Copyright   Avail: NTIS HC/MF A15;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The operational availability of a carrier depends to a large extent on the capacity of its equipment and its aviation to operate in a wide domain of meteorological conditions and sea states. Some equipments are under development for the future French nuclear carrier in order to extend its operational limits for aircraft launch and recovery: a deck motion tranquillization system, a deck motion prediction system, and an all-weather aircraft localization system. The impact on deck landing procedures for future carrier-based fighter aircraft is presented. An improved terminal guidance landing strategy making use of the prediction of the carrier motion is proposed. The actual glide path with fixed slope is replaced by a flight path along which the aircraft airspeed and flight path angle are updated in accordance with the predicted deck motion at touchdown, such that all the landing constraints are respected: minimum hook-to-ramp clearance, maximum touchdown sink rate.... The integration of the landing aid systems with the aircraft flight control system will allow the implementation of an automatic landing mode or advanced manual task-tailored control modes. Preliminary simulation results give a general idea on the improvement of deck landing performances with respect to the accuracy of the prediction of the carrier motion.   Author

N92-21959#   Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France).
APPROACH AND LANDING ASSISTED BY ONBOARD IMAGE PROCESSING [APPROCHE ET APPONTAGE ASSISTES PAR TRAITEMENT D'IMAGE EMBARQUE SUR AERONEF]
Y. LEGUILLOUX   *In* AGARD, Aircraft Ship Operations 10 p (SEE N92-21951 12-05)   Nov. 1991   In FRENCH
(AGARD-CP-509)   Copyright   Avail: NTIS HC/MF A15;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    A study is made of automation of visual control by an aircraft pilot during landing. The system that is envisaged, comprising one camera (infrared) and the associated electronics for real time image processing, will provide continuous 3-D representation of the aircraft's position in relation to the ship. To do this, the principal characteristics of the aircraft carrier are first localized in the image, then paired with their equivalents in the 3-D model of an a priori known aircraft carrier. By inverse perspective transformation, the pilot is able to determine the position of the ship relative to the aircraft, and from this information he can derive the position and movement of the aircraft relative to the ship. Thus, the system is able to measure the distance from an ideal landing scenario and from there the appropriate compensating actions can be determined. Furthermore, the absolute movement of the aircraft, given by the inertial system, may be combined with the relative movement to give the absolute movement of the ship.   Author

N92-21960#   Royal Aerospace Establishment, Bedford (England).
APPROACH AND LANDING GUIDANCE
A. J. SMITH and E. J. GUIVER   *In* AGARD, Aircraft Ship Operations 15 p (SEE N92-21951 12-05)   Nov. 1991
(AGARD-CP-509)   Copyright   Avail: NTIS HC/MF A15;
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AGARD/Scientific Publications Executive
    The final approach and landing of any aircraft operating from a ship is always a difficult task, even in benign conditions. Ship motion, adverse winds, and atmospheric attenuation compound the problems. High levels of integrity and reliability are an essential feature of any guidance aid in the ship environment since diversion facilities are often not available. Issues related to cost, maintainability, levels of training, and covertness further constrain the choice of guidance aid. The handling characteristics of the user aircraft and operational procedures also influence the choice of aid. To achieve the objective of regular and safe operations in all weather conditions, some form of guidance must be provided. The options range from painted markings and lighting systems that are used by the pilot to augment naturally occurring visual cues to precision radio or radar systems that are integrated into cockpit displays and flight control systems. In military operations there is a perceived need for passive or covert forms of guidance. The development of electro-optical sensors in recent years has increased the number of options and the availability of the Global Positioning System (GPS) will provide even more potential solutions to the design problems of providing precision guidance. The topics of approach and landing guidance has encouraged a large amount of research and development over the years, with many special-to-type solutions being devised. Except for the helicopter landing case, where relatively little research and development effort has been expended, the system designer is confronted with a large number of potential solutions. The above topics are addressed and conclusions are presented.   Author

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AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

N89-10056# Societe Nationale Industrielle Aerospatiale, Paris (France). Tactical Missile Div.
SIMULATION WITH REAL ELEMENTS OF EXOCET ANTI-SHIP MISSILES [SIMULATION AVEC ELEMENTS REELS DES MISSILES ANTI-NAVIRES EXOCET]
CHRISTIANE RENON, GUY LEGALLO, and GERARD SELINCE *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 9 p (SEE N89-10048 01-08) Jul. 1988
In FRENCH
(AGARD-AG-273) Copyright Avail: NTIS HC A07/MF A01
Simulation results gained on the first 1500 production anti-ship missiles of the EXOCET family (MM 38, MM 40, AM 39, SM 39) are presented. After describing the simulation facilities of the tactical missile division of Aerospatiale and in particular Subdray facility located near Bourges in France, the role of simulation is shown from the beginning of the project, through development up to the production of the missiles. The advantage of such simulation during the production phase is emphasized. It is used to improve the quality of missiles, to gain knowledge useful for the development of new versions and as a quality insurance method during production. Author

N89-10057# Rockwell International Corp., Columbus, OH.
HELLFIRE SYSTEM MODEL VALIDATION
R. V. HUPP *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 13 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Copyright Avail: NTIS HC A07/MF A01
The hybrid simulation facilities, system modeling, and validation process for a U.S. Army missile development program are discussed. Two fundamental problems in missile system design and development require an accurate, valid, proven computer simulation; analysis of errors and performance verification. The classical approach to error analysis is by Monte Carlo simulation. System performance over the entire spectrum of operating conditions cannot be verified by field tests alone due to economic constraints; it must be verified by simulation. Verification of total system performance was a major analytical effort in the development program. A complete hybrid computing facility was procured and dedicated to this end. Two independent system simulations were developed; a hybrid simulation and an all digital simulation. The development program was very successful. The computer simulation equipment procured for this effort was found to be quite adequate for the task and cost effective. Author

N90-10062*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NEW TEST TECHNIQUES TO EVALUATE NEAR FIELD EFFECTS FOR SUPERSONIC STORE CARRIAGE AND SEPARATION
WALLACE C. SAWYER, ROBERT L. STALLINGS, JR., FLOYD J. WILCOX, JR., A. B. BLAIR, JR., WILLIAM J. MONTA, and ELIZABETH B. PLENTOVICH *In* AGARD, Stability and Control of Tactical Missile Systems 9 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
CSCL 01/3
Store separation and store carriage drag studies were conducted. A primary purpose is to develop new experimental methods to evaluate near field effects of store separation and levels of store carriage drag associated with a variety of carriage techniques for different store shapes and arrangements. Flow field measurements consisting of surface pressure distributions and vapor screen photographs are used to analyze the variations of the store separation characteristics with cavity geometry. Store carriage drag measurements representative of tangent, semi-submerged, and internal carriage installations are presented and discussed. Results are included from both fully metric models and models with only metric segments (metric pallets) and the

relative merits of the two are discussed. Carriage drag measurements for store installations on an aircraft parent body are compared both with prediction methods and with installations on a generic parent body. Author

N90-10069# Naval Weapons Center, China Lake, CA. Dynamics and Control Branch.
ANALYSIS AND TESTING OF A HIGH PERFORMANCE AIR-AIR MISSILE
GERALD L. STEVENS *In* AGARD, Stability and Control of Tactical Missile Systems 15 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
Hardware-in-the-loop (HWIL) testing of air-air missiles is performed at the Naval Weapons Center (NWC), China Lake. To illustrate the procedures, this presentation follows a highly maneuverable flight test vehicle from initial hardware testing, through the launch, to the subsequent postflight analysis. HWIL testing combines a real-time simulation with flight hardware. The purpose of the dynamic simulation is to validate stability and controllability of the missile system, debug flight hardware, help to characterize the missile subsystems and test interfaces used throughout the hardware. The simulation that results helps to characterize the air-air missile and its capabilities. Author

N90-10070# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
MARGINAL RELEASE DISTURBANCES ON ADVANCED MISSILES
RONALD DESLANDES *In* AGARD, Stability and Control of Tactical Missile Systems 12 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
Today's store separation analysis is more and more confronted to marginal clearance situations due to increasing requirements imposed by the aircraft operators. In fact, that an advanced missile has to be perfectly released during arbitrary aircraft maneuvers and variable installations affords the accurate knowledge of the missile's motion during tip-off. The engineering task is therefore no longer focussed exclusively on the analysis of safety aspects of separation, but is now to be extended on the consideration of compatibility between operator's requirements to allow any strength of release disturbances and the missile control system to overcome such situations. The results expected from such an analysis is an accurate indication of any marginal limitation respective to safety or to controllability. Based on simulations performed with a powerful 6-DOF code developed at MBB during the last decade, this paper deals with such inconsistancies implicated by excessive roll or pitch-motions during different rail-launch situations. After a short description of the basic algorithms, computed results involving data from flight test movie will be displayed by 3D-video, in order to prove that the problem area is well handled. Author

N90-10072# Selenia S.p.A., Rome (Italy). Missile System Div.
EXPERIENCE GAINED IN THE IMPROVEMENT OF THE ASPIDE AERODYNAMIC CONFIGURATION FOR THE SURFACE TO AIR ROLE
S. MAZZUCA *In* AGARD, Stability and Control of Tactical Missile Systems 10 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
From the beginning to the end, the development process of the new aerodynamic version of the Aspide in the surface to air roles is described. The aims, constraints and main activities of the project are reported. The entire decision process is also analyzed in great detail. The successful completion of the above process, with the new configuration in full production constitutes the solid background for further improvements or new designs. Author

N90-10073# Selenia S.p.A., Rome (Italy). Missile Systems Div.
WINGED VERSUS WINGLESS AIRFRAMES
A. GAZZINA and S. MAZZUCA *In* AGARD, Stability and Control of Tactical Missile Systems 20 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
An analytical method developed with the purpose to compare the kinematic and dynamic performance of a winged configuration with respect to a wingless configuration of a tactical anti-air missile is described. A reference mission of the missile is firstly defined and the analytical method is built-up through the introduction of

suitable assumptions and simplifications. The method is then applied to an actual missile for which wind tunnel results are available in its winged and wingless configuration. The peculiar aspects of both configurations are identified and highlighted. Even if the method was developed for a specific aim it revealed suitable and accurately enough for general application mainly for a quick evaluation of a missile kinematic performance and to conduct sensitivity analysis of the mass, propulsion, and aerodynamic properties of a generic tactical missile. Author

N90-10860# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
FLIGHT TEST TECHNIQUES
Jul. 1989 419 p In ENGLISH and FRENCH Symposium held at Edwards AFB, CA, 17-20 Oct. 1988
(AGARD-CP-452; ISBN-92-835-0509-3; AD-A213795) Copyright Avail: NTIS HC A18/MF A03
It is important that the flight test community meet regularly so that techniques for flight test, instrumentation and data analysis can be disseminated to ensure safe, efficient, and timely testing. The number of systems submitted for airborne trials and testing is increasing. The major development and test challenge common to most aircraft is that of avionic/software subsystems development and integration. Systems and applications include programmable signal process radars, integrated flight, fire and propulsion systems, multifunction pilot displays, and other on-board software-intensive systems. The focus was on the means of reducing the overall cost of test and development within defence program. Ground based simulation offers the potential for saving many test flying hours in the area of system integration. It is an indispensable tool for system failure analysis for sophisticated avionics of all types. For individual titles, see N90-10861 through N90-10887.

N90-10861# Naval Air Test Center, Patuxent River, MD. Advanced Tactical Aircraft Program.
US NAVY PRINCIPAL SITE TESTING CONCEPT AND THE F-18
JOE L. DUNN In AGARD, Flight Test Techniques 4 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
In 1975, a decision was made to conduct the F-18 Full Scale Development (FSD) Program at a primary Navy location, the U.S. Naval Air Test Center (NAVAIRTESTCEN). Previous FSD programs had utilized multiple test locations which resulted in significant program duplication from a facilities, logistics, and test data viewpoint. The principal site concept provides for a primary Navy location where all test assets are co-located. These assets include developmental aircraft, contractor and Navy test personnel, maintenance personnel, and all test equipment. The success of the F-18 principal site testing program paved the way for the AV-8B and LAMPS MK 3 programs at the NAVAIRTESTCEN. The principal site concept has had excellent benefits for the U.S. Navy in terms of improved test aircraft utilization, better visibility into the contractor's test program, elimination of redundant testing by utilizing a common data base, and improved utilization of government test facilities. From the Navy's T and E community viewpoint, it is preferable to conduct the programs at a Navy test activity. Due to program funding constraints, this may not always be possible. With the F-14D and A-6F upgrade programs, the testing is being conducted at the contractor's facility as opposed to a Navy facility. In this case, the Navy has established a Navy Test Team on-site and is participating actively with the contractor during the FSD programs. The impact of the principal site testing concept will be examined from the prospective of both the Navy and the contractor in terms of impact on the individual organizations. Author

N90-10862# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. for Flight Mechanics.
ATTAS FLIGHT TESTING EXPERIENCES
H.-H. LANGE, D. ROHLF, A. ZACH, and H.-L. MEYER In AGARD, Flight Test Techniques 14 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
An overview of recent development and flight test experiences of the DFVLR's flight test vehicle Advanced Technologies Testing Aircraft System (ATTAS) equipped with a digital fly-by-wire/light

flight control system is presented. System design, multiprocessor communication management, parallel data processing, redundancy management as well as software development and validation are summarized. Further, the role of ground based system simulation for development and testing, flight test procedures and interesting flight test results are dealt with in several examples. Author

N90-10863# I.A.M. Rinaldo Piaggio, Finale Ligure (Italy).
P-180 AVANTI: PROJECT AND FLIGHT TEST PROGRAM COMPREHENSIVE OVERVIEW
R. DEPOMPEIS and E. TRAINI In AGARD, Flight Test Techniques 28 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
Among the turboprops in advanced flight testing phase, the Piaggio P-180 AVANTI possesses exciting features. Very unconventional shape, characterized by 3 lifting surfaces, pusher props, mid-wing very rearback mounted, is coupled with outstanding speed and range performances. The project and flight test programs planning has required much care for the peculiar characteristic of the aircraft. Areas of extensive in-flight investigation were: flutter expansion; stability and control at high angle of attack; laminar flow investigation; flap system tuning; and propeller stress. The focus is on the P-180 project and flight test programs presenting the project concepts and the test results achieved to date. The flight test program, actually in the certification phase, has achieved more than 600 flight hours and RAI/FAA initial certification is expected for mid 1989. Author

N90-10864# Airbus Industrie, Blagnac (France). Dept. Essais en Vol.
A320 FLIGHT TESTS: PARTICULARITIES AND INNOVATIONS [ESSAIS EN VOL A320]
GERARD GUYOT In AGARD, Flight Test Techniques 5 p (SEE N90-10860 02-05) Jul. 1989 In FRENCH
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The general architecture of the electronic flight control system for the A320 Airbus is described and the functions of the SPATIAL system are outlined. Protection against electromagnetic radiation is addressed and related ground and flight tests are briefly described. Author

N90-10865# British Aerospace Public Ltd. Co., Preston (England). Military Aircraft Div.
THE EXPERIMENTAL AIRCRAFT FLIGHT TEST PROGRAMME
R. A. HARTLEY In AGARD, Flight Test Techniques 11 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The Experimental Aircraft Program has grown out of the studies carried out over the last decade to investigate the needs for the next generation of fighter. These studies resulted in the definition of a large number of new technologies for which it was recognized that there would be significant benefits to be gained by their integration into a demonstrator aircraft. The objectives and progress of the flying program are described for this demonstrator and how it has lead on to the European Fighter Aircraft. Author

N90-10866*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
REAL-TIME FLIGHT TEST ANALYSIS AND DISPLAY TECHNIQUES FOR THE X-29A AIRCRAFT
JOHN W. HICKS and KEVIN L. PETERSEN In AGARD, Flight Test Techniques 17 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
CSCL 01/3
The X-29A advanced technology demonstrator flight envelope expansion program and the subsequent flight research phase gave impetus to the development of several innovative real-time analysis and display techniques. These new techniques produced significant improvements in flight test productivity, flight research capabilities, and flight safety. These techniques include real-time measurement and display of in-flight structural loads, dynamic structural mode frequency and damping, flight control system dynamic stability and control response, aeroperformance drag polars, and aircraft specific excess power. Several of these analysis techniques also provided for direct comparisons of flight-measured results with analytical predictions. The aeroperformance technique was made possible by the concurrent development of a new simplified in-flight net thrust computation method. To achieve these levels of on-line

flight test analysis, integration of ground and airborne systems was required. The capability of NASA Ames Research Center, Dryden Flight Research Facility's Western Aeronautical Test Range was a key factor to enable implementation of these methods.
Author

N90-10867# Avions Marcel Dassault-Breguet Aviation, Istres (France).
FLIGHT TEST TECHNIQUES ADOPTED BY AVIONS MARCEL DASSAULT-BREGUET AVIATION
JEAN COSTARD *In* AGARD, Flight Test Techniques 35 p (SEE N90-10860 02-05) Jul. 1989 In FRENCH and ENGLISH
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The ever-increasing complexity of aircraft and systems entailed, in parallel, a very substantial increase in development tests, and consequently a rise of cost. Avions Marcel Dassault-Breguet Aviation (AMD-BA) have adopted techniques enabling to reduce the number of flight tests for the benefit of less expensive ground tests: flights must be saved for demonstation with the aim of qualification. These techniques allowed to keep in control of data acquisition rates while preserving reasonable means of computation and facilitating analysis.
Author

N90-10868# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.
GRATE: A NEW FLIGHT TEST TOOL FOR FLYING QUALITIES EVALUATION
R. KOEHLER, E. BUCHACKER, and D. J. BIEZAD (Air Force Inst. of Tech., Wright-Patterson AFB, OH.) *In* AGARD, Flight Test Techniques 18 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
A flight test tool was worked out by DFVLR for flying quality evaluations of ground attack tracking phases. This Ground Attack Technique (GRATE) was proven in test flights of the German Federal Armed Forces Engineering Center for Aircraft and was integrated in the Large Amplitude Multimode Aerospace Research Simulator (LAMARS) of Air Force Wright Aeronautical Laboratories (AFWAL) in Dayton. The German/U.S. cooperation was supported by the Memorandum of Understanding (MoU) Flight Control Concepts. A description of the flight test method and of the pilot's role and ratings is given. Head-up-display films evaluated to determine a so called align-time and a circular error probability (CEP). The influence of different test conditions on the mission parameters were investigated. The results of the numerical analysis and the pilot ratings were compared. The determined gradients show the sensitivity of a pilot rating to the mission parameters. In this context a configuration with slight PIO-tendencies is discussed. Simulator tests have shown that the technique is an effective tool for unmasking aircraft handling problems. The effects caused by different turbulence levels on pilot ratings were found to be small in comparison to conventional methods.
Author

N90-10869# Aeritalia S.p.A., Caselle Torinese (Italy). Combat Aircraft Group.
IN FLIGHT RELIGHT TESTS ON AM-X SINGLE ENGINE FLY-BY-WIRE AIRCRAFT
G. MENSO and G. GAMALERO *In* AGARD, Flight Test Techniques 17 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The in-flight relight evaluation of a single engine aircraft could be considered one of the more interesting aspects of flight testing. When the engine is intentionally shut down in flight to attempt the relight, possibility of an unsuccessful one must always be taken into account and therefore a flame out landing must be contemplated, otherwise the aircraft is lost. This event may be particularly serious on a fly-by-wire aircraft on which the loss of the engine and all its driven accessories will make control very difficult if not impossible. Therefore, the planning and the execution of this kind of test not only concerns the propulsion aspects, but involves all the aircraft, because full evaluation (both theoretic and flight test) of aircraft and systems performance and reliability in engine out condition must be carried out in advance of the actual relight tests. Besides the relight evaluation must be carried out as early as possible on the program to allow safe performing of those tests that may cause a flame out. All the activities carried out by AERITALIA Flight Test Department in connection with relight

tests of AM-X are described and may therefore be looked upon as a reference for smooth test planning and execution. Author

N90-10870# Technische Univ., Brunswick (Germany, F.R.). Inst. for Flight Guidance and Control.
FLIGHT TEST RESULTS OF A COMPLEX PRECISE DIGITAL FLIGHT CONTROL SYSTEM
GUNTHER SCHAENZER *In* AGARD, Flight Test Techniques 9 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The presented flight control systems consist of an open loop control system and a more conventional state vector feed back closed system. The open loop actuator control includes a quasistationary aircraft model and a full state command model. For the flight tests of this control system, the minimization of the state vector error was the basic target. To improve the flight test quality, an onboard real time wind and turbulence measurement system has been used. The flexible flight test instrumentation including sensors and computers will be described and some typical flight test results will be demonstrated. Author

N90-10871# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. Automatique.
ANALYSIS OF FLUTTER TESTS WITH THE USE OF A TELEMETRY SYSTEM [ANALYSE DES ESSAIS DE FLOTTEMENT A L'AIDE D'UN SYSTEME DE TELEMESURE]
ALAIN BUCHARLES, GERALD LIGNON, and HENRI CASSAN (Aerospatiale, Toulouse, France) *In* AGARD, Flight Test Techniques 10 p (SEE N90-10860 02-05) Jul. 1989 In FRENCH
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The principles and procedures of in-flight flutter testing are discussed with particular emphasis given to the use of telemetry. Data processing and analysis techniques are described. Application of such in-flight testing methods to the A320 Airbus is discussed.
Author

N90-10872# Air Force Flight Test Center, Edwards AFB, CA.
THE AIR FORCE FLIGHT TEST CENTER FLIGHT TEST SAFETY PROGRAM
KELLY J. ADAMS and MARK R. CRAWFORD *In* AGARD, Flight Test Techniques 10 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The success of the AFFTC flight test safety program is based on: (1) careful attention to the safety planning aspects of testing by each program manager, with thorough review of any applicable formal safety analyses, investigation of more experienced personnel in the subject of test and review of past programs of similar nature for successful and faulty safety planning; (2) management review of the safety aspects, endorsement and approval of every new and modified test program; (3) the establishment of a staff system safety division which facilitates an independent review of every new and modified test program; (4) flexibility in the safety documentation when programmatic changes occur; (5) attention to test disciplines of control room procedures, conduct and communication; and (6) the presence of a Unit System Safety Officer at each project to review the safety documentation for completeness and accuracy. Author

N90-10873# Aeronautica Macchi S.p.A., Varese (Italy). Technical Dept.
RESULTS AND PRACTICAL EXPERIENCE USING PARAMETER IDENTIFICATION TECHNIQUES ON THE AM-X PROGRAM AT AERMACCHI
M. LUCCHESINI, P. MAESTRELLI, L. MANFRIANI, and P. CHIMETTO *In* AGARD, Flight Test Techniques 16 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The results and the practical experience gained by introducing the parameter identification technique in AM-X flight test analysis at Aermacchi are presented. Taking into account the Company's requirement, preference was given to a well known and established program that could guarantee excellent cost effectiveness. The Iliff-Maine code used (MMLE3 program) during the flight test program is shown to be robust enough to provide useable results rapidly in almost any conditions. Aerodynamic derivatives were evaluated using linear and parabolic models over a wide range of Mach numbers, altitudes and angles of incidence. Both longitudinal

results and an analysis of a lateral departure are presented.
Author

N90-10874# Centre d'Essais en Vol, Bretigny-sur-Orge (France).
LESSONS LEARNED FROM THE INTEGRATION OF FLIGHT SYSTEMS [LES ENSEIGNEMENTS DE L'INTEGRATION DES SYSTEMES EMBARQUES]
JACQUES TRESSET In AGARD, Flight Test Techniques 9 p (SEE N90-10860 02-05) Jul. 1989 In FRENCH
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
Suggestions for minimizing overall costs and delays of flight tests related to the integration of aircraft flight systems are presented. Experiences with the ACT Rafale program are discussed.
Author

N90-10875# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.
FLIGHT TESTING OF THE TORNADO TERRAIN FOLLOWING SYSTEM
THOMAS FLECK In AGARD, Flight Test Techniques 12 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The flight test activities on the assessment of the Tornado Terrain Following System are reviewed. Extensive hardware and pilot in the loop simulation, a stepwise approach to the lowest height and proceeding from VMC to IMC kept the risk at a minimum level. For a demonstration of system performance a method of comparing simulation was applied that considers avionic parameters, aerodynamic parameters, and flight control data. Special emphasis was placed on system integrity and flight safety, including human factors of the aircrew. Today, after having absolved more than 200 successful test flights and rectified a considerable number of problems, the system was adopted by the services and is a substantial part of the low level missions. Author

N90-10876# Royal Aerospace Establishment, Farnborough (England).
EVALUATION OF STORE CARRIAGE (AND RELEASE) ENVIRONMENT USING FLIGHT INSTRUMENTED STORES
H. A. TORODE, P. J. DRIFFILL, and D. CHARLES (Cranfield Inst. of Tech., Bedford, England) In AGARD, Flight Test Techniques 19 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The approach adopted by Attack Weapons Department, Royal Aerospace Establishment, Farnborough, in conjunction with Cranfield Institute of Technology for obtaining experimental data pertinent to the carriage and release of conventional free fall weapons is described. To this end a series of instrumented, flight cleared stores were developed for various data gathering exercises, and results from several of the flight experiments completed to date, are discussed. In addition some future developments are presented. Author

N90-10877# Aerospace Engineering Test Establishment, Cold Lake (Alberta).
CF 18 480 GALLON EXTERNAL FUEL TANK STORES CLEARANCE PROGRAM
DOUGLAS N. KOBAYASHI and MIRKO B. ZGELA In AGARD, Flight Test Techniques 15 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The Canadian Government has embarked on a program with Canadian industry to manufacture a composite 480 gallon external fuel tank (EFT) designed for the CF-18 aircraft by McDonnell Aircraft Company (McAir). Prior to commencing the production phase of the program, the Aerospace Engineering Test Establishment (AETE) of the Canadian Forces (CF) was tasked to support McAir in the flight test certification of the 480 EFT on the inboard wing stations of the CF-18. The main objective was to provide a proof of concept flight demonstration as well as establish an operational flight envelope for the carriage and jettison of the 480 EFT with and without adjacent stores. The certification process involved a progressive series of analyses, laboratory tests, wind tunnel tests, ground tests and flight tests. As the CF flight test authority, AETE was responsible for conducting all flight testing activities including flutter, active oscillation control (AOC), structural mode interactions (SMI), stability and control, structural carriage loads, separation/jettison, and dynamic response testing. An overview is

presented of the the joint CF-18 480 EFT stores clearance program and its main emphasis is in describing the analyses and tests performed during the ground vibration testing, flutter, AOC, SMI and carriage loads phases. The aircraft instrumentation and the qualification/ground tests performed on the tanks prior to the beginning of flight test activities are briefly discussed. Test results and the technical problems encountered during the program are also presented. Author

N90-10878*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FLOW VISUALIZATION TECHNIQUES FOR FLIGHT RESEARCH
DAVID F. FISHER and ROBERT R. MEYER, JR. In AGARD, Flight Test Techniques 32 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
CSCL 01/3
In-flight flow visualization techniques used at the Dryden Flight Research Facility of NASA Ames Research Center (Ames-Dryden) and its predecessor organizations are described. Results from flight tests which visualized surface flows using flc / cones. tufts, oil flows, liquid crystals, sublimating chemicals, and emitted fluids were obtained. Off-surface flow visualization of vortical flow was obtained from natural condensation and two methods using smoke generator systems. Recent results from flight tests at NASA Langley Research Center using a propylene glycol smoker and an infrared imager are also included. Results from photo-chase aircraft, onboard and postflight photography are presented. Author

N90-10879# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Survivability Enhancement Branch.
AIRCRAFT LIVE FIRE TESTING
R. W. LAUZZE and M. D. WADDELL In AGARD, Flight Test Techniques 10 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
Testing military systems in peacetime to determine their ability to successfully operate in a combat environment was done for years. Some of the tough lessons learned on the battlefield and in the skies during wartime can be examined in the laboratory to help assure that new systems do not incorporate the shortcomings of those of the past. Live Fire Testing (LFT) of aircraft, that is, actual ballistic testing of full scale aircraft/aircraft subsystems, can be performed to evaluate their ability to resist or tolerate battle damage. This testing, combined with analytical tools, can assist the designer in assuring that the aircraft incorporates optimum protection for the system and crew at minimum weight. Events such as a fuel or hydraulic fire in flight, hydraulic ram damage due to a tumbling projectile in a fuel tank, or synergistic effects such as bleed air enhancing a dry bay fire are extremely difficult to analyze. Live fire testing allows evaluation of these and other effects and allows a check of vulnerability analyses that were performed. It also provides an effective tool for evaluation of Aircraft Battle Damage Repair (ABDR) techniques. Author

N90-10880# Aeritalia S.p.A., Caselle Torinese (Italy). Flight Test Dept.
FLIGHT TESTING A NEWLY-DESIGNED STAND-OFF WEAPON DISPENSER
G. FERRETTI and P. DURANTI In AGARD, Flight Test Techniques 18 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
Skyshark is a newly-designed Stand-off Weapon Dispenser recently developed by AERITALIA and SNIA-BPD. These Italian companies formed in 1986 a joint venture named CASMU, which in Italian stands for Multi-Usage Stand-off Armament Consortium. Designed specifically for being launched by AM-X and Tornado aircraft, the Skyshark will be easily integrated with most of the modern attack aircraft. Released at a distance from the target variable with speed/altitude conditions this new weapon, capable of following a pre-defined path, will operate independently thanks to a proper inertial navigation system coupled to a pre-programmed computer for stabilization and maneuvering. Once reached the target, a dedicated armament system will come into action dispensing submunitions that can, as the case requires, be selected amongst various combinations and timed for the attack. Five of the planned six demonstration launches were performed so far with satisfactory results, allowing to acquire significant data about aerodynamics, flight-control and armament systems characteristics.

The flight test activities carried out during the demonstration phase, aimed at proving the correctness of the general concept are presented. The most interesting peculiarities related to test-flying such unusual flying machine and the experiences acquired are described. Author

N90-10882# Army War Coll., Carlisle Barracks, PA. Military History Inst.
FLIGHT TESTING AND FLIGHT RESEARCH: FROM THE AGE OF THE TOWER JUMPER TO THE AGE OF THE ASTRONAUT
RICHARD P. HALLION *In* AGARD, Flight Test Techniques 13 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03

Since the beginning of flight, aerospace vehicle design has depended upon data gathered from the performance of actual flight vehicles. This flight testing and flight research process has led to today's air-and-space-craft, and points the way for future flight. Within this process, the flight test planner, test pilot, and flight test engineer occupy positions of critical importance. A review of the history of flight testing and flight research indicates that both were traditionally characterized by a professional approach emphasizing the derivation and utilization of methodologies to best enable investigators to acquire a maximum amount of information as quickly as is consistent with safety. As the technological sophistication of aircraft systems has increased, so, too, has the necessity for improving, modifying, and adding to the capabilities of the flight testing and flight research process. This pattern may be expected to hold true for the subsequent development of future advanced aerospace vehicle systems. Author

N90-10884# National Aerospace Lab., Amsterdam (Netherlands).
FLIGHT TESTING IN THE NETHERLANDS: AN OVERVIEW
J. T. M. VANDOORN and R. L. VANDERVELDE in AGARD, Flight Test Techniques 25 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03

An overview is given for the flight test activities and capabilities in The Netherlands. A general description of the flight test programs of the last decades with civil and military aircraft, helicopters and research aircraft are given. Some of the highlights of the more recent programs are presented, i.e., the type certification of the Fokker 50 and Fokker 100 civil transport aircraft, evaluation and certification trials with the military F16 fighter aircraft, helicopter-ship compatibility testing and the determination of the mathematical model of the Cessna Citation 500 for a Phase 2 flight simulator. Furthermore a short description is given of the flight test instrumentation and flight test techniques that have become available in The Netherlands during the last decade. Author

N90-10885# Lisbon Univ. (Portugal). Inst. Superior Tecnico.
ON THE DEVELOPMENT OF A BASIC FLIGHT TEST CAPABILITY AND SOME RELATED RESEARCH PROJECTS
L. M. B. C. CAMPOS, A. A. FONSECA, and H. F. RAMOS *In* AGARD, Flight Test Techniques 26 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03

The development of a basic flight test capability in Portugal, through the cooperation between the Portuguese Air Force (FAP) and Lisbon Technical University (UTL), with support from The National Aerospace Laboratory (NLR) in The Netherlands and Braunschweig Technical University (TU-BS) in Germany, under the AGARD support program for the NATO Southern Flank Nations is described. After indicating in the introduction the motivations for this program, the National Flight Test Facility (LNEV) is described. Indicating the forms of program management used in the development of the instrumentation system, the first research projects which the facility will be used, are outlined, mentioning in passing application programs, and concentrating on two projects of fundamental rsearch on flight in perturbed atmospheres and linear stability. In conclusion, some of the benefits of the program are mentioned. Author

N90-14218# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
FLIGHT IN ADVERSE ENVIRONMENTAL CONDITIONS
J. F. RENAUDIE Oct. 1989 29 p Presented at the Flight Mechanics Panel Symposium in Gol, Norway, 8-11 May 1989
(AGARD-AR-277; ISBN-92-835-0531-X; AD-A215876) Copyright Avail: NTIS HC A03/MF A01

Four aspects of adverse environmental conditions of interest to the flight mechanics specialists were addressed by this symposium: atmospheric disturbances, reduced visibility, icing and electromagnetic disturbances. All four of these can seriously affect flight safety, comfort and operational capability. The topic was and still is considered to be particularly relevant to the needs of the military community which is putting increased emphasis on the ability of today's and tomorrow's aircraft to fly safely and effectively in the adverse conditions dealt with in this symposium. Author

N90-15042# Flight Safety Foundation, Inc., Arlington, VA.
THE HUMAN ELEMENT: THE KEY TO SAFE, CIVIL OPERATIONS IN ADVERSE WEATHER
JOHN H. ENDERS *In* AGARD, Flight in Adverse Environmental Conditions 7 p (SEE N90-15041 07-01) Sep. 1989
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The problems of civil flight in adverse weather was discussed in general terms and specific examples were used to illustrate the nature of technical, procedural and human factors, with a view toward the mitigation of serious events. Author

N90-15047# Test Group (6520th), Edwards AFB, CA.
THE UNITED STATES AIR FORCE APPROACH TO ALL-WEATHER TESTING
CLIFFORD D. TOMPKINS and JAMES A. FORD *In* AGARD, Flight in Adverse Environmental Conditions 7 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

All-weather test programs historically reveal design deficiencies that impact the operational capabilities of the vehicle involved. Therefore, testing is required to ensure that Air Force weapon systems can be effective under varying or extreme environmental conditions. The major purpose of all-weather testing is to determine to what extent a weapon system, its essential support equipment and crews, can accomplish the design mission in the required climatic conditions. The requirements, purposes, and methods for conducting ground and flight tests under simulated and actual climatic extremes are addressed. The ideal all-weather test program is discussed in sufficient detail for an overall understanding of the major phases. The United States Air Force (USAF) approach to all-weather testing is presented, including regulatory requirements. The current methods of planning, extent of participating test organization involvement, and need for concurrent testing in USAF all-weather test programs of new weapon systems are discussed. Author

N90-15058*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.
A STUDY OF THE EFFECTS OF ROTATING FRAME TURBULENCE (RFT) ON HELICOPTER FLIGHT MECHANICS
D. P. SCHRAGE, J. V. B. PRASAD, and G. H. GAONKAR (Florida Atlantic Univ., Boca Raton.) *In* AGARD, Flight in Adverse Environmental Conditions 13 p (SEE N90-15041 07-01) Sep. 1989
(Contract NCA2-266)
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01/3

The turbulence actually experienced by a helicopter blade-element significantly differs from the space-fixed free atmospheric turbulence. The turbulence in the rotor disk requires a rotationally sampled description in a rotating frame of reference. It is referred to as the rotating frame turbulence or RFT which exhibits a striking phenomenon. The RFT spectral density versus frequency shows high peak values at 1P,2P, or 3P, frequencies.

The energy increase at these peaks is balanced by an energy decrease primarily at the lower-than-1P frequency range. Particularly for low altitude flight regimes of pure helicopters, such as the nap-of-the-earth maneuvers, the conventional space-fixed description of turbulence is not a good approximation, since the turbulence scale length can have values comparable to the rotor radius. Accordingly the flight mechanics characteristics with RFT description are compared with those based on the conventional space-fixed turbulence description. The results demonstrate that the RFT qualitatively and quantitatively affects the prediction of helicopter flight mechanics characteristics in turbulence. Such comparisons should play an important role in the new development of handling qualities specifications for helicopters.   Author

N90-15063#   Texas A&M Univ., College Station. Dept. of Aerospace Engineering.
ICE INDUCED AERODYNAMIC PERFORMANCE DEGRADATION OF ROTORCRAFT: AN OVERVIEW
K. D. KORKAN and R. K. BRITTON   In AGARD, Flight in Adverse Environmental Conditions 34 p (SEE N90-15041 07-01)   Sep. 1989
(AGARD-CP-470)   Copyright   Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The renewed interest in evaluating the performance degradation of helicopters due to icing has resulted in the development of methodologies to analytically predict the aerodynamic degradation increment. The progress in understanding the basic icing technology is reviewed citing major references. The analytical methodology is then summarized with respect to performance degradation of propellers, helicopter in hover, helicopter in forward flight, and the forerunner of the V-22 Osprey, the XV-15 propulsion mode(s). The experimental studies of the NACA 0012 airfoil with/without generic ice and the model helicopter main rotor experiments with/without generic ice are reviewed. Based upon these results, refinements are suggested to the current methodology with respect to near term/far term.   Author

N90-15066#   Aeroplane and Armament Experimental Establishment, Boscombe Down (England).
AIRCRAFT TESTING IN THE ELECTROMAGNETIC ENVIRONMENT
P. M. NEWTON   In AGARD, Flight in Adverse Environmental Conditions 8 p (SEE N90-15041 07-01)   Sep. 1989
(AGARD-CP-470)   Copyright   Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Testing aircraft flight safety critical systems against the effects of electromagnetic interference (EMI) is normally performed on the ground for reasons of safety, practicality and cost. The threat and the effects of EMI on aircraft systems is discussed. The current ground test methods used at Aeroplane and Armament Experimental Establishment (A and AEE) are reviewed, including the limitations, uncertainties of measurement and safety margins. A flight test method for assessing the effects on critical systems from both the on-board and external electromagnetic environment is described which should enable the ground test results to be factored thus providing a more precise clearance for service use without compromising safety.   Author

N90-15904#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
FUEL TANK TECHNOLOGY
Nov. 1989   171 p   In ENGLISH and FRENCH   Meeting held in Ottawa, Ontario, 23-28 Apr. 1989
(AGARD-R-771; ISBN-92-835-0534-4; AD-A217832)   Copyright
Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Experiences and information concerning aircraft fuel tank technology, and information concerning current design practices were exchanged and detection and repair of fuel leaks and modification practices to improve fuel tank integrity were discussed. For individual titles, see N90-15905 through N90-15916.

N90-15905#   British   Aerospace   Public   Ltd.   Co., Kingston-upon-Thames (England).
INTEGRAL FUEL TANK SEALING PRACTICE AT BRITISH AEROSPACE (KINGSTON)
G. N. SHERIDAN   In AGARD, Fuel Tank Technology 7 p (SEE N90-15904 08-05)   Nov. 1989
(AGARD-R-771)   Copyright   Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The current integral fuel tank sealing and repair procedures at British Aerospace (Kingston) were reviewed. It describes the materials and processes used in the design and initial manufacture of integral fuel tanks. The methods used for the repair of leaks in integral fuel tanks are described. The need to review the current procedures for use on future aircraft using composite materials is highlighted.   Author

N90-15906#   Avions Marcel Dassault, Saint-Cloud (France).
INTEGRAL FUEL TANKS - DESIGN, PRODUCTION, AGING, REPAIR [LES RESERVOIRS DE CARBURANT STRUCTURAUX CONCEPTION, REALISATION, VIEILLISSEMENT, REPARATION]
C. A. PICARD   In AGARD, Fuel Tank Technology 12 p (SEE N90-15904 08-05)   Nov. 1989   In FRENCH
(AGARD-R-771)   Copyright   Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The advantages of using integral tanks for aircraft fuel containment are discussed and compared to those of flexible fuel tanks. The design elements of integral tanks that ensure leak-proof characteristics are described including joints, fasteners, and ports. Various types of leakage problems are outlined and repair methods are discussed. Finally, the problem of microbial corrosion is addressed.   Transl. by M.G.

N90-15907#   Aeritalia S.p.A., Turin (Italy).   Defence Aircraft Group.
AIRCRAFT FUEL TANK CONSTRUCTION AND TESTING EXPERIENCE
ERNESTO LIOSSI and CORRADO BIANCO   In AGARD, Fuel Tank Technology 18 p (SEE N90-15904 08-05)   Nov. 1989
(AGARD-R-771)   Copyright   Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The evolution of aircraft structures manufacturing technology has moved the choice of solutions for fuel tanks, from welded sheet metal components to flexible rubber fuel cells up to now when airplanes manufacturers are going to address their choices, toward more extensive adoption of integral fuel tanks. The Aeritalia experience in fuel tanks construction is presented with a short view on flexible fuel tank applications (advantages and disadvantages) and the technological solutions adopted for integral fuel tanks constuction and performances quality assurance. The integral fuel tanks are designed as primary structures to sustain high loads, therefore the critical target is to obtain a leak proof structure and to guarantee no leakage for the aircraft service-life.   Author

N90-15908#   Royal Air Force, Dereham (England).
THE REPAIR OF AIRCRAFT INTEGRAL FUEL TANKS IN THE RAF: A USER'S VIEW OF FUEL TANK TECHNOLOGY
G. DAWSON   In AGARD, Fuel Tank Technology 8 p (SEE N90-15904 08-05)   Nov. 1989
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    The sealing and repair of aircraft fuel tanks was a thorn in the side of aircraft maintenance personnel for a considerable number of years. In the Royal Air Force in particular, repairing and resealing integral fuel tanks was always difficult and has frequently required several attempts to achieve an acceptable seal. In justifying this repair expenditure, it would be easy to conclude that all problems resulted from poor design, ineffective sealants, poor information or even bad weather. However, although all of these factors play a part in repair procedures, some problems were generated for ourselves, and these require considerable commitment on the part of the managers to resolve. Some progress was already made in resolving the more critical of the problems,

and the success rate in effective, long-term repairs has begun to improve. However, it is expected that the process of gradual improvement will continue for the foreseeable future. In order to achieve this improvement, a number of areas of concern were summarized, beginning with background to fuel tank repair in the RAF, and including Health and Safety problems, leak testing, tank venting, surface preparation and resealing. In each area both equipment and procedures are being continually improved in order to reduce aircraft downtime and improve repair effectiveness at all depths of maintenance. Finally, the problems generated by aircraft design, and in particular access provided to integral fuel tanks are examined. As in the other areas, we have identified problems and suggested improvements for future aircraft as well as highlighting the reliability and maintainability implications of poor design. The problems faced by Royal Air Force maintenance engineers in repairing aircraft integral fuel tanks are documented.
Author

N90-15913# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.
DESIGN PHILOSOPHY AND CONSTRUCTION TECHNIQUES FOR INTEGRAL FUSELAGE FUEL TANKS
G. KAGERBAUER, M. VOGLSINGER, and L. LEMMER In AGARD, Fuel Tank Technology 20 p (SEE N90-15904 08-05) Nov. 1989
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The fuel tanks of modern military aircraft are designed as integral fuel tanks. The design features and sealing systems which were adopted for integral fuselage fuel tanks, to satisfy the requirement for tightness during the entire service life, are presented. The design aim was to minimize penetrations into the fuel compartments and to reduce the probability of fuel leaks by the application of redundant sealing barriers. The adopted sealing systems for the sealing of internal metallic substructure, and to an outer CFRP skin are described. Selected sealing systems were tested in a representative sideskin test box in fatigue and the experience gained was introduced into the design of a fuselage sealing box to aircraft standard which was also tested in fatigue. The representative fuel tank structure of the sealing box was used to demonstrate accessability for repair and to proof that repair actions to the sealing system are possible with suitable equipment.
Author

N90-15914# Lockheed Aeronautical Systems Co., Marietta, GA.
FUEL TANK EXPLOSION PROTECTION
M. E. BORDERS, G. E. KNOWLES, D. E. MEADOWS, C. C. RANDALL, T. F. CHRISTIAN, JR., and T. M. JENNINGS (Warner Robins Air Logistics Center, Robins AFB, GA.) In AGARD, Fuel Tank Technology 17 p (SEE N90-15904 08-05) Nov. 1989
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The modernization of military aircraft has included the addition of fuel tank fire/explosion protection. A military transport, like any other aircraft, is susceptible to fuel tank explosions from a number of sources, including combat gunfire. Studies have shown that the fuel tanks are the largest single contributor to the vulnerability from high explosive incendiary (HEI) rounds for transport aircraft. Since no aircraft has the inherent capability to suppress flames within the fuel tank ullage, it is important to provide a tank explosion protection system that prevents fires and explosions inside the fuel tanks during all modes of aircraft operation. The Lockheed Aeronautical Systems Company and the United States Air Force have acquired considerable knowledge about explosive suppressant foam through its use in the Lockheed-built C-130 aircraft. This foam material prevents or limits flame and pressure wave propagation and acts as an anti-slosh baffle. In-service experience with the foam is discussed. Associated maintenance problems and impacts on man-hours, weight, and cost is also reviewed. The status of the new foam materials being developed to eliminate electrostatic problems with the present explosion suppressant foam will be stated and assessed. Alternative techniques and methods to achieve fuel tank explosion protection were proposed for the C-130 and will be compared to the performance of the foam installation. Finally, explosion suppression is put into perspective with other C-130 wing modernization features.
Author

N90-15915# McDonnell Aircraft Co., Saint Louis, MO. Structural Dynamics Dept.
A DYNAMICIST'S VIEW OF FUEL TANK SKIN DURABILITY
M. A. FERMAN, M. D. HEALEY, W. H. UNGER, and MARTIN D. RICHARDSON (Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.) In AGARD, Fuel Tank Technology 17 p (SEE N90-15904 08-05) Nov. 1989
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Widespread leakage of fuel tanks in military aircraft is believed to be aggravated by small cracks induced by premature fatigue of skins from fluid structure interaction loading and dynamics. A developing method is shown that will help improve designs to avoid this recently recognized problem. The technique treats flat panels, curved panels, and stiffened panels. Parallel panels configured as sides or top and bottom pairs are included. Panels of a representative fuel tank section of typical aircraft construction were analyzed, tested, and are included. This method was under steady and careful development for a number of years so that high confidence would be established at each step. A well balanced analytical and experimental approach was taken. It is now mature and ready for full scale application.
Author

N90-15916# Air Force Wright Research and Development Center, Wright-Patterson AFB, OH.
INTEGRAL FUEL TANK CERTIFICATION AND TEST METHODS
MARTIN D. RICHARDSON In AGARD, Fuel Tank Technology 13 p (SEE N90-15904 08-05) Nov. 1989
(AGARD-R-771) Copyright Avail: NTIS HC A08/MF A01;
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Fuel tanks make up a significant structural volume of present aircraft designs. Life cycle costs and the repair of fuel tank leaks are significant. The efforts accomplished, and now in progress, to develop methods to certify the fuel containment integrity of future USAF aircraft are described. The methods use the idea of combining the aircraft structural durability testing requirements with a fuel tank certification requirement. The application of this concept during the development phase of a new aircraft design will enable deficiencies in fuel tank sealing designs to be discovered early, before production begins. The work accomplished to date using C-130 wing fuel tank components, has shown that this approach is possible and does provide valid results. The requirement to employ environmental exposures, including the use of actual jet fuels, and not water or simulants, is emphasized.
Author

N90-15930# Lockheed Missiles and Space Co., Austin, TX.
UNMANNED AIR VEHICLES PAYLOADS AND SENSORS
GROVER S. AMICK In AGARD, Guidance and Control of Unmanned Air Vehicles 18 p (SEE N90-15924 08-08) Aug. 1989
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The Lockheed Corporation developed a family of payload sensors for use in unmanned air vehicle applications. The program was initially conceived as an extension of the U.S. Army Aquila Remotely Piloted Vehicle (RPV) Program and is applicable to a much wider variety of uses and applications. The design concept utilized a universal gimbal platform with interchangeable sensor spheres. The concept and implementation process was directed to develop a low-cost sensor system which could easily accommodate new sensors as they become available. The system has been developed and demonstrated using the Lockheed Altair UAV system and is available for use. A family of seven sensor types were successfully demonstrated, and others are in development. The system is known as the Lockheed Adaptive Modular Payload System (LAMPS).
Author

N90-15931# Lockheed Missiles and Space Co., Austin, TX.
AUTOMATED SEARCH TECHNIQUES APPLIED TO OPTICAL PAYLOADS IN UNMANNED AIR VEHICLES
ROBERT L. MOODY and JAMES L. THOMPSON *In* AGARD, Guidance and Control of Unmanned Air Vehicles 7 p (SEE N90-15924 08-08) Aug. 1989
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The missions of the U.S. Army Aquila Remotely Piloted Vehicle (RPV) system include reconnaissance and target acquisition. To aid the operator in the accomplishment of these missions, Lockheed has developed automated target search software which ensures a thorough, systematic search of a designated area and reduces the operator workload while the search is being conducted. Various factors, internal and external to the unmanned air vehicle (UAV) system, are discussed which affect the probability of detecting a target of military interest. Search parameters were implemented within the software to optimize the capabilities of the Aquila System to detect targets under varying environmental conditions. The automated search algorithm (autosearch) was successfully demonstrated in flights conducted by the Army in a Force Development Test and Experimentation (FDT and E). Author

N90-15932# Merit Technology, Inc., Plano, TX.
AN INTELLIGENCE-DRIVEN RPV MISSION PLANNER
KLAUS DANNENBERG, MEL BARNEY, and CHUCK KIRKLEN *In* AGARD, Guidance and Control of Unmanned Air Vehicles 8 p (SEE N90-15924 08-08) Aug. 1989
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The time required to plan Remotely Piloted Vehicles (RPV) missions can be greatly reduced by the application of technology currently available. Additionally, the effectiveness of these missions can be increased significantly. The application of expert system based processing of near real time intelligence, route planning techniques, and high resolution graphics to the RPV mission planning process can result in an integrated planning aid that accomplishes both a savings in planning time and an increase in mission effectiveness. Expertise in RPV mission planning is acquired by the repetitive performance of planning and observing actual RPV missions. The requirements for these systems are driven by mission requirements, and are often heavily derived from the tools available. The new tools suggested will have a significant impact on the planning process. The development of the system suggested will require participation by these experts. The most time consuming part of an RPV mission planning exercise is the collection and assimilation of relevant intelligence data. These data include enemy threat tactical, communication, and situation data, as well as friendly tactical, communication, and situation data. A system that collects and filters these data was demonstrated. The heart of this system, the Intelligence-Driven Mission Planning Station (IMPS), successfully provided relevant intelligence data for the Wild Weasel defense suppression mission. The combination of onboard sensors and stored terrain data bases have made possible the development of algorithms that select optimum routings for air-to-ground penetration missions. Optimal route generation can first be exercised in the ground based mission planner, and the resulting data can be used to provide onboard mission replanning. The graphics required to plan an effective RPV mission quickly include plan view, God's-eye view, perspective view, and analytical statistical graphs. All these capabilities were successfully developed, demonstrated, and delivered in the form Battle Area Simulation (BATS) software package. Author

N90-15933# Lockheed Missiles and Space Co., Austin, TX.
DISTRIBUTION OF HARDWARE AND SOFTWARE ELEMENTS IN UNMANNED AIR VEHICLE SYSTEMS
LARRY D. SAUVAIN *In* AGARD, Guidance and Control of Unmanned Air Vehicles 10 p (SEE N90-15924 08-08) Aug. 1989
(AGARD-CP-436) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Future unmanned air vehicle systems will be highly automated in order to accomplish their intended mission. These increased levels of automation are best achieved when the computer and man-machine interface elements are incorporated into the initial system design. Adequate capacity, growth capabilities and the maximum use of previously developed system elements are essential considerations in the computer hardware selection. The software structure must be modular, maintainable and have adequate configuration management tools to assure that the correct software is in use at all times. Since additional unplanned mission requirements may evolve, it is important that the man-machine interface elements be easily reconfigured. The basis for these assertions and how they were achieved within the ground control station portion of the Lockheed Demonstration and Research Test System will be addressed. Author

N90-15934# British Aerospace Public Ltd. Co., Lancashire (England). Military Aircraft Div.
TECHNOLOGY AND EVALUATION OF UNMANNED AIR VEHICLES
GEORGE R. SEYFANG *In* AGARD, Guidance and Control of Unmanned Air Vehicles 5 p (SEE N90-15924 08-08) Aug. 1989
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The 15 years of UMA studies and experimental work done at BAe indicate that all of the technologies required to allow UMA to fulfull the air-to-ground roles in increasingly dangerous scenarios now exist. There appears to be the potential for significant savings in peacetime operating costs with UMA, although there would have to be changes to the services' infrastructure to gain all of these potential savings. Author

N90-20056# Laboratoire do Medecine Aerospatiale, Bretigny-sur-Orge (France).
PARACHUTE OPENING SHOCKS DURING HIGH SPEED EJECTIONS: NORMALIZATION [CHOCS A L'OUVERTURE LORS DES EJECTIONS A GRANDE VITESSE? QUELLES NORMES?]
A. LEGER, P. DOLOU, P. SANDOR, and P. BEAUDOUIN (Service Technique des Programmes Aeronautiques, Paris, France) *In* AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 7 p (SEE N90-20054 13-03) Feb. 1990 In FRENCH
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Conditions which evolve during combat flight leads to the consideration of the probability of pilot ejection at low altitude high speed flight. Problems associated with wind blast and the stability of the ejection seat could lead to the risk of injury connected to parachute opening. A study demonstrating the compatibility of the MK 10 seat ejection with different combat aircraft was carried out by testing on a dynamic rail. The results show a significant increase in recorded G(z) acceleration during the opening of the main parachute. A biomechanical analysis of the shocks shows the role played by different phases during the c ...g. These data are given so that the normalization problem and ... criteria can be considered. Author

N90-20976# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
COMPUTATIONAL METHODS FOR AERODYNAMIC DESIGN (INVERSE) AND OPTIMIZATION
Mar. 1990 331 p In ENGLISH and FRENCH Meeting held in Loen, Norway, 22-23 May 1989
(AGARD-CP-463; ISBN-92-835-0542-5; AD-A220870) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Computational Fluid Dynamics (CFD) play an increasingly important role in the aerodynamic design of flight vehicles. The main reasons for this are the rapid developments in computer hardware and solution algorithms in combination with the increasing requirements (and potential) for improving aerodynamic quality and reducing design cycle time and cost. This meeting focused on those CFD-based methods which address the problem of design for given aerodynamic characteristics in a direct sense. Examples are inverse methods which provide the detailed geometry required to generate a given pressure distribution and methods utilizing numerical optimization techniques to obtain the geometry that

minimizes, subject to constraints, a given aerodynamic objective function. For individual titles, see N90-20977 through N90-20999.

N90-20978# Aircraft Research Association Ltd., Bedford (England).
AEROFOIL DESIGN TECHNIQUES
A. J. BOCCI *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 18 p (SEE N90-20976 14-05) Mar. 1990 Sponsored in part by Procurement Executive, Ministry of Defence; British Aerospace Aircraft Group, Hatfield, England; Dowty Rotol Ltd.; and Dept. of Trade and Industry
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Various airfoil design exercises carried out at ARA over the years are described, concentrating on the part played by the inverse methods. The design of an airfoil suitable for the wing of a combat aircraft research model was successful in meeting a number of performance requirements but the inverse supercritical method used gave an unsatisfactory intermediate profile and off-design calculations were necessary to resolve the problem. In a research exercise involving the design of an airfoil suitable for the wing of a transport aircraft to take advantage of full-scale Reynolds number, the inverse supercritical method used produced changes to the geometry in an opposite sense to those finally required. It is suggested that the difficulties with the inverse supercritical methods arose because appropriate design target pressures were not known and because viscous effects were not included in the methods. Subsequent designs of laminar flow airfoils and high-speed propeller blade airfoils are described. For these cases, a technique was used involving a subcritical method, with progressive adjustment of target pressures until a geometry arose with suitable flow development according to a viscous supercritical method, with little use of supercritical inverse methods. Author

N90-20979# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Entwurfsaerodynamik.
AERODYNAMIC DESIGN TECHNIQUES AT DLR INSTITUTE FOR DESIGN AERODYNAMICS
H. KOESTER, C.-H. ROHARDT, K.-H. HORSTMANN, and R. RADESPIEL *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 15 p (SEE N90-20976 14-05) Mar. 1990
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Some general remarks about aerodynamic design are given first. Then, a short survey of the design methods used here including the basic ideas and, particularly, an improvement of the design method of McFadden for supercritical airfoils are presented. Also, an overview is given of the analysis methods in use at the DLR institute for design aerodynamics. Design procedures, which use the forementioned design and analysis methods, are explained in detail. With these procedures, several designs of airfoils and nacelles were performed. Results of selected design examples are discussed. Author

N90-20980# Grumman Aerospace Corp., Bethpage, NY.
INVERSE DESIGN OF AIRFOIL CONTOURS: CONSTRAINTS, NUMERICAL METHOD, AND APPLICATIONS
G. VOLPE *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 18 p (SEE N90-20976 14-05) Mar. 1990
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The classical problem of constructing an airfoil profile that corresponds to an arbitrarily prescribed speed distribution is discussed and recast in a form suitable for transonic applications. The problem, in general, is not well posed unless the specified speed distribution satisfies certain constraints. Thus, a solution exists only if the speed distribution contains a sufficient number of free parameters with values that can be adjusted in order to satisfy the constraints. The nature of the constraints are discussed and several strategies proposed for introducing the necessary freedom in the speed distribution. The computational method described determines the values of the parameters as part of the

solution. It is based on the numerical solution of the full potential equation in conservation form with Dirichlet-type boundary conditions by a multigrid-ADI scheme. The general applicability and the accuracy of the numerical method are illustrated by several examples. Author

N90-20981# Textron Bell Helicopter, Fort Worth, TX.
AN EFFICIENT AIRFOIL DESIGN METHOD USING THE NAVIER-STOKES EQUATIONS
J. B. MALONE, J. C. NARRAMORE, and L. N. SANKAR (Georgia Inst. of Tech., Atlanta.) *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 18 p (SEE N90-20976 14-05) Mar. 1990
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An airfoil design procedure is described that was incorporated into an existing 2-D Navier-Stokes airfoil analysis method. The resulting design method, an iterative procedure based on a residual-correction algorithm, permits the automated design of airfoil sections with prescribed surface pressure distributions. The inverse design method and the technique used to specify target pressure distributions are described. It presents several example problems to demonstrate application of the design procedure. It shows that this inverse design method develops useful airfoil configurations with a reasonable expenditure of computer resources. Author

N90-20982# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Dept. of Theoretical Aerodynamic.
AN INTENSIVE PROCEDURE FOR THE DESIGN OF PRESSURE-SPECIFIED THREE-DIMENSIONAL CONFIGURATIONS AT SUBSONIC AND SUPERSONIC SPEEDS BY MEANS OF A HIGHER-ORDER PANEL METHOD
L. FORNASIER *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 10 p (SEE N90-20976 14-05) Mar. 1990
(Contract T/RF-41/E0010/E14)
(AGARD-CP-463) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An advanced panel method employing singularity distributions of higher order and based on mixed boundary conditions of Dirichlet- and Neumann-type was recently developed for the potential flow analysis of arbitrary airplane configurations at subsonic and supersonic speeds. Some work is in progress to provide this method with a design option capable of relofting the surface of a given configuration from prescribed pressure distributions. The purpose is to present the mathematical background of the inverse algorithm and to account on some examples of application. Author

N90-20983# National Aerospace Lab., Amsterdam (Netherlands).
A SYSTEM FOR TRANSONIC WING DESIGN WITH GEOMETRIC CONSTRAINTS BASED ON AN INVERSE METHOD
F. J. BRANDSMA and J. M. J. FRAY *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 9 p (SEE N90-20976 14-05) Mar. 1990
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A new system was described for transonic wing design with prescribed pressure distribution in the presence of a fixed body. The residual correction method, on which the design system is based, combines a complex direct flow solver with simple correction rules (inverse supersonic wavy-wall plus inverse 3-D panel method). It is possible to define geometric constraints for the wing to be designed, which is an essential part of the method. Weight factors on the pressure defect corrections and on the corrections associated with the geometric constraints can be adjusted during the iteration process, allowing a maximal control over the design procedure. In order to reach the design goals in the best possible way. The practical applicability of the transonic wing design system was demonstrated by an example. Author

N90-20984# Politecnico di Milano (Italy). Dipartimento di Ingegneria Aerospaziale.
A FAST COLLOCATION METHOD FOR TRANSONIC AIRFOIL DESIGN
SERGIO DEPONTE, MAURIZIO BOFFADOSSI, and CLAUDIO MANTEGAZZA (Aeronautica Macchi S.p.A., Varese, Italy.) *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 7 p (SEE N90-20976 14-05) Mar. 1990
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In the method of ficticious gas for transonic airfoil modification, an attempt was made to introduce a fully elliptic calculation code by the use of compressibility sources. This is done both with the idea of overcoming some of the finite-difference limitations and in order to reduce the computational time. Taking as reference the standard Hess-Smith panel method in two dimensions, compressibility effects are taken into account by means of source panels into the flowfield. The panels form a grid which is limited in extension only where Mach number gradients are expected and much more limited compared to usual computational domains. The system is fast and in general does not present convergence problems from the practical point of use, although large numbers of iterations may have some convergence problems. The final result is always a very strong reduction in wave drag of the airfoil, as it is the aim of the method. Author

N90-20986# Middle East Technical Univ., Ankara (Turkey).
A COMPUTATIONAL DESIGN METHOD FOR SHOCK FREE TRANSONIC CASCADES AND AIRFOILS
T. A. CETINKAYA, I. S. AKMANDOR, and AHMET S. UCER *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 10 p (SEE N90-20976 14-05) Mar. 1990
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A computational method was formulated for efficient inverse design of blading. The surface pressure distribution is specified and, as a result, the geometric shape of an airfoil or cascade blade is obtained. A steady, two-dimensional Euler code for transonic flow was implemented. The code uses a finite volume technique on a computational grid which is based on assumed streamlines. The grid is being updated during the solution procedure. The blade contour, being a streamline, corresponds to a part of the solution domain boundary where the desired pressure distribution is given. Free parameters are introduced into the prescribed pressure distribution and this satisfies the closure constraints. Examples based on redesign of known shapes are presented. Author

N90-20987# Stuttgart Univ. (Germany, F.R.). Inst. fuer Aero- und Gasdynamik.
INVERSE COMPUTATION OF TRANSONIC INTERNAL FLOWS WITH APPLICATION FOR MULTI-POINT-DESIGN OF SUPERCRITICAL COMPRESSOR BLADES
E. SCHMIDT and F. KLIMETZEK (Daimler-Benz A.G., Stuttgart, Germany, F.R.) *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 13 p (SEE N90-20976 14-05) Mar. 1990 Sponsored by Deutsche Forschungsgemeinschaft and Forschungsvereinigung Verbrennungskraftmaschinen
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The method solves the inverse problem for supercritical blade-to-blade flow on stream surfaces of revolution with variable radius and variable stream surface thickness in a relative system. Some provisions for the treatment of the ill-posed design problem in local supersonic regions are discussed. A procedure for the design of cascades with improved off-design behavior is described and compared with experimental results. Comparisons with other numerical methods and experimental results are also included. Author

N90-20991*# Sverdrup Technology, Inc., Eglin AFB, FL.
AERODYNAMIC OPTIMIZATION BY SIMULTANEOUSLY UPDATING FLOW VARIABLES AND DESIGN PARAMETERS
M. H. RIZK *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 18 p (SEE N90-20976 14-05) Mar. 1990
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The application of conventional optimization schemes to aerodynamic design problems leads to inner-outer iterative procedures that are very costly. An alternative approach is presented based on the idea of updating the flow variable iterative solutions and the design parameter iterative solutions simultaneously. Two schemes based on this idea are applied to problems of correcting wind tunnel wall interference and optimizing advanced propeller designs. The first of these schemes is applicable to a limited class of two-design-parameter problems with an equality constraint. It requires the computation of a single flow solution. The second scheme is suitable for application to general aerodynamic problems. It requires the computation of several flow solutions in parallel. In both schemes, the design parameters are updated as the iterative flow solutions evolve. Computations are performed to test the schemes' efficiency, accuracy, and sensitivity to variations in the computational parameters. Author

N90-20992# National Aerospace Lab., Amsterdam (Netherlands).
CONSTRAINED SPANLOAD OPTIMIZATION FOR MINIMUM DRAG OF MULTI-LIFTING-SURFACE CONFIGURATIONS
R. F. VANDEDAM *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 14 p (SEE N90-20976 14-05) Mar. 1990 Sponsored by Netherlands Agency for Aerospace Programs
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An interactive computer program system was developed that can be used in aircraft drag minimization studies. It comprises algorithms for choosing the spanwise distributions of lift, pitching moment, chord, and thickness-to-chord ratio of lifting elements. The choices are optimal in that they minimize induced plus viscous drag while satisfying constraints of aerodynamic, flight-mechanical and structural nature. The configurations that can be dealt with, may consist of a number of segments representing, for instance, wings or parts of wings, horizontal tails or canards, winglets or flaprail-fairings. Also the interaction between propellers and lifting elements may be included in the procedure. The induced drag is computed using the Trefftz-plane integral (farfield analysis), while the viscous drag follows from form factor methods. Mathematical formulations of the constrained optimization problems are used, that are based on the calculus of variations. The method was integrated in an infrastructure that allows the capabilities of the method to be efficiently exploited in a multidisciplinary environment. The theoretical models and methods underlying the analysis and optimization capability, comparisons with other theories, information aspects, and some examples of applications, are presented. Author

N90-20993# National Aerospace Lab., Amsterdam (Netherlands).
NUMERICAL OPTIMIZATION OF TARGET PRESSURE DISTRIBUTIONS FOR SUBSONIC AND TRANSONIC AIRFOIL DESIGN
J. A. VANEGMOND *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 11 p (SEE N90-20976 14-05) Mar. 1990
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Inverse aerodynamic design, calculating the geometry from prescribed pressure distributions, leaves the designer with the problem to define proper target pressure distributions. Numerical optimization techniques are employed to support the aerodynamic designer in the definition of target pressure distributions for subsonic and transonic airfoil design. A general parametric

representation of airfoil pressure distributions is given, taking into account the physical characteristics of the airfoil flow. This parametric representation enables the designer to define optimum target pressure distributions through numerical optimization techniques. Worked out examples show that a large class of airfoils can be described by the proposed procedure, a simple line search method. In general, a large number of iterations is needed to arrive at the final (optimal) solution. However the requirement of a large number of iterations is not a serious drawback of the approach described. Finally, it is concluded that application of numerical optimization techniques is not (yet) to be considered as a routine job but considerable possibilities are offered to improve design results. Author

N90-20994# Aeronautica Macchi S.p.A., Varese (Italy). Dept. of Advanced Studies.
A TOOL FOR AUTOMATIC DESIGN OF AIRFOILS IN DIFFERENT OPERATING CONDITIONS
L. GHIELMI, R. MARAZZI, and A. BARON (Politecnico di Milano, Italy) In AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 12 p (SEE N90-20976 14-05) Mar. 1990
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An optimization procedure is described which applies to the design of airfoils able to satisfy requirements essentially set for transonic flight. Suitable airfoils are obtained through radical changes of the starting geometry with little time consumption. One of the main features of the design methodology is an extensive use of constraints; it proved to be very efficient both to obtain a good quality of the design and to reduce the time needed. Another feature is the use of effective shape functions, which are not aerofunctions obtained through inverse methods. The results show airfoils designed to satisfy both a maneuver and a dash performance requirement. A comparison of different design approaches is also presented; this is made possible by the short times required for the design, which includes the optimized deflections of the leading edge and trailing edge flaps. Suggestions are given for further developments of a smart system for airfoil design. Author

N90-20995# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THE USE OF NUMERICAL OPTIMIZATION FOR HELICOPTER AIRFOIL AND BLADE DESIGN
J. RENEAUX and M. ALLONGUE (Aerospatiale, Marignane, France) In AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 12 p (SEE N90-20976 14-05) Mar. 1990 In FRENCH, ENGLISH summary
(AGARD-CP-463) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The numerical optimization methods were successfully applied to airfoil design at ONERA, and to helicpter blade design at the Aerospatiale Helicopter Department. The constrained minimization method chosen is the one developed by Vanderplaats. For the design of helicopter airfoils, the minimization algorithms and transonic viscous flow analysis method are linked together. The design of a 12 percent thick airfoil and a 9 percent thick airfoil for helicopter blades were carried out with two design points, one corresponding to the advancing blade conditions and the other to the retreating blade conditions in forward flight. Two-dimensional tests performed in the ONERA S3MA wind tunnel confirmed the theoretical predicted gains. The design of helicopter blades is achieved through the association of the minimization method and a rotor performance analysis method using the blade element theory. The optimization of the spanwise locations of the airfoils of different thickness-to-chord ratios were carried out with one or two design points corresponding to different flight conditions. The method was applied to the rotor design for a helicopter of the 8 to 10 tons gross weight class. The applications discussed show the interest of the numerical optimization techniques for the helicopter rotor design particularly when several flight conditions and many parameters and constraints have to be taken into account. Author

N90-20996# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
AERODYNAMIC DESIGN BY OPTIMIZATION
K.-W. BOCK In AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 12 p (SEE N90-20976 14-05) Mar. 1990
(AGARD-CP-463) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The experience gained when coupling different aerodynamic analysis codes and optimization procedures is described. First a simple problem is considered (airfoil of minimum wave drag, analysis by shock expansion theory) in order to compare the usability of a random search procedure to that of a gradient method (COPES by G. N. Vanderplaats). The second one shows a superior performance. Then three aerodynamic programs are coupled with COPES and tested: Euler space-marching program for bodies of revolution at supersonic; transonic airfoil redesign method (fictitious gas concept); and multiple airfoil analysis code for flap position optimization. It can be demonstrated that COPES is a very universal optimization tool which can be easily combined even with complex aerodynamic codes. Its convergence is good even under constraints. This is important because the number of analysis calculations is most important for typical aerodynamic problems of high numerical expense. Author

N90-20997# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NUMERICAL OPTIMIZATION OF WINGS IN TRANSONIC FLOW
D. DESTARAC, J. RENEAUX, and D. GISQUET (Aerospatiale, Toulouse, France.) In AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 12 p (SEE N90-20976 14-05) Mar. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-463) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The numerical optimization method for wings in transonic flow presented associates a constrained minimization program, a fast direct aerodynamic code, and a shape modification technique. Possibilities of optimization with regard to the total aerodynamic coefficients of a wing are shown. A method for estimating inviscid drag is recommended. Two application cases of the optimization method in the quasi inverse mode, by aiming at a given pressure distribution, are described. One is the adaptation of the inner part of a transport aircraft wing, a problem to which optimization is a well suited approach, considering the highly three-dimensional phenomena involved, and the necessity of respecting constraints related to the aircraft design. Another example, the modification of a four-engined jet aircraft in order to reduce perturbations created by the propulsive system, shows that interference problems between the wing and other components of the aircraft can also be approached by numerical optimization. Author

N90-21984# National Aerospace Lab., Amsterdam (Netherlands).
DESIGN AND TESTING OF A MULTIBLOCK GRID-GENERATION PROCEDURE FOR AIRCRAFT DESIGN AND RESEARCH
J. W. BOERSTOEL, J. M. J. W. JACOBS, A. KASSIES, A. AMENDOLA, R. TOGNACCINI, and P. L. VITAGLIANO (Aeritalia S.p.A., Pomigliano D'Arco, Italy) In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 16 p (SEE N90-21975 15-34) Mar. 1990
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A multiblock grid-generation procedure embedded in a numerical flow simulation system is described. Major features of the grids are: suitable for complex aerodynamic configurations; grid lines continuous, in particular, over block faces; grid lines not slope-continuous over block faces, topology and geometry of block decomposition first specified, and then grid-point distributions; application of transfinite interpolation and elliptic techniques. It is possible to construct multiblock grids around complex configurations with 250 to 1000 blocks, and to compute (Euler) flows on such grids. New technical concepts are proposed, to improve the accuracy of the flow simulation results, and to reduce

manhour investments in the construction of multiblock grids. These concepts concern the use of compound faces and edges; the application of grid refinement per block and per coordinate direction, to remove the constraining effect of grid-line continuity on grid-point-density control; the use of new techniques for analytic aerodynamic geometry modeling, to reduce the dependence on non-CFD geometry software packages; the control of grid quality and acceptability with weight functions in the independent variables of the 3D vector functions defining the geometrical shape of edges, faces and blocks; and use of hyperblocks to speed up the block decomposition. Author

N90-21986# British Aerospace Public Ltd. Co., Hatfield (England). Airlines Div.
MULTIBLOCK TOPOLOGY SPECIFICATION AND GRID GENERATION FOR COMPLETE AIRCRAFT CONFIGURATIONS
STEVE ALLWRIGHT *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 11 p (SEE N90-21975 15-34) Mar. 1990
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The ability to calculate the flow around complex geometries is fundamentally controlled by the ability to generate grids of suitable structure and quality around the configurations of interest. The approach to Multiblock topology specification and grid generation pursued within British Aerospace, targeted to make Multiblock flow prediction methods available for use at all stages of the aerodynamic design process is discussed. The grids and computed flow solutions for a number of complex geometries are shown, and the capability for rapid systematic analysis of similar configuration geometries is illustrated. Author

N90-27696# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
INTEGRATION OF EXTERNALLY CARRIED WEAPON SYSTEMS WITH MILITARY HELICOPTERS
1990 . 102 p
(AGARD-AR-247; ISBN-92-835-0556-5; AD-A223938) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Detailed discussions of the aeromechanical aspects of helicopter weapons integration are contained. Particular emphasis is placed on flying qualities and performance with externally mounted weapons systems as well as weapons separation characteristics. In addition, structural mechanics topics, operational issues, and special problems are discussed. Each technical area is discussed in terms of analytic methodology, ground testing, and flight testing procedures, instrumentation, and an assessment of the state-of-the-art, where possible. Appendix 1 is a synoptic table which relates each particular undesirable characteristic to various effects and results and, further, suggests solutions. Appendix 2 is a listing of known helicopter weapons certification programs completed to date that have either produced experimental results or a fully qualified system. Appendix 3 is a compendium of case histories which are referred to by the text and which will serve to explain more fully the phenomena discussed. Author

N90-23077# National Aeronautical Establishment, Ottawa (Ontario). Structures and Materials Lab.
A TECHNIQUE FOR RAPID INSPECTION OF COMPOSITE AIRCRAFT STRUCTURE FOR IMPACT DAMAGE
JERZY P. KOMOROWSKI, RONALD W. GOULD, and WALTER J. PASTORIUS (Diffracto Ltd., Windsor, Ontario) *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 10 p (SEE N90-28068 22-38) May 1990
(AGARD-CP-462) Copyright Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A technique using the Diffracto D-Sight method to locate indentations associated with low energy impact damage is described. In graphite/epoxy specimens good correlation was observed between internal impact damage as shown on ultrasonic C scan images and indentations detected with the D-Sight method. Test specimens are currently mounted on the aircraft to observe the influence of in-service surface degradation on technique resolution. The method has the potential for inexpensive, rapid

and objective detection of low energy impact damage over large areas of composite aircraft structure. Application of this method, because of its inherent reliability, could result in the increasing of the design allowable strain levels for some composite components. Included are two examples of possible application of D-Sight to metal aircraft for inspection of cold worked holes and detection of cracks. Author

N90-28513# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
AERODYNAMICS OF COMBAT AIRCRAFT CONTROLS AND OF GROUND EFFECTS
Apr. 1990 337 p In ENGLISH and FRENCH Symposium held in Madrid, Spain, 2-5 Oct. 1989
(AGARD-CP-465; ISBN-92-835-0555-7; AD-A223680) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An updated review is provided for the aerodynamic design of controls for combat aircraft. The scope included the aerodynamic design of controls for take-off and landing conditions; for maneuvering at subsonic, transonic, and supersonic speeds; for high angles of attack and yaw; and for departure prevention and post-stall maneuvering. Ground effects; computational experimental methods; and jet effects on flow-field forces and intake flows were also reviewed. For individual titles, see N90-28514 through N90-28534.

N90-28514# Wright Research Development Center, Wright-Patterson AFB, OH.
AERODYNAMIC AND PROPULSIVE CONTROL DEVELOPMENT OF THE STOL AND MANEUVER TECHNOLOGY DEMONSTRATOR
DAVID J. MOORHOUSE, JAMES A. LAUGHREY, and RICHARD W. THOMAS (McDonnell Aircraft Co., Saint Louis, MO.) *In* AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 23 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The STOL and Maneuver Technology Demonstrator (S/MTD) program was structured to investigate, develop, and validate through analysis, experiment, and test flight, four specific technologies related to providing current and future high performance fighters with both STOL capability and enhanced combat mission performance. The four technologies are: two-dimensional thrust vectoring and reversing exhaust nozzle; integrated flight propulsion control (IFPC) system; advanced pilot vehicle interface (PVI) and rough/soft field landing gear. In addition to the required technologies, all-moving canard surfaces were also incorporated into the baseline F-15B. Starting with an existing aircraft, wind tunnel tests were performed to define the incremental effects of the specific technology items. A single data base was defined that was used by all the different functional design groups. The components of most interest are the canard and jet effects, both in and out of ground effects, and their use as control effectors. The intent is to present the progress of the S/MTD configuration towards meeting its goals. First, the design requirements and their rationale are discussed. Second, the aerodynamics of the canard and jet effects of vectoring and reversing are discussed followed by their implementation and impact on the control system. Ground effects with and without reversing are discussed, including a comparison of static and moving model test approaches. The results of a test to define inlet ingestion are presented. Then the control laws to counter the ground effects are discussed. Lastly, some preliminary flight test correlations are presented Author

05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

N90-28519# Technische Univ., Brunswick (Germany, F.R.).
Institut fuer Stroemungsmechanik.
**EFFECTS OF CANARD POSITION ON THE AERODYNAMIC
CHARACTERISTICS OF A CLOSE-COUPLED CANARD
CONFIGURATION AT LOW SPEED**
D. HUMMEL and HANS-CHRISTOPH OELKER   *In* AGARD,
Aerodynamics of Combat Aircraft Controls and of Ground Effects
18 p (SEE N90-28513 23-05)   Apr. 1990
(Contract DFG-HU-254/8)
(AGARD-CP-465)   Copyright   Avail: NTIS HC A15/MF A02;
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    Comprehensive wing-tunnel investigations were carried out on
a close-coupled A = 2.31 delta-canard configuration at low speed.
Based on three-component, surface pressure, and flowfield
measurements as well as on oilflow patterns, the flow about the
coplanar normal configuration may be regarded as well understood.
Three parameters describing the position of the canard relative to
the wing were varied systematically within certain limits: vertical
distance (3 locations: high, coplanar, low), longitudinal distance (3
locations: front, mid, rear), and canard setting angle (-12 deg is
less than or equal to epsilon is less than or equal to 12 deg).
The results of three-component measurements are presented and
the corresponding flow structure is analyzed by means of pressure
distribution measurements and oilflow patterns. For a large variety
of parameter combinations in the vicinity of the normal configuration
the same state of the flow with two separate vortex systems for
canard and wing was found, and the effects of different canard
positions relative to the wing on the aerodynamic coefficients could
be explained by this mechanism. For low canard positions and
large setting angles, however, the formation of vortices on the
lower surface of the wing as well as the merging of the canard
vortices with the wing vortex system on the upper surface was
observed. This flow structure leads to abrupt changes in the
aerodynamic coefficients which are unacceptable for practical flight
conditions.   Author

N90-28520# Royal Aerospace Establishment, Bedford (England).
Dept. of Aerodynamics.
**THE EFFECTS OF FOREPLANES ON THE STATIC AND
DYNAMIC CHARACTERISTICS OF A COMBAT AIRCRAFT
MODEL**
C. O. OLEARY and B. WEIR   *In* AGARD. Aerodynamics of Combat
Aircraft Controls and of Ground Effects 13 p (SEE N90-28513
23-05)   Apr. 1990
(AGARD-CP-465)   Copyright   Avail: NTIS HC A15/MF A02;
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    On a close coupled canard configuration there are strong
aerodynamic interactions between the forebody, foreplanes, and
wings which are likely to affect both the longitudinal characteristics
and the lateral/directional stability of the aircraft, especially at
high angle-of-attack. The nature and strength of these interactions
is likely to depend on the planform and deflection of the foreplanes.
Tests were made to investigate these effects on the RAE HIRM2
model in the 4 x 2.7 m Low Speed Wind Tunnel. The model was
tested with trapezoidal and gothic foreplanes on a static force
balance and on a lateral oscillatory rig. Effects on lift and pitching
moment were similar for the different types of foreplane. There
were significant effects on lateral and directional stability due to
foreplane and foreplane deflection.   Author

N90-28523# Stanford Univ., CA. Dept. of Aeronautics and
Astronautics.
**CONTROL OF VORTEX AERODYNAMICS AT HIGH ANGLES
OF ATTACK**
L. ROBERTS and N. J. WOOD (Bath Univ., England)   *In* AGARD.
Aerodynamics of Combat Aircraft Controls and of Ground Effects
9 p (SEE N90-28513 23-05)   Apr. 1990
(Contract F49620-86-10-0020)
(AGARD-CP-465)   Copyright   Avail: NTIS HC A15/MF A02;
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    The concept of tangential leading edge blowing was investigated
as a means of controlling the vortical flow over delta wings at
high angles of attack. At pre-stall angles of attack, tangential
leading edge blowing exerts rapid control of the vertical flow and
can control or impose asymmetries with either leading edge

influence uncoupled from the other. At post-stall angles of attack,
the response of the vortical flow to transient blowing is slower
due to the presence of vortex burst. However, a burst vortex may
be unburst by tangential leading edge blowing and significant rolling
moments produced at conditions where conventional controls are
ineffective. At these very high angles of attack, the left and right
side vortical flows appear to be strongly coupled.   Author

N90-28524#   Wright   Research   Development   Center,
Wright-Patterson AFB, OH.
A LOOK AT TOMORROW TODAY
LAWRENCE A. WALCHLI   *In* AGARD, Aerodynamics of Combat
Aircraft Controls and of Ground Effects 10 p (SEE N90-28513
23-05)   Apr. 1990
(AGARD-CP-465)   Copyright   Avail: NTIS HC A15/MF A02;
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    A broad overview of the X-29 forward swept wing technology
demonstrator traces its development and test path during the past
five years. Brief descriptions of the aircraft and its flight control
system provide insight for evaluating this vehicle. Results are
presented in several key technical areas and some general
comparisons are made with current frontline fighters. The baseline
flight control system provided a starting point for safe concept
evaluation and envelope expansion for the aircraft. Subsequent
up-dates resulted in performance levels favorably comparable to
current fighter aircraft. Plans are cited for expanding the X-29's
capabilities into the high angle-of-attack regime of flight. Aircraft
and flight control system modifications are described which will
permit the X-29 to fully exploit its technologies.   Author

N90-28526# Royal Aerospace Establishment, Bedford (England).
Dept. of Aerodynamics.
**THE STEADY AND TIME-DEPENDENT AERODYNAMIC
CHARACTERISTICS OF A COMBAT AIRCRAFT WITH A
DELTA OR SWEPT CANARD**
D. G. MABEY, B. L. WELSH, and C. R. PYNE   *In* AGARD,
Aerodynamics of Combat Aircraft Controls and of Ground Effects
13 p (SEE N90-28513 23-05)   Apr. 1990
(AGARD-CP-465)   Copyright   Avail: NTIS HC A15/MF A02;
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    The steady and time-dependent aerodynamic characteristics
for a low speed half model of a typical combat aircraft configuration
fitted with a 65 deg delta canard are compared with those for the
same model fitted with a 44.3 deg swept canard. The tests were
made in the RAE 13 x 9 ft wind tunnel on a large model of the
RAE High Incidence Research Model (HIRM 1), modified to
represent the Experimental Aircraft (EAP) configuration. For the
same platform area, the delta canard gives higher lift and
comparable pitching moments for trimming. For canard and wing
buffeting the differences are small. The pressures induced on the
wing by oscillation of either the delta or the swept canard are
very small and comparable. Overall, these low speed
measurements suggest that delta canards might have advantages
for future combat aircraft.   Author

N90-28527# Imperial Coll. of Science and Technology, London
(England). Dept. of Aeronautics.
**THE EFFECT OF RAPID SPOILER DEPLOYMENT ON THE
TRANSIENT FORCES ON AN AEROFOIL**
P. W. BEARMAN, J. M. R. GRAHAM, and P. KALKANIS   *In*
AGARD, Aerodynamics of Combat Aircraft Controls and of Ground
Effects 11 p (SEE N90-28513 23-05)   Apr. 1990
(AGARD-CP-465)   Copyright   Avail: NTIS HC A15/MF A02;
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    The Discrete Vortex Method (DVM) is used to simulate the
two-dimensional separated flow generated by a spoiler over the
upper surface of an airfoil. Cases of fixed and moving spoilers
are presented and particular attention is paid to the phenomenon
of short duration adverse lift which can be induced by rapid spoiler
deployment. Forces and pressure distributions on the airfoil and
spoiler are calculated and compared, where possible, with
experimental results. The model that was developed predicts the
delay times to maximum adverse lift at very high spoiler deployment
rates, as well as allowing the forces on the airfoil and the spoiler

to be computed separately. Numerical results are in good agreement with the experiment.   Author

N90-28528# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
INFLIGHT THRUST VECTORING: A FURTHER DEGREE OF FREEDOM IN THE AERODYNAMIC/FLIGHT MECHANICAL DESIGN OF MODERN FIGHTER AIRCRAFT
P. MANGOLD and G. WEDEKIND *In* AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 17 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Two different aspects of inflight thrust vectoring are discussed. In the first, more general part a rationale for the future use of thrust deflection including reverser modes is given by highlighting the overall possibilities and the potential of thrust vector devices within the aerodynamic/flight mechanical design of modern fighters. In the second part the most interesting results from 3 low speed wind tunnel test periods is presented showing beneficial and detrimental effects of in-flight thrust reverse on aerodynamic stability and control characteristics.   Author

N90-28529# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
AERODYNAMIC INTERFERENCES OF IN-FLIGHT THRUST REVERSERS IN GROUND EFFECT
G. WEDEKIND and P. MANGOLD *In* AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 9 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Overall design studies for future fighter aircraft have shown that it may be desirable or even necessary to install an in-flight thrust reversing mode during approach and landing in order to fulfill the growing requirements for optimum mission, maneuver, and point performance. With this device an additional optimization task is introduced into the aerodynamic design process, because adverse aerodynamic interference effects have to be avoided. The problems related to approach and landing may roughly be divided into two main subjects. Reingestion of the hot exhaust gases into the inlet of the engines has to be retarded. Detrimental aerodynamic interferences in terms of abrupt changes of the aerodynamic forces and moments are not tolerable, because the controllability of the aircraft has to be guaranteed within the whole approach and landing phase. In a close cooperation between Dornier and Northrop a design study for a twin engine fighter equipped with an in-flight thrust-reverser (N/D-102) was performed. During this period several low speed wind tunnel test phases were run in order to study the principal effects of such a device. Test results including force measurements are summarized, flow visualization is presented, and some design rules for a reverser system are derived. To illustrate a possible optimization procedure the most interesting results of the two test periods are presented and discussed.
                                                    Author

N90-28530# Centre d'Essais Aeronautique Toulouse (France).
STUDY OF THE GROUND EFFECTS IN THE CEAT AEROHYDRODYNAMIC TUNNEL: USING THE RESULTS [ETUDE DF L'EFFET DE SOL AU CEAT EXPLOITATION DES RESULTATS]
GEORGES VIDAL and JACQUES DESCHAMPS (Avions Marcel Dassault-Breguet Aviation, France) *In* AGARD, Aerodynamics of Combat Aircraft Control and of Ground Effects 33 p (SEE N90-28513 23-05) Apr. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Since 1979, the Aero-Hydrodynamic Tunnel (AHT) of CEAT Toulouse is equipped with a faired platform powered by an electrical linear induction motor enabling a maximum speed of 40 m/s. This method is chiefly used in aerodynamic tests to analyze the aircraft behavior in ground effect. The purpose is to show the equipment and facilities used for the ground effect tests, and to provide measurement data. For aircraft manufacturers it is essential

to know the effects of ground proximity on the aerodynamics of the wing. The ground effect was studied on a Falcon 900 model (scale 1/10) at the AHT of Toulouse. Results show that ground effect increases the lift coefficient and the pitching moment (nose down) for usual angle-of-attack. In the same way the drag decreases and the lift-to-drag ratio increases as the wing approaches the ground. On the contrary, stall C1 and stall angle-of-attack decrease in the ground effect. Numerical computation of pressure distribution by a panel method shows that on a wing profile the ground effect increases the pressure on the lower surface and decreases the pressure on the forward part of the upper surface. The overall result of ground effect is an increase in normal force. The computational results are in good agreement with the test results obtained at the Aero-Hydrodynamic Tunnel.   Author

N90-28531*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DYNAMIC GROUND EFFECTS
JOHN W. PAULSON, JR., GUY T. KEMMERLY, and WILLIAM P. GILBERT *In* AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 12 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 01/3
    A research program is underway at the NASA Langley Research Center to study the effect of rate of descent on ground effects. A series of powered models were tested in the Vortex Research Facility under conditions with rate of descent and in the 14 x 22 Foot Subsonic Tunnel under identical conditions but without rate of descent. These results indicate that the rate of descent can have a significant impact on ground effects particularly if vectored or reversed thrust is used.   Author

N90-28532# Institut de Mecanique des Fluides de Lille (France).
STUDY OF GROUND EFFECTS ON FLYING SCALED MODELS [ETUDE DE L'EFFET DE SOL SUR MAQUETTE EN VOL]
J. L. COCQUEREZ, P. COTON, and R. VERBRUGGE *In* AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 11 p (SEE N90-28513 23-05) Apr. 1990 In FRENCH; ENGLISH summary   Sponsored by Direction des Recherches, Etudes et Techniques
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The Institute of Fluid Mechanics of Lille (IFML), an establishment of ONERA, has developed for many years specific experimental methods based on the exploitation of flying scaled models in the laboratory. These methods are especially used to characterize and model the aircraft flight qualities in a disturbed or undisturbed environment. The methods were applied to ground effect studies in order to get a better control on approach and landing phases. The experimental technique and facilities are especially well adapted to this kind of study: realistic representation of the aircraft behavior and the involved aerodynamic phenomena (ground representation, no support interference, incompressible flow, and well-known environment); high accuracy on weight, inertia, and structural characteristics of the model; flight test data obtained through redundant measurements which allow an optimal evaluation of the state variables and the dynamic coefficients; application of parameters identification techniques widely complementary with low speed wind tunnel and other moving model techniques; and abilities to illustrate static and dynamic ground effect. The experimental techniques are emphasized. Some experimental results on ground effects, especially dynamic ones, are presented. The future developments of the mathematical modeling of the aircraft longitudinal behavior are also mentioned. Some ideas are suggested concerning aircraft on carrier or landing with atmospheric disturbances.   Author

N90-28533*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
AN IN-FLIGHT INVESTIGATION OF GROUND EFFECT ON A FORWARD-SWEPT WING AIRPLANE
ROBERT E. CURRY, BRYAN J. MOULTON, and JOHN KRESSE
In AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 11 p (SEE N90-28513 23-05) Apr. 1990 Previously announced as N90-14202
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A limited flight experiment was conducted to document the ground effect characteristics of the X-29A research aircraft. This vehicle has an aerodynamic platform which includes a forward-swept wing and close-coupled, variable incidence canard. The flight-test program obtained results for errors in the air data measurement and for incremental normal force and pitching moment caused by ground effect. Correlations with wind-tunnel and computational analyses were made. The results are discussed with respect to the dynamic nature of the flight measurements, similar data from other configurations, and pilot comments. The ground effect results are necessary to obtain an accurate interpretation of the vehicle's landing characteristics. The flight data can also be used in the development of many modern aircraft systems such as autoland and piloted simulation. Author

N90-28534# Aerospatiale, Toulouse (France).
DETERMINATION OF THE GROUND EFFECT ON THE CHARACTERISTICS OF THE A320 AIRCRAFT [DETERMINATION DE L'EFFET DE SOL SUR LES CARACTERISTIQUES DE L'AVION A320]
A. CONDAMINAS and J. P. BECLE (Office National d'Etudes et de Recherches Aerospatiales, Modane, France) *In* AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 12 p (SEE N90-28513 23-05) Apr. 1990 In FRENCH; ENGLISH summary Previously announced in IAA as A90-21048
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The ground effect on the aerodynamic response of the A320 is investigated experimentally using a 1:7.6-scale model equipped with two motorized nacelles in the S1 wind tunnel at ONERA Modane-Avrieux. The design and instrumentation of the model are described; the measurement apparatus and procedures are explained; and the results are presented in extensive graphs and characterized in detail. Particular attention is given to the treatment of the floor boundary layer and the corrections for the side walls and model support in the data analysis. Good general agreement with flight-test data is demonstrated with respect to life and mean deflection; the airspeed errors are found to be comparable to the precision of the pressure sensors. Author

N91-10042# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
ROTORCRAFT DRIVETRAIN LIFE SAFETY AND RELIABILITY
DEREK G. ASTRIDGE, ed. and M. SAVAGE, ed. (Akron Univ., OH.) Jun. 1990 83 p
(AGARD-R-775; ISBN-92-835-0540-9; AD-A226496) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

This is a portion of an intended volume on Transmission Systems for Power Transfer in Helicopters and Turboprops. Lessons learned from accident data of large civil transport helicopters are examined, as are recent improvements in design and component technology, including recommendations and safety benefits achievable by monitoring systems. A statistical analysis was made of drive system life and reliability. A proper evaluation was made of drive system design and the understanding and control of mean life and life scatter of a drive system at the design stage. For individual titles, see N91-10043 through N91-10044.

N91-10043# Astridge (Derek) and Associates, Langport (England).
HELICOPTER TRANSMISSIONS: DESIGN FOR SAFETY AND RELIABILITY
DEREK G. ASTRIDGE *In* AGARD, Rotorcraft Drivetrain Life Safety and Reliability p 1-34 (SEE N91-10042 01-05) Jun. 1990 Previously announced in IAA as A90-20608
(AGARD-R-775) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

An analysis of the UK CAA's world wide helicopter accident data indicates that transmissions accounted for 22 percent of potentially airworthiness related accidents in civil helicopters of more than 4550 kg gross weight. An evaluation is made of design and technology advancements over the last decade which should benefit helicopter transmission safety and reliability. These encompass improved steels with superior fatigue performance, S/N curve refinement, computer aided design analysis systems, CAD/CAM, improved lubricants and filtration systems, and expert systems retaining a collective memory with regard to design practices' relationship to service experience. E.R.

N91-10044# Akron Univ., OH.
DRIVE SYSTEM LIFE AND RELIABILITY
M. SAVAGE *In* AGARD, Rotorcraft Drivetrain Life Safety and Reliability p 35-71 (SEE N91-10042 01-05) Jun. 1990
(AGARD-R 775) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Fuel efficiency is an important objective in aircraft propulsion. In design, the requirements of light weight and high reliability conflict. Designers use highly stressed, high quality alloy steels in the major load bearing components to resolve the conflict. One estimate for the service needs of a drive system comes from its life and reliability models. The design objectives of long life between repairs and high reliability are design goals. The statistics of drive system life and reliability are discussed. The statistics develop reliability models for repair prediction. The modes of failure which are the basis for these models are also discussed. Coverage of the two parameter Weibull distribution model for component and system life is detailed. Similar coverage is made of the Miner Palmgren load-life model. Based on this model, the theory of mission spectrum averaging is presented. Mission spectrum averaging determines the equivalent constant load which has the same life as the mission spectrum. Also the component life and reliability models for bearings and gears are described. On-board monitoring systems are described. Estimates of the drive system failure rate and replacement needs are still essential at the design stage. E.R.

N91-10969# Technische Univ., Brunswick (Germany, F.R.).
COMPARISON OF A MATHEMATICAL ONE-POINT MODEL AND A MULTI-POINT MODEL OF AIRCRAFT MOTION IN MOVING AIR
R. BROCKHAUS *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3: Impact of New On-Board Technologies on Aircraft Operation 17 p (SEE N91-10967 02-04) Mar. 1990
(AGARD-AG-301-VOL-1-PT-1-3) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The steadily growing capacity of computers favors increasingly exact simulation of even complex processes. On the other hand, parameter identification and state estimation require much more precise models than are generally used for the design of feedback systems. A multi-point model of the aircraft motion is proposed in which the different coupling effects between the two sub-processes, aircraft and air flow, can be modeled with much higher accuracy than is obtained by using the ordinary one-point model, where all the force, moment, and velocity vectors are referred to the aircraft center of gravity. The modeling of the effects of aircraft rotation, wing down-wash, wind gradients, and other unstationary effects should be greatly improved by a multi-point approach, provided that the aerodynamic effects on the aircraft components can be described appropriately. The nonlinear equations of the total process are set up for the one-point and multi-point models and compiled into block diagrams, from which the physical background

of the interrelations between air and aircraft motion can be seen very clearly. The possible improvement in model quality and the additional computer capacity needed are estimated by comparing the two approaches.   Author

N91-10971# Toronto Univ. (Ontario). Inst. for Aerospace Studies.
CRITICAL ASPECTS OF TRAJECTORY PREDICTION: FLIGHT IN NON-UNIFORM WIND
BERNARD ETKIN and DAVID ALEXANDER ETKIN (Canadian Climate Centre, Downsview, Ontario) In AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3: Impact of New On-Board Technologies on Aircraft Operation 12 p (SEE N91-10967 02-04) Mar. 1990
(AGARD-AG-301-VOL-1-PT-1-3) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The genesis of natural wind is described from a meteorological standpoint. Its influence on aircraft trajectories is discussed with reference to steady winds, turbulence, and wind shear. The main problems exist when flight is close to the ground, during landing, take-off, or terrain following. A model for analysis and simulation is presented consisting of four components - dynamics, kinematics and transformations, aerodynamics, and wind. The axis systems chosen are well suited to simulation of landing and take-off.
                                                              Author

N91-10972# Technische Univ., Brunswick (Germany, F.R.). Inst. of Flight Guidance and Control.
EFFECT OF WIND AND WIND VARIATION ON AIRCRAFT FLIGHT-PATHS
K.-U. HAHN, T. HEINTSCH, B. KAUFMANN, G. SCHAENZER, and M. SWOLINSKY In AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3: Impact of New On-Board Technologies on Aircraft Operation 27 p (SEE N91-10967 02-04) Mar. 1990 Sponsored by DFG
(AGARD-AG-301-VOL-1-PT-1-3) Copyright Avail: NTIS HC/MF A12, Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Wind shear accidents during landing and approach could generally be avoided by using modern flight control systems. The problem is to inform the pilot by an adequate wind shear warning display, that he can understand the reaction of the control system. Wind shear is particularly dangerous if it occurs in a height of approximately 80 to 120 m, where the attention of the cockpit crew is affected by getting view contact to the ground. Wind shear during take-off and go-around is a pure flight performance problem. Pilots should avoid a take-off into a thunderstorm. In moderate downbursts a practicable escape maneuver is to maintain the flight level at a low height to pass the core of the downburst before starting the climb. This procedure can also be applied on the go-around.   Author

N91-10973# Southampton Univ. (England).
AIRCRAFT FLIGHT IN WIND-SHEAR
D. MCLEAN In AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3: Impact of New On-Board Technologies on Aircraft Operation 10 p (SEE N91-10967 02-04) Mar. 1990
(AGARD-AG-301-VOL-1-PT-1-3) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A brief account of wind-shear and some representations is given before discussing the effects of wind-shear on aircraft motion. A procedure for estimating the vertical and horizontal velocity components of a wind-shear microburst, based on observer theory is developed, and a brief discussion of flying in wind-shear concludes the paper.   Author

N91-10974# Airbus Industrie, Blagnac (France).
HOW TO FLY WINDSHEAR
PAUL CAMUS In Agard, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3: Impact of New On-Board Technologies on Aircraft Operation 10 p (SEE N91-10967 02-04) Mar. 1990
(AGARD-AG-301-VOL-1-PT-1-3) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Aviation safety history is a long fight against severe environmental constaint. Modern aircraft are able to face safely most of them but one still remains a potential killer, that is what is generally described as a windshear situation. What can be done, necessarily fall either in how to timely detect such a situation in order to avoid it or/and what tools could be given to the crew to better escape should they are trapped in. Latest state of build-in equipment, 3-D Navigation, electronic displays and flight control, provide now all necessary tools to develop an efficient in-board detection and protection system. Such a system will be described altogether with a review of some fundamental criteria to be considered when assessing their efficiency.   Author

N91-10976# Smiths Industries, Inc., Grand Rapids, MI.
AIRCRAFT TRAJECTORY: PREDICTION AND CONTROL IN THE AIR TRANSPORT FLIGHT MANAGEMENT COMPUTER SYSTEMS
PETER J. HOWELLS In AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3· Impact of New On-Board Technologies on Aircraft Operation 13 p (SEE N91-10967 02-04) Mar. 1990
(AGARD-AG-301-VOL-1-PT-1-3) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The declining cost of computing power and memory has enabled avionic manufacturers to develop sophisticated airborne computing systems. One of the most complex aircraft systems on modern air transport aircraft is the Flight Management Computer System (FMCS). The FMCS has reduced pilot workload by taking over the more mundane but complex functions, such as calculating the most economical speed, and, together with improvements in cockpit displays and monitoring systems, has allowed the transition from the three to two crew airline cockpit. The FMCS can compute the most economical path from one airport to another and then fly the aircraft along that path. To achieve this the computer must be able to select the most economical speed schedules for each phase of flight, then predict the complex vertical and horizontal profile that the aircraft would fly and, when connected to the aircraft's autopilot, control the aircraft along that three dimensional flight path. The forth dimension of time can also be selected as a control criteria, and the FMCS will compute the speed schedules and flight path based on a required time of a arrival at a selected point along the flight plan. In addition to reducing pilot workload, air traffic control efficiency is increased because the airborne navigation data base can be used to select and accurately fly published arrival and departure procedures without supervision from the ground controllers. The algorithms used for the Smiths Industries 737 FMCS prediction and control functions are described. The requirements for successful implementation and some of the difficulties that may be encountered are identified.   Author

N91-10977# Airbus Industrie, Blagnac (France). Flight Div.
IMPACT OF NEW TECHNOLOGY ON OPERATIONAL INTERFACE: FROM DESIGN AIMS TO FLIGHT EVALUATION AND MEASUREMENT
J. J. SPEYER, C. MONTEIL, R. D. BLOMBERG, and J. P. FOUILLOT (Paris V Univ., France) In AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3: Impact of New On-Board Technologies on Aircraft Operation 37 p (SEE N91-10967 02-04) Mar. 1990
(AGARD-AG-301-VOL-1-PT-1-3) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Since the early 1980s Airbus Industrie has conducted a progressive research program investigating the ergonomic, physiological, and psychological factors affecting flight crew in their

working environment, and progressively refining the data acquisition and analysis techniques. This self-imposed commitment to a dedicated appreciation of man-machine aspects was met in two ways: informally, by stringent application of human engineering principles, although in short supply in as far as their explicit formulation is concerned; and formally, by continuous development of statistical methods and engineering experiments, concentrating on pilot questionnaires, performance evaluations and workload models. A statistical workload calculation model highlights the link that enables correlation of pilot performance parameters with estimates on the impact of new technology on the operational interface. The purpose is to review the space between initial design aims and subsequent flight evaluation and measurement. A practical review is presented of the operational objectives and technological modules that marked the outgrowth of the Airbus family of commercial aircraft.   Author

N91-10981# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
AIRCRAFT TRAJECTORIES: COMPUTATION, PREDICTION, CONTROL, VOLUME 2: AIR TRAFFIC HANDLING AND GROUND-BASED GUIDANCE OF AIRCRAFT. PART 4: AIR TRAFFIC HANDLING. PART 5: GUIDANCE OF AIRCRAFT IN A TIME-BASED CONSTRAINED ENVIRONMENT. PART 6: SURVEILLANCE. PART 7: METEOROLOGICAL FORECASTS. PART 8: AIRCRAFT OPERATION IN AIR TRAFFIC HANDLING SIMULATION
ANDRE BENOIT, ed.   May 1990   453 p   In ENGLISH and FRENCH
(AGARD-AG-301-VOL-2-PT-4-8; ISBN-92-835-0562-X; AD-A225265)   Copyright   Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
This volume (part of a set of three) is composed of a preface and 28 papers covering respectively, the following topics. (1) Air traffic handling: Integration of control phases; A future European ATC concept; On-line prediction of aircraft trajectories; and Air traffic management. (2) Guidance of aircraft in a time based constrained environment: Guidance and control principles and concepts; Conduct of Air Traffic Control in a Zone of Convergence; Ground-based 4-D guidance of aircraft in moving atmosphere; and The Computer/Controller/Pilot dialogs. (3) Surveillance: Radar tracking; and Satellite techniques. (4) Meteorological forecasts: Impact of forecasts quality on trajector prediction; and Flight operations within a terminal area. (5) Aircraft operation in air traffic handling simulation: Realistic operation and motion of aircraft; and Flight operations within a terminal area. For individual titles, see N91-10982 through N91-11008.

N91-10984# Royal Radar Establishment, Malvern (England).
PREDICTION OF AIRCRAFT TRAJECTORIES
STANLEY RATCLIFFE   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 40 p (SEE N91-10981 02-05)   May 1990
(AGARD-AG-301-VOL-2-PT-4-8)   Copyright   Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Air traffic management, in designing route structures, drawing up rules for flight in various types of airspace, and in framing the instructions for air traffic controllers, are concerned with predicting the behavior, often on worst case assumptions, of each class of traffic with which they may have to deal. The problems are examined of on-line trajectory prediction to a time-horizon perhaps a little longer than the estimated time of the flignt or as short as a few tens of seconds, the object being to predict and avoid collision with terrain or with another aircraft, and to ensure that any in-flight delays due to traffic congestion along the route are absorbed as economically as possible. Military aircraft are concerned with the avoidance of anti-aircraft missiles and in intercepting airborne targets. This latter problem may, very loosely, be regarded as collision avoidance in reverse, and is briefly discussed, as is the problem of terrain-following by high performance low flying military aircraft. The conclusion draws

attention to areas where further R and D would seen desirable.
                                                                    Author

N91-10985# Universite Catholique de Louvain (Belgium). Dept. de Mecanique.
AIRCRAFT DYNAMICS FOR AIR TRAFFIC CONTROL
P.-Y. WILLEMS   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 19 p (SEE N91-10981 02-05)   May 1990
(AGARD-AG-301-VOL-2-PT-4-8)   Copyright   Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The equations of motion of airplanes in the context of Air Traffic Control (ATC) are discussed. The basic laws of mechanics are examined together with a mathematical model of mechanical systems which is suitable for airborne systems; the generally accepted (but often implicit) assumptions of usual models are pointed out. A simplified description of the main dynamical effects (gravity and aerodynamical interactions) are given together with a complete kinematical description of the system. The coherence with ISO norms (ISO - 1985) are respected as far as possible; some dynamical short commings of these norms are mentioned.
                                                                    Author

N91-10987# European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
GENERATION OF AIRCRAFT TRAJECTORIES FOR ON-LINE OPERATION: METHODS, TECHNIQUES, AND TOOLS
ANDRE BENOIT and SIP SWIERSTRA   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Habdling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecas. Part 8: Aircraft Operation in Air Traffic Handling Simulation 12 p (SEE N91-10981 02-05)   May 1990
(AGARD-AG-301-VOL-2-PT-4-8)   Copyright   Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An appreciable amount of work has been conducted at the EUROCONTROL Agency's Engineering Directorate in the division engaged in the Study of Long Term Air Traffic Control (ATC) System Requirements in order to generate accurate aircraft trajectory predictions for use in both ATC on-line operation and real time simulations in current and realistic conditions, human interfaces included. The basic approach developed for two distinct classes of application are outlined: (1) the on-line generation of predictions for use in actual operation and, accessorily, real time ATC simulations; and (2) the introduction of realistic aircraft response and motion into ATC simulations, with pilot/auto-pilot interfaces included.   Author

N91-12689*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE INTEGRATED AIRFRAME/PROPULSION CONTROL SYSTEM ARCHITECTURE PROGRAM (IAPSA)
DANIEL L. PALUMBO, GERALD C. COHEN (Boeing Advanced Systems Co., Seattle, WA.), and CHARLES W. MEISSNER   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 5 p (SEE N91-12682 04-08)   Apr. 1990
(AGARD-CP-456)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 01/3
The Integrated Airframe/Propulsion Control System Architecture program (IAPSA) is a two-phase program which was initiated by NASA in the early 80s. The first phase, IAPSA 1, studied different architectural approaches to the problem of integrating engine control systems with airframe control systems in an advanced tactical fighter. One of the conclusions of IAPSA 1 was that the technology to construct a suitable system was available, yet the ability to create these complex computer architectures has outpaced the ability to analyze the resulting system's performance. With this in mind, the second phase of IAPSA approached the same problem with the added constraint that the system be

designed for validation. The intent of the design for validation requirement is that validation requirements should be shown to be achievable early in the design process. IAPSA 2 has demonstrated that despite diligent efforts, integrated systems can retain characteristics which are difficult to model and, therefore, difficult to validate.
Author

N91-13434# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
MISSILE INTERCEPTOR GUIDANCE SYSTEM TECHNOLOGY
Sep. 1990 159 p Lecture series held in Hamburg, Fed. Republic of Germany, 11-12 Oct. 1990; in Amsterdam, Netherlands, 15-16 Oct. 1990; and in Cambridge, MA, 25-26 Oct. 1990
(AGARD-LS-173; ISBN-92-835-0587-5; AD-A228936) Copyright
Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Most operational interceptor tactical guidance systems are employing technologies which were developed more than two decades ago. Newer technologies have been slow to replace these mature technologies that meet the requirements; however, future interceptor guidance systems will have more demanding requirements and technological advances will have great payoff potential. The guidance system technology fundamentals are presented which will serve as background so that theoretical advances in future and proposed systems can be both understood and appreciated. For individual titles, see N91-13435 through N91-13442.

N91-13435# Johns Hopkins Univ., Laurel, MD. Applied Physics Lab.
MODERN ROBUST CONTROL FOR MISSILE AUTOPILOT DESIGN
ROBERT T. REICHERT and DAVID J. YOST In AGARD, Missile Interceptor Guidance System Technology 15 p (SEE N91-13434 05-05) Sep. 1990
(AGARD-LS-173) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The applicability of H(infinity) control to the design of automatic flight control systems for highly maneuverable, tail-controlled missiles is examined. The fundamentals of modern robust control analysis and synthesis are reviewed. Problem formulation with emphasis on selection of frequency domain weighting functions for design specifications and the role of modeling uncertainty are considered. An example problem is included as a tutorial overview of these methods.
Author

N91-14281# Royal Aeronautical Society, London (England). Aerodynamics Group Committee.
STORE CARRIAGE, INTEGRATION, AND RELEASE
A. B. HAINES In AGARD, Missile Aerodynamics 8 p (SEE N91-14278 06-02) Oct. 1990
(AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The highlights of the conference are summarized and a balanced view of recent developments and prospects for the future in both design and prediction are given. New design concepts (internal carriage, improved launch systems, and active control during launch); mathematical modeling for predictions of store release; development and application of experimental and engineering level prediction methods for installed drag, carriage loads, effects on aircraft stability, and store release trajectories; the RAE Tornado flight research programs to provide data for the evaluation of prediction methods (aircraft flow fields, store carriage loads, and release trajectories); and application of computational fluid dynamics to problems of store carriage and release - design and prediction are discussed.
Author

N91-14324# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AIRCRAFT DYNAMIC LOADS DUE TO FLOW SEPARATION
Sep. 1990 274 p In ENGLISH and FRENCH Meeting held in Sorrento, Italy, 1-6 Apr. 1990
(AGARD-CP-483; ISBN-92-835-0582-4; AD-A229616) Copyright
Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A state-of-the-art review of all types of separated-flow dynamic problems to be encountered in present and future aircraft is provided. In particular, the following topics are presented: evaluation of aerodynamic buffet input characteristics; in-flight and wind tunnel buffeting measurements; and aeroelastic buffeting prediction techniques. For individual titles, see N91-14325 through N91-14340.

N91-14334# Royal Aerospace Establishment, Bedford (England).
INTERACTION BETWEEN THE CANARD AND WING FLOW ON A MODEL OF A TYPICAL COMBAT AIRCRAFT
D. G. MABEY, B. L. WELSH, and C. R. PYNE In AGARD, Aircraft Dynamic Loads Due to Flow Separation 19 p (SEE N91-14324 06-05) Sep. 1990
(AGARD-CP-483) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The main features of canard/wing interaction were established by a comprehensive test of a half model of a typical combat aircraft in the RAE 13 x 9 ft Low Speed Wind Tunnel. The measurements comprised overall steady forces, buffeting on the wing and the canard, and steady and unsteady pressure distributions on the wing. The results show that the canard effective incidence (determined by the canard setting and the body/wing upwash) controls the canard/wing interaction. With attached flow the canard produces a downwash field which has significant effects when the wing flow is attached. With separated flow on the canard the downwash field is still produced but in addition there is vigorous mixing which inhibits the development of wing flow separations, increasing the overall lift, reducing the wing buffeting and reducing the drag. The process by which this favorable effect is achieved is illustrated by an analysis of the steady and unsteady pressure distributions on the wing at three spanwise sections. These results have important implications with respect to the development and optimization of other canard/wing configurations, particularly at high angles of incidence.
Author

N91-18076# Aeronautical Systems Div., Wright-Patterson AFB, OH. Systems Program Office.
C-17 PILOTED COCKPIT TESTING
WILLIAM G. HECKATHORN In AGARD, Progress in Military Airlift 14 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The C-17 aircraft under development will have a worldwide airlift mission in both combat and peacetime environments. With only two pilots in the cockpit, (eliminating the navigator and flight engineers, standards of Military Airlift Command (MAC) operations) design and testing must be logically thought out and executed to enhance mission completion and reduce the pilot workload. Numerous test facilities are being used to test the state-of-the-art avionics, its interference with the pilots, and the ability of the pilots to accomplish this mission.
Author

N91-18082# De Havilland Aircraft Co. of Canada Ltd., Downsview (Ontario). Powered Lift Technology Div.
THE DEVELOPMENT OF VERY THICK MULTI-FOIL WINGS FOR HIGH SPEED, POWERED LIFT TRANSPORT AIRCRAFT APPLICATIONS
J. E. FARBRIDGE   *In* AGARD, Progress in Military Airlift 20 p (SEE N91-18067 10-03)   Dec. 1990   Sponsored in part by Department of National Defence, Ottawa, Ontario and Department of Industry, Ottawa, Ontario
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   The theoretical development of the multi-foils between 18 and 30 percent thickness/chord is discussed and results are presented from high Reynolds number, high speed, 2D and 3C tunnel tests on foils up to 24 percent thickness/chord ratio. Both blown and unblown characteristics of the foils are reviewed. The integration of these multi-foil sections into high speed advanced USTOL (Ultra-Short Takeoff and Landing) transport aircraft studies using the ejector flap concept led to the potential for very efficient cruising transport aircraft with USTOL capability using only the thrust required for cruise. Several other potential applications for thick multi-foil sections are also discussed.   Author

N91-18084# Military Airlift Command, Scott AFB, IL.
C-130 REAR VISION DEVICE (BUBBLE)
MARK JULICHER   *In* AGARD, Progress in Military Airlift 5 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   Three devices for providing rearward vision were developed and tested. The first device was a standard HC-130 observation door as used in search and rescue operations. The second device was a 180 deg field-of-view (FOV) bubble mounted on the cockpit overhead escape hatch. The third device was similar to the second but provided a 360 deg FOV. The three devices were tested at various exercises and in special sorties against fighters. The test findings confirmed that the 360 deg FOV bubble proved to be the best of the three devices for warning against air-to-air attack and for observing the attacking aircraft during evasive maneuvers. A great deal of experience has now been gained through bubble operations. That experience can be conveniently divided into three parts: equipment, training, and the tactics. Those three topics and the future of the rear vision device program are also discussed.
Author

N91-18085#   Wright   Research   Development   Center, Wright-Patterson AFB, OH. Technology Exploitation Directorate.
TECHNOLOGY AND DESIGN CONSIDERATIONS FOR AN ADVANCED THEATER TRANSPORT
RICHARD V. WIBLE   *In* AGARD, Progress in Military Airlift 11 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   The design and technology issues posed by the perceived mission requirements for a twenty first century theater transport are addressed. The theater transport of the future will be called upon to operate throughout the world in a variety of climatic conditions, into and out of remote and austere locations with unimproved runways, limited or non-existing landing aids, and in many cases no cargo handling equipment. Such an airlifter will be required to operate near, and occasionally, into enemy territory, where the threat will be more lethal than in the past. The design and technology implications of these perceived requirements are discussed relative to three design/technology issues: field length, which addresses both the impact of takeoff and landing rules on Short Takeoff and Landing aircraft design, and the impact of propulsion and vertical lift payload on Vertical or Short Takeoff and Landing aircraft design; payload/aircraft size, which addresses typical theater transport payloads, productivity as a function of payload and the contribution of advanced materials on aircraft size; and survivability, which addresses the impact of low observables considerations upon theater transport design.
Author

N91-18087#   Aeroplane and Armament Experimental Establishment, Boscombe Down (England). Fixed Wing Engineering Section.
PROBLEMS IN CONVERTING CIVIL AIRCRAFT TO THE MILITARY TANKER ROLE
R. J. KILFORD   *In* AGARD, Progress in Military Airlift 6 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
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   Military tanker aircrafts are being increasingly produced by conversion of civil airliners. Civil and military aircrafts are designed to different philosophies and operated in different ways, the civil operation being predictable, the military less so. These different philosophies are discussed, as well as the problems arising from typical aircraft conversions. It is also suggested how future conversions can benefit from the lessons of the past.   Author

N91-18088# Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.).
C 160-TRANSALL LIFE TIME EXTENSION
HARTMUT GRIEM   *In* AGARD, Progress in Military Airlift 13 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
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AGARD/Scientific Publications Executive
   The C 160-Transall aircraft is described. Procedures for life time extension are discussed. The following subject areas are covered: measures referring to structure; systems modifications and replacements; and program procedures, documentation; and data bases.   Y.S.

N91-18089# Lockheed Aeronautical Systems Co., Palmdale, CA.
THE HIGH TECHNOLOGY TEST BED: A RESEARCH PROGRAMME FOR TECHNOLOGY DEVELOPMENT
C. B. PAYNE   *In* AGARD, Progress in Military Airlift 14 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
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AGARD/Scientific Publications Executive
   Proposed roles for future tactical airlift drive requirements for research and development in the areas of advanced Short Takeoff and Landing (STOL), Electronic Systems, Survivabililty, and Advanced Cockpit capabilities. A common scenario may involve deep penetration into enemy territory with no air or ground support. The transport may be required to land on bomb damaged runways, highways, or dirt roads. The aircraft may have to take on cargo in this area and get airborne again with the same runway requirement. The High Technology Test Bed (HTTB), an Independent Research and Development Program (IRAD) was begun to address technologies required for these future tactical transports. The program utilizes a commercial, stretched C-130 transport as the technology focal point. The aircraft is highly modified to perform the STOL mission and is fully instrumented with a real time data acquisition system. The HTTB undergoes modification spans followed by flight spans to evaluate systems performance.
Author

N91-18090# Douglas Aircraft Co., Inc., Long Beach, CA.
THE C-17: MODERN AIRLIFTER REQUIREMENTS AND CAPABILITIES
LEONARD R. TAVERNETTI   *In* AGARD, Progress in Military Airlift 10 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
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   The newest military airlift aircraft C-17 can rapidly move substantial quantities of large, modern weaponry in fighting condition any place on the globe. The new air transport capability capitalizes on proven technology which is currently incorporated into today's commercial airliners and front-line fighter aircraft. It is described how existing technology is being applied on the C-17 to satisfy the requirements for modern military airlift aircraft. The C-17 expands the traditional airland and airdrop modes of transportation to include direct delivery of large outsize equipment. This airlifter transports M-1 tanks, AH-64 helicopters, and Bradley Fighting Vehicles, and delivers them to semiprepared austere

airfields. The aircraft is operated by a crew of three employing fly-by-wire and mission computer technologies to integrate information and operations. Author

N91-22104# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON AIRCRAFT DYNAMICS AT HIGH ANGLES OF ATTACK: EXPERIMENTS AND MODELLING
Mar. 1991   144 p   Special course held in Hampton, VA, 8-11 Apr. 1991 and in Rhode-Saint-Genese, Belgium, 22-25 Apr. 1991; sponsored by AGARD and the von Karman Inst.
(AGARD-R-776; ISBN-92-835-0607-3; AD-A235321) Copyright Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Lecture notes for an AGARD Fluid Dynamics Panel Special Course on 'Aircraft Dynamics at High Angles of Attack: Experiments and Modelling' are presented. These notes present the latest information on the development and use of dynamic experiments in wind tunnels from several NATO nations. Current oscillatory and rotary test techniques, experimental results for typical configurations, and the use of these data for flight mechanics applications are addressed. Subjects include dynamic lift, wing rock, fluid dynamics of rotary flows, mathematical modelling, nonlinear data representation, vortex manipulation for control enhancement, and correlations of predictions based on rotary and oscillatory wind tunnel and flight test results. For individual titles, see N91-22105 through N91-22110.

N91-22106*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DYNAMIC STALL EFFECTS AND APPLICATIONS TO HIGH PERFORMANCE AIRCRAFT
JAY M. BRANDON   In AGARD, Special Course on Aircraft Dynamics at High Angles of Attack: Experiments and Modelling 15 p (SEE N91-22104 14-05)   Mar. 1991
(AGARD-R-776) Copyright Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 01/3

Recent research conducted at the NASA Langley Research Center on the effects of large amplitude pitching motions on the aerodynamic characteristics of modern fighter aircraft configurations is highlighted. Wind tunnel tests were conducted on simple flat-plate wings to gain understanding of the complex flow phenomena during unsteady motions at high angles of attack. Studies then progressed to a representative modern fighter configuration. Using a computer controlled dynamic apparatus, tests were conducted to investigate effects of pitch rate and motion time history and to determine the persistence of unsteady effects. Data were also obtained in sideslip and with control surface deflections to investigate dynamic effects on lateral stability and available control power. Force and moment data were obtained using a 6-component internal strain-gage balance. To aid in the interpretation of the results, flow visualization using a laser light-sheet system was also obtained. Results of these tests are discussed, along with their implications on the maneuverability of future advanced airplanes designed to operate in the highly dynamic, high angle-of-attack environment. Author

N91-22110# Eidetics International, Inc., Torrance, CA.
FOREBODY VORTEX CONTROL
GERALD N. MALCOLM   In AGARD, Special Course on Aircraft Dynamics at High Angles of Attack: Experiments and Modelling 40 p (SEE N91-22104 14-05)   Mar. 1991
(AGARD-R-776) Copyright Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Because conventional fighter aircraft control surfaces (e.g. rudder) become ineffective at high angles of attack, alternate means of providing aerodynamic control are being explored. A prime potential source for improved control power is the vortex flowfield existing on typical fighter aircraft forebodies. Several techniques to manipulate the forebody vortices to produce controlled forces and moments at high angles of attack have been investigated by a number of researchers in the past few years. Some of the research results and the merits of several methods applied directly to the forebody are discussed. These methods include movable strakes, blowing surface jets, blowing and suction through surface slots, suction through surface holes, and miniaturized rotatable tip

strakes. All of these were found to be effective over a varying range of angles of attack and sideslip. Most of the methods work on the basis of boundary layer separation control. The presence of closely spaced forebody vortices enhances the effectiveness, since controlling the separation controls the vortices which, in turn, creates large changes in forebody forces. Regardless of which method is employed, the maximum effectiveness is realized if it is applied near the forebody tip. The advantage of one method over another will depend on the configuration and specific performance requirements. Author

N91-23108# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
FLYING QUALITIES
Feb. 1991   379 p   In ENGLISH and FRENCH   Symposium held in Quebec City, Quebec, 15-18 Oct. 1990
(AGARD-CP-508; ISBN-92-835-0602-2; AD-A235323) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The purpose of this symposium was to review flying quality issues of today and to report progress towards their resolution. The following topic areas were covered: (1) flying qualities experiences and contemporary aircraft; (2) application of flying qualities specifications; (3) flying qualities research; and (4) flying qualities at high incidence. For individual titles, see N91-23109 through N91-23131.

N91-23109# Thomas (Dieter), Fuerstenfeldbruck (Germany, F.R.).
THE ART OF FLYING QUALITIES TESTING
DIETER THOMAS   In AGARD, Flying Qualities 12 p (SEE N91-23108 15-05)   Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A veteran test pilot discusses the need for flight test engineers to listen to test pilot opinion in designing cockpits and flight control systems. Through personal experiences, the test pilot illustrates the practical evaluation of good flying qualities and techniques used in this evaluation for the promotion of air safety through the expression of pilot opinion. K.S.

N91-23110# McDonnell-Douglas Helicopter Co., Mesa, AZ.
ADFCS AND NOTAR (TRADEMARK): TWO WAYS TO FIX FLYING QUALITIES
CHANNING S. MORSE   In AGARD, Flying Qualities 13 p (SEE N91-23108 15-05)   Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The development, flight tests, and flying qualities of the Advanced Digital Flight Control System (ADFCS) and No Tail Rotor (NOTAR) System for military helicopters are reviewed. Emphasis is placed on some of the directional control problems faced on the ADFCS program in left sideward flight and the potential for the NOTAR system to improve the flying qualities of an advanced, highly augmented rotorcraft. Author

N91-23111# Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH.
MIL-STD-1797 IS NOT A COOKBOOK
DAVID B. LEGGETT and G. THOMAS BLACK (Aeronautical Systems Div., Wright-Patterson AFB, OH.)   In AGARD, Flying Qualities 19 p (SEE N91-23108 15-05)   Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Despite many years of experience, some confusion still exists concerning the nature, purpose, and application of the flying qualities specifications. Much of this confusion stems from the form of the requirements themselves. A question frequently raised is whether flying qualities are pilot-oriented properties or whether they are the parameters defined in the requirements of the flying qualities specification. This question arises from the fact that most of the objective criteria in the specification are not closed-loop (pilot-in-the-loop) performance criteria or pilot acceptance criteria, but rather are criteria on open-loop (pilot-out-of-the loop)

characteristics of the augmented aircraft. Another source of confusion concerns the role of the specification itself: is it only a contractual document, or is it also a design guide. If the latter, is it equally effective in both roles. Consideration of the above questions leads to yet another. If the specification is intended as a design guide and the criteria are open-loop properties instead of closed-loop properties, which is more important: pilot satisfaction with closed-loop performance or compliance with the open-loop requirements? These questions are addressed by reviewing the background of the United States military flying qualities specifications. The advantages and disadvantages of different types of requirements are discussed. The way the specification is used by the USAF Aeronautical Systems Division Program offices is described.   Author

N91-23112#   Aeritalia S.p.A., Turin (Italy).   Flight Mechanics Group.
FLYING QUALITIES EXPERIENCE ON THE AMX AIRCRAFT
BAVA RENZO   In AGARD, Flying Qualities 20 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17;
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    The AMX is a subsonic ground attack aircraft with a fly-by-wire flight control system (FCS) built into a digital flight control computer. From the flight mechanics point of view, it was designed against the MIL-F87985-C requirement. For some specific flight tasks, the need of more demanding requirements was envisaged. Modern handling qualities criteria were applied in the area of longitudinal and lateral-directional precision tracking task and pilot-induced oscillation (PIO) tendencies to cope with operational problems. High incidence criteria were used in the design and evaluation of control modifications which improve the flying qualities in the stall and post stall regions. Comparisons between analytical predictions, manned simulation, and in-flight results were made. Indications of agreement or disagreement with data and new criteria are presented.   Author

N91-23115#   Aeronautical Systems Div., Wright-Patterson AFB, OH.
DO CIVIL FLYING QUALITIES REQUIREMENTS ADDRESS MILITARY MISSIONS FOR OFF-THE-SHELF PROCUREMENT
G. THOMAS BLACK, WALTER A. GRADY (Test Wing, 4950th, Wright-Patterson AFB, OH), and DANN C. MCDONALD   In AGARD, Flying Qualities 8 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17;
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    Off-the-shelf procurement of civil aircraft for use by the military services is a tradition dating back to the earliest days of aviation. This relieves the military of the responsibility for development costs, takes advantage of civil designs already in existence, and has resulted in the development of many capable military aircraft. However, while civil aircraft missions have remained relatively unchanged for over half a century, new military mission have continued to evolve. Yet, the military services still procure civil certified aircraft to accomplish these demanding missions. In the United States, Federal Aviation Regulations 23 and 25 and their predecessors are the certification standards for civil aircraft. The primary objective of these regulations is to insure a minimum standard of airworthiness. Flying qualities requirements make up only a small portion of these regulations, and address primarily static stability characteristics. This has sometimes led to undesirable flying qualities when attempting to perform demanding military mission while civil certificated aircraft. The unique military missions are addressed in the U. S. military flying qualities specification, MIL-STD-1797A, and its predecessors (MIL-F-8785 series). These military specification requirements are compared to the civil requirements to substantiate their applicability to off-the-shelf procurement. Specifically, where military and civil missions differ, military flying qualities requirements should be invoked. To illustrate this, several examples are examined. Finally, the future of off-the-shelf procurement is contemplated, some implications discussed, and recommendations made.   Author

N91-23118#   Pisa Univ. (Italy).   Dipartimento di Ingregneria Aerospaziale.
METRICS FOR ROLL RESPONSE FLYING QUALITIES
MARIO INNOCENTI   In AGARD, Flying Qualities 11 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    Roll characteristics of highly augmented aircraft during compensating tasks such as tracking and landing are shown to present degraded flying qualities and unstable oscillations similar to those observed in the pitch axis. The ideas behind Gibson's method are extended to develop handling qualities criteria for the roll axis control system. The analysis is performed using an existing data base for highly augmented class IV aircraft and parameters such as roll time constant, systems delay, and loop sensitivity are considered for designing for good handling qualities and to evaluate control systems performance. Levels of flying qualities are determined in the time domain as well as in the frequency domain for both tracking and landing tasks. The presence of pilot induced oscillations and roll ratcheting are identified.   Author

N91-23120#   Calspan Advanced Technology Center, Buffalo, NY. Flight Research Dept.
THE FLYING QUALITIES INFLUENCE OF DELAY IN THE FIGHTER PILOT'S CUING ENVIRONMENT
RANDALL E. BAILEY   In AGARD, Flying Qualities 25 p (SEE N91-23108 15-05) Feb. 1991
(Contract F33615-83-C-3603)
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17;
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    Flight testing has amply demonstrated the serious flying qualities deficiencies that can occur from excessive control system delay. Delay outside of the control system, yet within the pilot's cuing environment, can be potentially as deleterious as control system delay effects. Summarized here are the results of flight tests to evaluate the effect on flying qualities on time delay in the pilot's cuing environment introduced outside the flight control system. These delays were introduced in the tactile cuing, head-up display visual cuing, and the motion and visual cuing during the simulation of fighter aircraft.   Author

N91-23121#   Systems Technology, Inc., Hawthorne, CA.
ESTIMATION OF PILOT RATINGS VIA PILOT MODELING
DUANE MCRUER   In AGARD, Flying Qualities 24 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    In well-designed flying qualities experiments, pilot ratings and commentaries become fundamental indicators of pilot and system dynamic behavior, system performance, and pilot workload. Accordingly, they are intrinsically associated with pilot models. Some of these connections are summarized. A brief review of appropriate pilot dynamic models is followed by an introduction to pilot ratings in general. One approach that has been used to connect the pilot's assessments to pilot and pilot-vehicle system dynamics, is to associate pilot and system dynamic and performance characteristics with ratings using functional relationships. Representative forms of pilot rating functionals are given and illustrated by an extensive cross section of examples. A means of combining single axis ratings into a multi-axis estimate is developed. The development relies on workload and attentional demand concepts, although the ultimate combination rules have a validity based on experiment which transcends any such basis. Also covered is a clinical approach to rating estimates, which is more general and does not rely directly on empirical correlations.   Author

N91-23122# National Aeronautical Establishment, Ottawa (Ontario). Flight Research Lab.
AN INITIAL STUDY INTO THE INFLUENCE OF CONTROL STICK CHARACTERISTICS ON THE HANDLING QUALITIES OF A FLY-BY-WIRE HELICOPTER
J. MURRAY MORGAN *In* AGARD, Flying Qualities 13 p (SEE N91-23108 15-05) Feb. 1991 Sponsored in part by Department of National Defence, Ottawa, Ontario
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A piloted experiment was flown using the Institute for Aerospace Research Bell 205A variable stability helicopter. The experimental variables were the static and dynamic characteristics of a conventional center-mounted cyclic controller. The cyclic controller characteristics were changed by varying the mass and spring gradient to provide five basic cases, while for each case the dynamics of the stick were varied to provide critically damped, underdamped, and overdamped models. Two pilots were asked to fly a variety of tasks designed to exercise three fundamental modes of helicopter flight, high frequency stabilization, gross single axis tasks with off axis stabilization and simultaneous multi axis control. The stick sensitivity was adjusted in proportion to the spring gradient to give constant static sensitivity with respect to applied force. A first order filter was incorporated on an optional basis to reduce the command response bandwidth of the roll channel to the Level 1/Level 2 boundary of the ADS-33C criterion for divided attention operation. The results achieved indicate that cyclic stick characteristics are of considerably less importance than had been previously thought, that large values of overdamping can be tolerated even in low frequency sticks, but that underdamped sticks should be avoided especially if the resonant frequency of the stick is close to an undesirable and easily excited aircraft mode. There was a suggestion that a boundary based on undamped natural frequency also existed. The results did not support the contention that inertia alone is enough to specify an acceptable/unacceptable boundary for stick design. Author

N91-23126# Test Squadron (6510th), Edwards AFB, CA.
B-1B HIGH AOA TESTING IN THE EVALUATION OF A STALL INHIBITOR SYSTEM
MARK S. SOBOTA *In* AGARD, Flying Qualities 21 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

High angle-of-attack (AOA) B-1B flight tests were conducted to evaluate a flight control Stall Inhibitor System/Stability Enhancement Function (SIS/SEF). The SIS/SEF system was integrated into the basic B-1B flight control system because of an inherent stability problem in the B-1 aircraft design. The problem lies in the fact that aerodynamically the B-1 was stability limited and not lift limited. This resulted in a lack of longitudinal stability while operating at high AOA conditions with no warning or natural cues to the pilot that the aircraft was approaching an unstable region. To safely utilize all the available AOA at the higher gross weights demanded, some means of providing 'apparent' stability was essential to provide cues to the pilot of these stability limitations. Significant test results of the SIS/SEF flight test program are presented. Author

N91-23127*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
FLYING QUALITIES OF THE X-29 FORWARD SWEPT WING AIRCRAFT
LAWRENCE A. WALCHLI (Wright Research Development Center, Wright-Patterson AFB, OH.) and ROGERS E. SMITH *In* AGARD, Flying Qualities 13 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01/3

An overview of the X-29 Forward Swept Wing Technology Demonstrator traces its development and test path during past years. Brief descriptions of the aircraft and its flight control system provide insight for evaluating this unique vehicle. The baseline flight control system provided a starting point for safe concept evaluation and envelope expansion for the aircraft. Subsequent up-dates resulted in performance levels favorably comparable to

current fighter aircraft. Efforts are described for the current expansion of the X-29's capabilities into the high angle-of-attack (AOA) regime of flight. Control law changes have permitted all axis maneuvering to 40 deg AOA with pitch excursions to 66 deg, thereby exploiting the full potential of the X-29 forward swept wing configuration. Author

N91-23128# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.
HANDLING QUALITIES EVALUATION FOR HIGHLY AUGMENTED HELICOPTERS
HEINZ-JUERGEN PAUSDER and WOLFGANG VONGRUENHAGEN *In* AGARD, Flying Qualities 14 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The realization and utilization of the helicopter airborne simulator ATTHeS (Advanced Technology Testing Helicopter System) are described. The explicit model following control system which is designed for ATTHeS is briefly presented. The potential is reviewed of the simulation system which is illustrated by the overall system performance identified from flight test data. Due to the implemented explicit model following systems, the in-flight simulation facility is provided with the capability of a flexible and broad variation of stability and control characteristics. Finally, results of a bandwidth phase delay study are presented and the influence of coupling on handling qualities evaluation is discussed. Author

N91-23129# Naval Air Development Center, Warminster, PA. Flight Dynamics Branch.
AGILITY: A RATIONAL DEVELOPMENT OF FUNDAMENTAL METRICS AND THEIR RELATIONSHIP TO FLYING QUALITIES
C. J. MAZZA *In* AGARD, Flying Qualities 7 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The results of the first phase of a three year agility program are presented. A highly valuable approach was produced for developing a rational concept of agility and for relating agility to the flight dynamics, maneuvering performance, and to the design of the aircraft. The flight mechanics of a rigid aircraft in three-space maneuvering flight are examined with respect to total velocity, acceleration, and the time-rate-of-change of accleration. The terms of the expanded 'agility vector' are interpreted with regard to their potential for providing a rational basis for the evaluation of any given set of agility metrics and for suggesting, directly, a new set of metrics. A potential form of agility is offered for which a readily acceptable relationship is traced to both flying qualities and maneuvering performance. Author

N91-23130# British Aerospace Public Ltd. Co., Preston (England). Military Aircraft Div.
A REVIEW OF HIGH ANGLE OF ATTACK REQUIREMENTS FOR COMBAT AIRCRAFT
K. MCKAY and M. J. WALKER *In* AGARD, Flying Qualities 12 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Design of an aircraft for use at high angles of attack can have major implications on the configuration which is chosen. The objective is to review the implications of designing for high angle of attack on configuration. This naturally leads onto consideration of agility and the criteria which could be used in the early design stages to ensure an aircraft is adequately agile. Author

N91-23131# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
X-31A AT FIRST FLIGHT
W. B. HERBST *In* AGARD, Flying Qualities 8 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The X-31A accomplished its first flight on October 11, 1990. A summary is presented about objectives of this international

experimental flight test development program, its status, and follow-on planning.   Author

N91-25146#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Flight Mechanics Panel.

HANDLING QUALITIES OF UNSTABLE HIGHLY AUGMENTED AIRCRAFT
May 1991   120 p
(AGARD-AR-279; ISBN-92-835-0609-X; AD-A237854)   Copyright
Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Reviewed here are handling quality issues of highly augmented unstable aircraft. Handling qualities criteria for both large and small amplitude longitudinal maneuvers are presented. Basic aerodynamic design, specific issues relating to the feel system and control sensitivity, evaluation techniques, and the handling qualities design process are discussed. The subjects of careful handling, lateral-directional criteria and agility are presented in separate appendices.   Author

N91-28150#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Structures and Materials Panel.

LANDING GEAR DESIGN LOADS   .
1990   283 p   In FRENCH and ENGLISH   Meeting held in Povoa de Varzim, Portugal, 8-12 Oct. 1990
(AGARD-CP-484; ISBN-92-835-0611-1; AD-A239914)   Copyright
Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Papers presented to a Specialists Meeting organized by the Structures and Materials Panel are reported. The meeting provided a forum for the exchange of experiences between the NATA nations with the aim of advancing landing gear design criteria and methods of landing gear analysis. The meeting reviewed existing design practices and specifications, considered the various methods for load measurement and data analysis, and formulated guidelines for future design procedures. For individual titles, see N91-28151 through N91-28166.

N91-28151#   National Defence Headquarters, Ottawa (Ontario). Directorate Aerospace Support Engineering.

FAILURE ANALYSIS CASE HISTORIES OF CANADIAN FORCES AIRCRAFT LANDING GEAR COMPONENTS
P. BEAUDET and M. ROTH (Department of National Defence, Ottawa, Ontario)   In AGARD, Landing Gear Design Loads 24 p (SEE N91-28150 20-05)   1990
(AGARD-CP-484)   Copyright   Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Despite the extensive landing gear design analyses and tests carried out by the designers and manufacturers, and the large number of trouble-free landings accumulated by the users, the Canadian Forces, as well as others, have experienced a range of problems or failures with landing gear components. Different data banks were surveyed and over 200 cases histories on more than 20 aircraft types were reviewed in order to assess trends in failure mechanisms and their causes. Fatigue and corrosion were found to be the main mechanisms. Fatigue occurred mainly in steel components while corrosion occurred mainly with aluminum alloy components and wheels. Very few overload failures were noted. Different failure causes were identified. Design deficiencies and manufacturing defects led mainly to fatigue failures while poor material selection and improper field series of preventive measures was either recommended or re-emphasized. While fatigue can best be addressed by improving the quality of manufacturing and by better characterizing in-service and manufacturing stress, much work remains to be done on the time-dependent degradation processes. Their synergism with fatigue and corrosion has often been neglected in both the design and testing stages as well as in the maintenance domain.   Author

N91-28152#   Aeronautical Systems Div., Wright-Patterson AFB, OH.

APPLICATION OF THE AIR FORCE GUIDE SPECIFICATION 87221A TO GROUND LOADS
DAN SHEETS and ROBERT GERAMI   In AGARD, Landing Gear Design Loads 6 p (SEE N91-28150 20-05)   1990
(AGARD-CP-484)   Copyright   Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The U.S. Air Force has eliminated the use of rigid and mandatory structural design specifications. In their place a new approach has been instituted that requires that every system structural specification be rationally tailored to the actual anticipated aircraft usage. The Air Force Guide Specification (AFGS-87221A) produces total system performance requirements as opposed to the old approach of meeting selected, isolated criteria. This new approach entails the conversion of operational requirements into the associated and anticipated loading environments. Examples of how this new design approach is applied are given.   Author

N91-28153#   Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).

DEVELOPMENT OF UNDERCARRIAGE DESIGN LOADS
G. KEMPF and G. H. HAINES (Dowty Aerospace Gloucester, England)   In AGARD, Landing Gear Design Loads 12 p (SEE N91-28150 20-05)   1990
(AGARD-CP-484)   Copyright   Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    During the different phases of development from feasibility studies to the final design, the landing gear designer applies increasingly refined methods of analysis to derive the loads to which the system is designed. Future design procedures should reflect such a staged approach leading to designs which are fully optimized with the aid of rational methods of analysis to meet the complete range of aircraft operating conditions. Here, the design process is described. Comparisons are made of design load cases obtained using current landing gear requirements and those derived by rational analysis. These comparisons are made for the critical phases of landing touchdown, derotation onto the nosegear, landing roll out, repaired runway operation, etc. The application of the rational method of analysis to determining aircraft operating envelopes under asymmetric landing conditions is also discussed. Finally areas of work are identified which need addressing further, in order that a staged approach can be adopted completely in the future military landing gear design procedures.   Author

N91-28154#   Wright Research Development Center, Wright-Patterson AFB, OH.

RECENT DEVELOPMENTS IN THE AREA OF AIRCRAFT ROUGH FIELD PERFORMANCE
DAVID MORRIS and TONY GERARDI   In AGARD, Landing Gear Design Loads 10 p (SEE N91-28150 20-05)   1990
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    Under project Have Bounce (HB), the USAF successfully determined the level of surface roughness that could be tolerated by most aircraft in the inventory. The runway roughness capability of each aircraft was determined by developing a sophisticated computer model of each aircraft. In most cases these computer models were validated with aircraft tests on rapidly repaired runways. This multimillion dollar effort has resulted in the definition of surface roughness criteria (repair criteria) for each aircraft. The knowledge gained as a result of all the testing and computer modeling has led to a much more thorough understanding of the complex interaction between the flexible structure, landing gear, and rough pavement. Discussed here is the development, laboratory qualification testing, and taxi testing of an improved F-15 rough field landing gear which provides a significant improvement in rough field and sink rate performance over the existing F-15 landing gear. This landing gear design utilizes passive, internal strut modification to achieve this performance without any effect on reliability and maintainability. Also discussed are the advantages of an automated Personal Computer (PC) based process for selecting the minimum operating strip (MOS) and for determining the minimum level of runway repair required. As backup to this automated approach, a novel technique for quantifying the

ability of a given aircraft to traverse rough surfaces is also discussed. This method assigns a Vulnerability Index (VI) to each aircraft. The VI is a reflection of the aircraft's ability to absorb the energy that is transmitted from the pavement to the struts and the airframe. This method will give the base commander a tool for making good intuitive decisions in the event that the automated process cannot be used. It can also be used as a validation technique for the automated method.   Author

N91-28155#   British   Aerospace   Public   Ltd.   Co., Kingston-upon-Thames (England). Aerodynamics Dept.
THE SPECIAL REQUIREMENTS OF A VSTOL AIRCRAFT
D. C. THORBY, J. JOHNSON, A. B. K. AULD, H. T. NEWMAN, and M. J. BROOKER   *In* AGARD, Landing Gear Design Loads 24 p (SEE N91-28150 20-05)   1990
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        The special landing gear requirements of the Harrier family of aircraft are described. Only topics peculiar to the Vertical and Short Take Off and Landing (VSTOL) aspects of this aircraft are addressed. Of the four possible modes of take-off, ramp-assisted (the ski jump) presents unique landing gear problems. This is described, covering the design of ramp profiles and the procedures used to establish service operating limits for the landing gear, including the effects of ship motion. The particular problems associated with vertical landing are discussed. This mode of landing can produce landing gear side loads potentially much higher than are normally possible in a conventional landing with forward speed. Clearance procedures using a multivariate approach are described. The Harrier has also been cleared for operation on unprepared rough fields. The Monte Carlo method, applied to the results of numerical modeling using computer-generated surfaces, is described. Other topics discussed are runway directional stability, and the load and directional stability implications of converting to radial tires.   Author

N91-28156#   Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Airplane Div.
CONSIDERATIONS ON OPTIMALITY OF LANDING GEAR ARRANGEMENT AND DESIGN
A. J. KRAUSS   *In* AGARD, Landing Gear Design Loads 11 p (SEE N91-28150 20-05)   1990
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        Much effort has been spent and is still being spent on development and improvement of optimization procedures and computer codes. The formal task of optimization is to quantify that set of design variables which both satisfies a set of constraints and yields the absolute maximum or minimum of an objective function. One of the intrinsic problems of optimization is that the objective must be expressed as a numerical quantity, which often leads to conversion problems (in which way can one convert a quality into a nonnegative real number?). An other even more serious problem is that formal optimization requires that the dependence of the objective on the design variables must be analytically defined. In relation to these problems it appears of secondary importance that in most cases the optimization process will stop at the local optimum which is closest to the starting design, albeit there might exist better optimum solutions across the surrounding ridges of the objective function. Before formal (automatic) optimization methods are called in, the design must therefore be developed to a starting point in reasonable vicinity to the real optimum. A retractable landing gear is complex, requires a lot of internal space on the airplane, features a variety of doors, spoils the cleanliness of the structure by large cutouts and local introduction of large loads, and adds weight. Unquestionably the landing gear impairs flight performance proper of an airplane. However, operational benefit from a landing gear apparently is big enough to outweigh said disadvantages. It appears that the primary objective of airplane design is operational usefulness. Now, having accepted the landing gear as a basically useful subsystem, the aircraft designer should proceed by integrating the landing gear into overall functional optimization of the system. Based on a functionally sound general arrangement of the landing gear, specialists for aircraft-integrating the landing gear loads evaluation teamed with landing gear design specialists should provide for

optimum detail characteristics fulfilling a variety of design criteria.
                                                            Author

N91-28157#   Aeronautical Research Inst. of Sweden, Bromma. Structures Dept.
LONG TIME MEASUREMENTS OF LANDING GEAR LOADS ON SAAB SF-340 COMMUTER AIRCRAFT
A. I. GUSTAVSSON, A. F. BLOM, and L. HELMERSSON (Saab-Scania, Linkoping, Sweden)   *In* AGARD, Landing Gear Design Loads 16 p (SEE N91-28150 20-05) 1990 Sponsored in part by the Swedish Board for Technical Development; the Swedish Civil Aviation Admin.; and SAAB-SCANIA AB
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        Strain gauge measurements of forces acting on the nose gear and main gears of the commuter aircraft SAAB SF-340 are discussed. During initial flight tests, forces in the longitudinal, transversal and vertical directions were measured for various maneuvers such as take-off, landing, taxiing and towing. The investigation revealed high transversal loads at the main gears at touch-down. The nose gear is most severely strained when steering during taxiing run and when the aircraft is towed connected to a tractor with a tow-bar. The results from such initial measurements formed the basis for a subsequent investigation with on line data acquisition of landing gear loads on a commuter aircraft in service at Swedair AB. The data acquisition system and the data analysis methods are described in some detail. The data acquisition was continuously carried out during nearly six months, and included various parameters such as different aircraft weight and static landing gear loads. Results from these measurements are presented as cumulative exceedances of longitudinal, transversal and vertical loads obtained from the rain-flow count analysis performed on-line during the measurements.   Author

N91-28158#   Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.).
OPERATIONAL LOADS ON LANDING GEAR
V. LADDA and H. STRUCK   *In* AGARD, Landing Gear Design Loads 16 p (SEE N91-28150 20-05) 1990
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        Prior statistics of airworthiness authorities indicate that landing gear (safe life design) often fail during scheduled aircraft service. Therefore investigations have been carried out during the last two decades in Germany with the aim of determining operational loads acting on the landing gear during service and defining the load cases which have to be taken into consideration for fatigue investigations related to landing gear and airframe. Statistics about failures on landing gear for civil and military aircraft and relevant load cases as well as information about essential fatigue requirements are presented. Some results of different landing gear load measurements are compared and discussed. These results, presented in form of cumulative frequency distributions for the taxiing and landing impact load cases, originate from the following measurements: Airbus A320; Airbus A310; Airbus A300; VFW 614; F-104 G. The impact of towing and push back operations on the nose landing gear using conventional and advanced towing methods is discussed. The primary results of the landing gear loads measurements are accentuated. Examples for the disposition of landing gear fatigue tests are considered, and essential future actions concerning load monitoring activities including hard- and overweight landing detection are reviewed.   Author

N91-28159#   Wright   Research   Development   Center, Wright-Patterson AFB, OH.
LANDING GEAR IMPROVEMENTS FOR TRANSPORT AIRCRAFT
J. GREER MCCLAIN and B. M. CRENSHAW (Lockheed Aeronautical Systems Co., Marietta, GA.)   *In* AGARD, Landing Gear Design Loads 17 p (SEE N91-28150 20-05) 1990
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        Discussed here are development, testing, and analysis of retrofit nose and main landing gears designed for improvement in C-130 transport aircraft rough field capabilities, concentrating primarily

upon analytical model prediction aspects which might be applicable to other gear designs. Two levels of improvement are examined, with the second level resulting in a new longer stroke strut designed to retract into existing stowage volume. All improved gears are qualified by laboratory drop tests and also are compared with test results. Model improvements are developed where necessary, with particular attention to representing strut friction, predicting strut rebound damping, and modeling transition from isothermal toward adiabatic conditions in the strut inflation gas. Rough field capability estimates for the C-130 equipped with these gears are made. Recommendations for further analytical model improvements are included.   Author

N91-28160# Messier-Hispano-Bugatti S.A., Montrouge (France).
NUMERICAL SIMULATION OF THE DYNAMIC BEHAVIOR OF LANDING GEARS [SIMULATION NUMERIQUE DU COMPORTEMENT DYNAMIQUE DES ATTERRISSEURS]
JEAN LUC ENGERAND   In AGARD, Landing Gear Design Loads 28 p (SEE N91-28150 20-05)   1990   In FRENCH; ENGLISH summary
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    The aim here is to describe the Messier-Bugatti analysis and numerical simulation system used for solving landing gear dynamics problems. The system is designed around a finite elements software package for the analysis of mechanisms and flexible bodies. The following examples of applications are examined: simulation of landing, simulation of taxiing on rough fields or repaired runways, simulation of extension and retracting, simulation of catapulting, and analysis of shimmy stability.   Author

N91-28161# Dassault (E. M.) Co., Saint Cloud (France).
CALCULATION OF INTERACTIONS BETWEEN AIR AND GROUND OF LANDING
YVES MARTIN-SIEGFRIED   In AGARD, Landing Gear Design Loads 23 p (SEE N91-28150 20-05)   1990   In FRENCH; ENGLISH summary
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    The author presents the present state-of-the-art for the calculation of the ground dynamic response of the aircraft. The analysis tool described here forms a special branch of the CATINA-ELFINI system, the general purpose program for computer aided design (CAD) and structural analysis of DASSAULT. The system handles a large set of problems for ground dynamic response: landing impact, rough runway rolling and take off, catapulting and landing on carrier, etc. In these calculations, the structure is represented by a finite element model of the whole aircraft coupled with models of landing gears, aerodynamics, and other special systems (e.g., catapult). The time integration is performed via implicit finite differences scheme. The method handles nonlinearities with three levels of condensation: one time before integration; at each time step linearization of smooth nonlinearities (e.g., large rotations) and condensation of the problem for only nonlinearizable D.O.F. (as lamination); and resolution at each time step of these few hard nonlinear equations by a special B.F.G.S. method. The author presents some significant types of simulation stemming from analyses of Mirage III, Super-Etendard, Mirage 2000 and Rafale.   Author

N91-28162# Fokker B.V., Schipol-Oost (Netherlands).
THE USE OF MONTE CARLO SIMULATION IN DETERMINING LANDING GEAR LOADS DURING LANDING
R. VANDERVALK   In AGARD, Landing Gear Design Loads 12 p (SEE N91-28150 20-05)   1990
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    It is perceived by the airworthiness authorities that certification of automatic landing systems can only be done by applying statistical methods. However, if these particular statistical requirements are satisfied, there is no guarantee for the aircraft manufacturer that local limit and ultimate loads (stresses), developed during landing, occur at acceptable risk levels. Here, another approach is proposed, which is based on direct calculation of local loads by means of Monte Carlo simulation. In this context,

the concept of load cases is superfluous (apart from preliminary design). Limited and ultimate loads are obtained by reading probability of exceedance distributions at desired risk levels. Maxima and minima are used for calculation of limit and ultimate loads. The whole time histories are used for the calculation of fatigue loads.   Author

N91-28163# Politecnico di Milano (Italy). Dipt. di Ingegneria Aerospaziale.
DESIGN LANDING LOADS EVALUATION BY DYNAMIC SIMULATION OF FLEXIBLE AIRCRAFT
G. L. GHIRINGHELLI and M. BOSCHETTO (Aeronautica Macchi S.p.A., Varese, Italy)   In AGARD, Landing Gear Design Loads 12 p (SEE N91-28150 20-05)   1990
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    Some significant applications of the integrated system GRAALL (Ground Roll Air And Landing Loads) to the analytical prediction of aircraft landing loads carried out at Aermacchi are presented. The capabilities of the system, able to treat both rigid and flexible models, make it a tool that can be profitably used during different phases of the design process. The results reported here describe the whole development of an actual design application; comparisons between analytical and experimental data are also provided.   Author

N91-28164*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
F-106B AIRPLANE ACTIVE CONTROL LANDING GEAR DROP TEST PERFORMANCE
WILLIAM E. HOWELL, JOHN R. MCCEHEE, ROBERT H. DAUGHERTY, and WILLIAM A. VOGLER   In AGARD, Landing Gear Design Loads 8 p (SEE N91-28150 20-05)   1990
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    Aircraft dynamic loads and vibrations resulting from landing impact and from runway and taxiway unevenness are recognized as significant factors in causing fatigue damage, dynamic stress on the airframe, crew and passenger discomfort, and reduction of the pilot's ability to control the aircraft during ground operations. One potential method for improving operational characteristics of aircraft on the ground is the application of active-control technology to the landing gears to reduce ground loads applied to the airframe. An experimental investigation was conducted on series-hydraulic active control nose gear. The experiments involved testing the gear in both passive and active control modes. Results of this investigation show that a series-hydraulic active-control gear is feasible and that such a gear is effective in reducing the loads transmitted by the gear to the airframe during ground operations.
                                                                          Author

N91-28165# BMW-A.G., Munich (Germany, F. R.). Structural Dynamics and Acoustics.
ACTIVELY DAMPED LANDING GEAR SYSTEM
RAYMOND FREYMANN   In AGARD, Landing Gear Design Loads 18 p (SEE N91-28150 20-05)   1990
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    An active control undercarriage for the alleviation of aircraft landing gear and structural loads during operation on rough runway surfaces is described. For quantitative determination of the improvements obtained with an active control undercarriage compared with conventional landing gear systems, aircraft taxiing is realistically simulated by means of a laboratory test set-up especially designed for this kind of testing.   Author

N91-28166# SAC Technology Ltd., Walton-on-Thames (England).
ASSESSMENT OF THE APPLICATION OF THE WORKING GROUP 22 STANDARD BUMP CONCEPT TO A CURRENT MILITARY AIRCRAFT
E. F. WILD, B. R. MORRIS, and A. E. DUDMAN (British Aerospace Public Ltd. Co., Bristol, England) *In* AGARD, Landing Gear Design Loads 19 p (SEE N91-28150 20-05) 1990
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The application of standardized runway repair obstacles (SRO) for design purposes and post-design capability determinations was a basic outcome of SMP Working Group 22 deliberations. The WG 22 standardized shapes have been the basics of clearance work for a current military aircraft. To verify the adequacy of the SRO profile for this work the response to real repair profiles, obtained from practice repairs, has been related to the response to the SRO. Some comments on the SRO as a representation of real repairs and on some undesirable features of real repair profiles are presented. Author

N92-11001# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanic's Panel.
ROTORCRAFT SYSTEM IDENTIFICATION
Sep. 1991 291 p
(AGARD-AR-280; ISBN-92-835-0632-4; AD-A244250) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

For fixed wing aircraft, system identification methods to determine stability and control derivatives from flight test data are used with confidence. The application of the same techniques to rotorcraft is not so far advanced mainly because of the helicopter aeromechanical complexity. Only a few specialists have concentrated on this field and the application in industry is still sporadic. To coordinate these activities within the AGARD nations, a working group was constituted to focus on the applicational aspects of the various individual approaches and to evaluate the strengths and weaknesses of the different methods. The findings are presented of the Working Group including a documentation of the data bases, the applied identification methodologies, and major application areas. For each of the three helicopters, comparisons of the obtained results are discussed in the format of case studies, covering data quality evaluations, identification, and the verification of the obtained models. Author

N92-12534# Naval Air Development Center, Warminster, PA.
AI FOR RPVS, SENSOR DRIVEN AIRBORNE REPLANNER (SDAR), FOR A ROBOTIC AIRCRAFT SENSOR PLATFORM (RASP)
R. M. WILLIAMS and J. J. DAVIDSON *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 6 p (SEE N92-12517 03-63) Sep. 1991
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The Robotic Aircraft Sensor Platform (RASP) simulation developed at the Naval Air Development Center in Warminster, PA. is described. A hardware and associated software architecture was developed to use on-board sensor information for high level artificial intelligence (AI) decision making. The decisions then direct the flight path of the aircraft and camera gimbal through complex environments. This project has produced a system architecture that breaks the bottleneck of flyable real time AI control systems. The work has transitioned into three new efforts: a flight test effort for the Unmanned Air Vehicle Joint Program Office; an investigation into the use of SDAR for novel systems of sensors and platforms such as the Tactical Imaging System, and a study of applying this technology to manned platforms to assist human operators. Author

N92-17153# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
ROTORCRAFT SYSTEM IDENTIFICATION
Oct. 1991 257 p Lecture series held in Ottobrunn, Fed. Republic of Germany, 4-5 Nov. 1991, in Rome, Italy, 7-8 Nov. 1991, and in College Park, MD, 13-14 Nov. 1991
(AGARD-LS-178; ISBN-92-835-0640-5; AD-A244248) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Owing to the highly coupled flight dynamic behavior of rotorcraft configurations, long term interdisciplinary scientific knowledge combined with practical flight test experience is required to use system identification and mathematical modeling tools in the most efficient way. This lecture series is intended to establish an improved dialogue between government organizations, research institutions, and industry in order to apply these tools more routinely in rotorcraft system design, development, and evaluation. This lecture series is supported by a unique flight test data set which was specially generated and analyzed within a recent working group in the Flight Mechanics Panel of Advisory Group for Aerospace Research & Development (AGARD) on Rotorcraft System Identification (WB 18). This lecture series, sponsored by the Flight Mechanics Panel of AGARD, was implemented by the Consultant and Exchange Program. For individual titles, see N92-17154 through N92-17166.

N92-17154# Glasgow Univ. (Scotland). Dept. of Electronics and Electrical Engineering.
DESIGN OF EXPERIMENTS
DAVID J. MURRAY-SMITH and GARETH D. PADFIELD (Royal Aerospace Establishment, Bedford, England) *In* AGARD, Rotorcraft System Identification 8 p (SEE N92-17153 08-05) Oct. 1991
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The planning and conduct of flight experiments is a critically important part of the system identification process. Factors such as the choice of test input signal and the duration of the experiment can have a major influence on the quality of the identification results. Other factors such as the quality of flightcrew and groundcrew briefings and the availability of online monitoring facilities also greatly influence the effectiveness of any flight testing program. Inevitably there is a trade-off between performance and flight safety which must be taken fully into account at all stages of identification flight trials and influences the experiment design process and test matrix in a very significant way. Other important practical constraints arise in experiment design, especially when test input signals have to be applied manually by the pilot. An outline of the forms of test input most commonly used for identification is included, and an account of methods of experimental design is provided in which the value of a frequency-domain approach is emphasized. Author

N92-17155# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.
INSTRUMENTATION AND DATA PROCESSING
JUERGEN KALETKA *In* AGARD, Rotorcraft System Identification 18 p (SEE N92-17153 08-05) Oct. 1991
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The quality of measured flight test data is critically important to system identification. Inaccurate or kinematically inconsistent data can lead to identification of an incorrect model or inability to obtain convergence of the estimation solution. Therefore, this lecture concentrates on instrumentation and data processing aspects from a system identification point of view. It is mainly based on the work of the Advisory Group for Aerospace Research & Development (AGARD) Working Group WG-18 on Rotorcraft System Identification who concentrated on the identification of 6 degrees of freedom models. In addition, rotor blade instrumentation needed for the determination of extended models with explicit rotor degrees of freedom is addressed. Author

05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

N92-17156# National Aero- and Astronautical Research Inst., Amsterdam (Netherlands). Dept. of Flight Testing and Helicopters.

FLIGHT TEST DATA QUALITY EVALUATION

JAN H. BREEMAN *In* AGARD, Rotorcraft System Identification 8 p (SEE N92-17153 08-05) Oct. 1991
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The quality of the measurement data determines the quality of the parameter identification results. Visual inspection of data plots is the first step in the evaluation of data quality. The measurements can be scrutinized for obvious errors such as wrong signs, excessive measurement noise, data dropouts, spikes and missing (or even exchanged) data channels. In addition, frequency domain techniques can be very useful for data quality evaluation. Any redundancy in the measured variables can be exploited to verify the data quality. Kinematic compatibility checking is explained as well as a number of solution techniques such as weighted least squares, extended Kalman filter/smoother, output error, and filter error. Some computer programs used for compatibility checking are discussed. Author

N92-17157# Toronto Univ. (Ontario). Inst. for Aerospace Studies.

IDENTIFICATION TECHNIQUES: MODEL STRUCTURE AND TIME DOMAIN METHODS

JAAP H. DELEEUW *In* AGARD, Rotorcraft System Identification 9 p (SEE N92-17153 08-05) Oct. 1991
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An overview is given of rotorcraft system identification techniques used by WG 18. The selection of model structure is considered. Here, special emphasis is given to ensuring that the model structure is appropriate to the intended model application. For example, simple decoupled first-order models that characterize the helicopter dynamics over a limited frequency range may be suitable for handling-qualities applications, while coupled 6-DoF models suitable for a broader range are needed for piloted simulation. At the other end of the complexity spectrum are models needed for use in advanced high-bandwidth rotorcraft flight control system design that must consider the coupled fuselage/rotor/airmass dynamics. Both nonparametric model structures (frequency-responses) and parametric model structures (transfer functions and state-space equations) are considered in the two sections dealing with identification techniques. The next step in the identification problem definition is the formulation of the criterion or 'cost' function. Once the model structure and cost function have been defined, the model is identified from the input/output time-history data using either time-domain or frequency-domain methods. The final step in system identification is referred to as 'model verification.' Here the extracted model is driven with flight data not used in the identification process to ensure the correctness of the identification procedure, and the utility of the model in predicting control responses rather than simply matching them. Author

N92-17158# Army Aviation Systems Command, Moffett Field, CA. Aeroflightdynamics Directorate.

IDENTIFICATION TECHNIQUES: FREQUENCY DOMAIN METHODS

MARK B. TISCHLER *In* AGARD, Rotorcraft System Identification 4 p (SEE N92-17153 08-05) Oct. 1991
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The starting point in frequency-domain identification methods is the conversion of time-based data to frequency-based data. This conversion, which is a batch and non-iterative process, involves a considerable amount of data conditioning not required for time-domain methods. However, once the frequency-domain data base is completed, the computational burden of the parameter nonlinear search is considerably reduced. Also, there are some important benefits of formulating the cost function in the frequency-domain. An overview of frequency-domain methods used by WG 18 members is presented. Author

N92-17159# Glasgow Univ. (Scotland). Dept. of Electronics and Electrical Engineering.

MODELLING ASPECTS AND ROBUSTNESS ISSUES IN ROTORCRAFT SYSTEM IDENTIFICATION

DAVID J. MURRAY-SMITH *In* AGARD, Rotorcraft System Identification 9 p (SEE N92-17153 08-05) Oct. 1991
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The concept of robustness is examined and discussed in the context of rotorcraft system identification and modeling. A classification of robustness issues is proposed involving experimental design aspects, identification techniques, model structure estimation, parameter estimation and the robustness of the complete mathematical model resulting from the application of identification processes. Associated tests of robustness are proposed and a set of special recommendations is presented for each of the aspects considered. Within these recommendations particular emphasis is placed on the need for a good user interface which fully exploits the use of computer graphics and for reliable tools for the assessment of model structure. The need for preliminary flight tests to characterize the dynamics of the system and thus guide the design of identification experiments is also emphasized. A further recommendation is that design criteria should be established for verification inputs. Author

N92-17160# McDonnell-Douglas Helicopter Co., Mesa, AZ.

ASSESSMENT OF ROTORCRAFT SYSTEM IDENTIFICATION AS APPLIED TO THE AH-64

DEV BANERJEE and JEFF W. HARDING *In* AGARD, Rotorcraft System Identification 25 p (SEE N92-17153 08-05) Oct. 1991
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Flight test data from the U.S. Army/McDonnell Douglas AH-64 Apache attack helicopter was provided to the AGARD FMP Working Group 18 (WG-18) on Rotorcraft System Identification. Results from the application of system identification techniques on the data by several members are compared. The data are processed by the WG members to assure consistency and remove identified measurement biases. Various time domain identification procedures ranging from linear regression to maximum likelihood are used to identify coupled six degrees of freedom rigid body models. Stability and control derivative estimates and model eigenvalues are compared. Diagonal terms in the models are consistently identified while coupling derivative estimates vary widely. Eigenvalues associated with the slower modes (phugoid and spiral) are not consistently identified due to the limited 12 second record length of the available data. Roll convergence and Dutch roll models are consistent between the models. All the models do a good job of predicting primary axis response, however, improved correlation is achieved by eliminating insensitive stability and control derivatives from the parameter sets. Author

N92-17161# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.

BO 105 IDENTIFICATION RESULTS

JUERGEN KALETKA *In* AGARD, Rotorcraft System Identification 50 p (SEE N92-17153 08-05) Oct. 1991
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BO 105 flight test data generated particularly for system identification purposes were provided to the AGARD Working Group WG-18 on Rotorcraft System Identification. The accomplishments are summarized of the WG for the data consistency analyses, and the identification and verification results for 6 degrees of freedom models. The individually applied approaches are described and representative results are presented. It is shown that the flight test data were appropriate for use of system identification. The discussion of the identification and verification results show that there are significant differences depending upon the applied identification technique. The identification is addressed of higher order models and some results are presented which were obtained for an extended model with rotor degrees of freedom. Author

N92-17162# Royal Aerospace Establishment, Bedford (England). Aerospace Div.

SA 330 PUMA IDENTIFICATION RESULTS

GARETH D. PADFIELD   In AGARD, Rotorcraft System Identification 38 p (SEE N92-17153 08-05)   Oct. 1991

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The SA 330 Puma test data provided by the RAE were analyzed with a variety of different identification techniques by six of the participating organizations in AGARD Flight Mechanics Panel Working Group 18. The results of this work are presented. A detailed study of the data kinematic consistency conducted by the RAE is included, highlighting some of the difficulties that can be encountered, even with high quality measurements, and ways of overcoming them. The results of the six degrees of freedom identification are discussed in terms of the conventional rigid body modes of motion.   Author

N92-17163# McDonnell-Douglas Helicopter Co., Mesa, AZ.

INDUSTRY VIEW ON ROTORCRAFT SYSTEM IDENTIFICATION

DEV BANERJEE and JEFF W. HARDING   In AGARD, Rotorcraft System Identification 4 p (SEE N92-17153 08-05)   Oct. 1991

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An industry perspective on rotorcraft system identification is presented based on responses from eight major rotorcraft manufacturers to a questionnaire sent out by the AGARD FMP Working Group 18 on Rotorcraft System Identification. Several manufacturers are implementing system identification techniques for model validation and flight control law development. Concerns over costly data requirements and nonstandardized procedures are echoed. An example of the application of system identification for design support at McDonnell Douglas Helicopter Co. is discussed.   Author

N92-17164# Royal Aerospace Establishment, Bedford (England). Aerospace Div.

APPLICATION AREAS FOR ROTORCRAFT SYSTEM IDENTIFICATION: SIMULATION MODEL VALIDATION

GARETH D. PADFIELD and RONALD W. DUVAL (Advanced Rotorcraft Technology, Inc., Mountain View, CA.)   In AGARD, Rotorcraft System Identification 39 p (SEE N92-17153 08-05)   Oct. 1991

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The role of system identification in the validation of rotorcraft simulation models is examined in terms of the overall 'functional' fidelity and individual component 'physical' fidelity. Validation acceptance criteria are discussed in terms of modeling range and accuracy for the three fundamental flight mechanics problems - trim, stability, and response. Model development and upgrading are described as a natural part of validation, and the role that system identification can play in highlighting model deficiencies is discussed. An example from a six-degree-of-freedom analysis is presented to illustrate validation and the merits of model distortion analysis in identifying deficiencies. Results from a more detailed analysis of the SA 330 blade flapping dynamics are presented to illustrate physical validation.   Author

N92-17165# Army Aviation Systems Command, Moffett Field, CA. Aeroflightdynamics Directorate.

SYSTEM IDENTIFICATION METHODS FOR HANDLING-QUALITIES EVALUATION

MARK B. TISCHLER   In AGARD, Rotorcraft System Identification 9 p (SEE N92-17153 08-05)   Oct. 1991

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System identification methods for rotorcraft handling-qualities studies are discussed in this paper. A key factor that is responsible for the successful application of system identification techniques in the handling-qualities community is the relative simplicity of the models which are desired for pilot-in-the-loop analyses as compared to the full 6 Degree Of Freedom (DOF) models required

for most other applications. Generally, these analyses consider only the on-axis, single-input/single-output response of the pilot/vehicle system. The extracted vehicle model may be nonparametric, such as a frequency-response, or a low-order parametric model, such as a transfer function, or a simplified decoupled state-space representation. Both time- and frequency-domain methods have been widely used for these applications and are discussed in this paper. The requirements for flight testing, data analyses, and modeling for handling-qualities applications of system identification are contrasted with the requirements for extracting multi-input/multi-output state-space models for flight mechanics purposes. Typical handling qualities analysis results are illustrated using the WG 18 databases for the BO-105 and AH-64 helicopters.   Author

N92-18571#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Structures and Materials Panel.

FATIGUE MANAGEMENT

Dec. 1991   271 p   In ENGLISH and FRENCH   The 72d meeting was held in Bath, England, 29 Apr. - 3 May 1991

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At its seventy-second meeting, the Structures and Materials Panel held a conference of specialists focussing on the problem of fatigue management. Today's trend is to retain aircraft in service much longer than originally planned. This trend, coupled with the facts that airframe structures are much more precisely optimized and advance active control systems are common, makes it essential that state of the art fatigue monitoring procedures are used. Information from such systems is vitally important for efficient, cost effective fleet management. Such data are also important to procurement authorities when trying to plan aircraft replacements. For individual titles, see N92-18572 through N92-18595.

N92-18572#   British Aerospace Public Ltd. Co., Preston (England). Fatigue and Fracture Technology Div.

THE DEVELOPMENT OF FATIGUE MANAGEMENT REQUIREMENTS AND TECHNIQUES

A. P. WARD   In AGARD, Fatigue Management 4 p (SEE N92-18571 09-05)   Dec. 1991

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Fatigue management requirements and techniques have evolved over a period of 40 years or more. This paper provides an overview of these developments. An historical summary is presented covering the introduction of the different monitoring techniques ranging from the simple V-g recorder through to the multi-channel systems with on-board processing that now exist. The paper concludes with a summary of the main requirements for modern systems and then identifies a number of key issues that should be addressed during the course of the Specialists' Meeting.   Author

N92-18574#   Veritas Research A.S., Hovik (Norway).

PROBABILISTIC DESIGN AND FATIGUE MANAGEMENT BASED ON PROBABILISTIC FATIGUE MODELS WITH RELIABILITY UPDATING

R. SKJONG, G. SIGURDSSON, and M. K. NYGARD   In AGARD, Fatigue Management 7 p (SEE N92-18571 09-05)   Dec. 1991

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The fatigue limit state is the governing limit state for an aging airframe. The trend of operating aircraft longer than their originally planned life, calls for extensive testing and inspection. Current practice is to base decisions with respect to inspections and repair on the durability and damage tolerance methodologies. These procedures make little use of probabilistic methods. The paper addresses the same basic problems of similar fundamental models. The formulations are, however, casted into a probabilistic format. In particular the possibility of incorporating new inservice information, based on inspection results or load measurements, is discussed and demonstrated. The advantage of this formulation is illustrated by some examples. Some comments are about future

research that would be necessary to fully utilize the capabilities of probabilistic methods. Author

N92-18575# Wright Lab., Wright-Patterson AFB, OH. Structural Integrity Branch.
AGING AIRCRAFT STRUCTURAL DAMAGE ANALYSIS
J. G. BURNS, W. P. JOHNSON, and A. P. BERENS (Dayton Univ. Research Inst., OH.) *In* AGARD, Fatigue Management 15 p (SEE N92-18571 09-05) Dec. 1991
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The structural problems experienced by aging aircraft, both military and commercial, are described. The programs that are in place in the U.S. Air Force, the research that is being performed, and the facilities that are used to address the problem of aging aircraft are identified. The use of one research product, the computer program PRobability Of Fracture (PROF), describes how current technology can be used to predict damage in aging aircraft structures and the reliability of those structures. Areas where additional research is required are identified and conclusions are drawn. Author

N92-18576# Canadair Ltd., Montreal (Quebec). Military Aircraft Div.
A PROBABILISTIC PROCEDURE FOR AIRCRAFT FLEET MANAGEMENT
Y. THERIAULT and A. R. COLLE *In* AGARD, Fatigue Management 10 p (SEE N92-18571 09-05) Dec. 1991
(AGARD-CP-506) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A procedure for determining the probability of structural failure of an airplane at any stage of the operational life is described. This procedure is based on existing models for representing the size distribution of pre-service cracks, the distribution of the maximum service load expected in a single flight, and the reliability of the nondestructive method used for inspection. A case study is presented to show how the procedure can help the fleet manager set more realistic inspection and maintenance schedules and adopt more appropriate retirement policies. Author

N92-18578# National Aeronautical Establishment, Ottawa (Ontario). Structures and Materials Lab.
A PARAMETRIC APPROACH TO SPECTRUM DEVELOPMENT
D. L. SIMPSON, R. J. HISCOCKS, and D. ZAVITZ *In* AGARD, Fatigue Management 16 p (SEE N92-18571 09-05) Dec. 1991
Sponsored in part by Dept. of National Defence
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The parametric approach being pursued for the development of the test spectrum for the CF-18 center fuselage is described. An overview is provided of the F/A-18 International Follow-on Structural Test Program (IFOSTP) with emphasis on spectrum development. The specific technical elements of the spectrum development task are introduced and detailed information is provided on the CF-18 usage monitoring system, the approach to usage processing and the maneuver identification methodology which is forming the basis of the parametric approach to CF-18 spectrum development. A specific example of the maneuver identification process is provided and recommendations for future monitoring systems are offered. Author

N92-18579# Aerospatiale, Toulouse (France).
FATIGUE TESTING AND TEAR DOWN OPERATIONS ON AIRBUS A320 FORWARD FUSELAGE
R. BOETSCH and J. Y. BEAUFILS *In* AGARD, Fatigue Management 6 p (SEE N92-18571 09-05) Dec. 1991
(AGARD-CP-506) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The structural design substantiation of commercial transport aircraft is provided by full static and fatigue analyses supported by testing of complete primary structures. The fatigue and damage tolerance testing on full scale specimen representative of production aircraft and the teardown inspections performed at the end of the test permit the collection of a lot of data. Main objectives of fatigue tests are to identify weak points in primary structure and to quickly define corrective actions on in-service and production aircraft, and to check the efficiency of the inspection methods, to justify allowable damage and typical repairs of structural repair manuals, to study the propagation of artificial damages which are introduced during the test. The aim of teardown inspections is to verify and validate the inspection methods applied during the test on assembled structure and in addition to find hidden cracks with special nondestructive test methods. Also, from fatigue tests, areas will be found where there is a risk of wide spread fatigue damage and the performance of damage tolerance assessment on the basis of realistic cracking scenarios. Author

N92-18580# Alenia, Torino (Italy). Gruppo Aerei Difesa.
PROPOSAL FOR THE NEW FATIGUE MANAGEMENT SYSTEM FOR THE AMX
P. AMABILE and T. GIACOBBE *In* AGARD, Fatigue Management 9 p (SEE N92-18571 09-05) Dec. 1991
(AGARD-CP-506) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The structural monitoring systems produced for the Italian Air Force are briefly presented and discussed. From the previous experience, a new proposal for AMX aircraft monitoring arose and is shown. The proposed system is based mainly on in-flight monitoring of strain gage measurements with storage of some flight parameters for special investigations or simplified back-up analysis in case of failures of the main system. Elaboration methods to be used both on-board and on ground are described. Measurements on static and fatigue tests on ground were studied for a correct tuning of the system. Author

N92-18581# National Defence Headquarters, Ottawa (Ontario). Directorate Aerospace Support Engineering.
DURABILITY AND DAMAGE TOLERANCE TESTING AND FATIGUE LIFE MANAGEMENT: A CF-18 EXPERIENCE
M. B. ZGELA and W. B. MADLEY *In* AGARD, Fatigue Management 16 p (SEE N92-18571 09-05) Dec. 1991
(AGARD-CP-506) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Each CF-18 multirole fighter is equipped with a multichannel data acquisition system which records a number of parameters including measured strains, engine data, and various flight incident data. The analysis of this data has enabled the close monitoring of aircraft usage and the rate at which each aircraft accumulated fatigue damage. In 1986, in-service analysis of CF-18 fleet usage indicated that the aircraft were being operated in a significantly different manner than assumed for design, and that severity of the usage approached or exceeded the spectrum used for certification testing. To ensure the maximum economic life of the fleet, a Fatigue Life Management Program (FLMP) was implemented along with Durability and Damage Tolerance Testing activities. The development is described of various components of the FLMP, including the aircrew fatigue awareness program, CF-18 Individual Aircraft Tracking activities, the development and implementation of fatigue damage control measures, and lessons learned from the management of the FLMP. Author

N92-18582# Aeritalia S.p.A., Naples (Italy). Viale dell'Aeronautica.
THE G-222 AIRCRAFT INDIVIDUAL TRACKING PROGRAMME
A. MINUTO, A. APICELLA, A. LANCIOTTI, and L. LAZZERI (Pisa Univ., Italy) *In* AGARD, Fatigue Management 7 p (SEE N92-18571 09-05) Dec. 1991
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The G-222 is a transport aircraft designed about 20 years ago; from the fatigue point of view, the design is of the conventional 'safe life' kind, verified by means of a full scale test. The aircraft was equipped with a counting accelerometer, whose recordings were used, together with the pilot compiled forms, for the evaluation of life consumption. In recent years, following the Damage Tolerance evaluation of the structure, a different approach has been developed for fatigue damage monitoring; the same input data are used for the prediction of crack growth. The main drawback of this approach is the lack of information about the sequence of

load application, so that only non-interactive models can be properly used. For this reason, Aeritalia decided to improve the quality of in-flight recorded parameters, in order to get more data about the actual usage, while also taking the sequence of load application into account. The data acquisition approach is described and discussed.   Author

N92-18583#   National   Aerospace   Lab.,   Amsterdam (Netherlands).
LOAD MONITORING OF F-16 A/B AIRCRAFT OF THE RNLAF WITH A SMART ELECTRONIC DEVICE
D. J. SPIEKHOUT   In AGARD, Fatigue Management 17 p (SEE N92-18571 09-05)   Dec. 1991
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    Since the introduction of the F-16 weapon system in the RNLAF, load monitoring has been carried out with a mechanical strain recorder (MSR) in each aircraft and a flight loads recorder (FLR) in one sixth of the fleet. From 1990 on, these recorders have been replaced by instrumentation which is capable of recording peaks and troughs in the signal of a strain gage at the location of the MSR. This new instrumentation has been installed in three aircraft per squadron. The result is a calculated severity per mission type per squadron. By using the mission type mixture, the severity per base, squadron or tail number can be established. Inspection schemes, based on the recently developed fleet structural maintenance plan for the RNLAF, can be changed accordingly. Mission type and take off configuration for each flight is available from the oebriefing form. Besides the single channel measurements, supporting measurements with more channels have been carried out. In this way, it was checked whether the load severity for the MSR location can be used for other structural locations.   Author

N92-18584#   Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
AIRCRAFT TRACKING FOR STRUCTURAL FATIGUE
R. NEUNABER   In AGARD, Fatigue Management 9 p (SEE N92-18571 09-05)   Dec. 1991
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    Aircraft tracking is carried out for flight safety reasons, but with an increasing tendency also for economic reasons. With the latter aspect the cost-to-performance ratio becomes more and more important. To take care of both, for the WS Tornado, the parametric data acquisition of the crash recorder was extended to a multi-level tracking concept composed of the sectors temporary aircraft tracking, selected aircraft tracking, and individual aircraft tracking. The key elements of flight monitoring are the flight recorders that are distributed throughout all squadrons on a statistically representative basis and that register operating data for Selected Aircraft Tracking. In the Temporary Aircraft Tracking sector, the recorder parameter set also contains strain gauges in the various fatigue critical areas. Cyclical reading of these strain gauges ensures that any faults are revealed in the parametric algorithms. Individual Aircraft Tracking is carried out on the basis of a reduced pilot parameter set. The data transfer from the aircraft to the evaluation center for this task was converted from manual registration to electronic data processing, increasing the data processing capacity and at the same time significantly improving data quality.   Author

N92-18585#   Dassault-Breguet Aviation, Saint Cloud (France). Structure Div.
AIRCRAFT TRACKING OPTIMIZATION OF PARAMETERS SELECTION
R. J. CAZES and P. DEFOSSE   In AGARD, Fatigue Management 12 p (SEE N92-18571 09-05)   Dec. 1991
(AGARD-CP-506) Copyright Avail: NTIS HC/MF A12;
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    Any appropriate structural maintenance plan, based on a Safe-Life or a Damage Tolerance concept, is in close relation with the accuracy of in-service loads identification. The development of multichannel devices with integrated capabilities for in-flight pre-processing allows one to get in-service data and

flight results about any critical part of the equipped aircraft, but with sometimes such an amount of computations that the 'should-be simple' in flight processing has to be transferred toward a ground facility. In order to reduce the volume of data for calculations (and their cost of acquisition), we studied the relative influence of the various flight parameters considered during the static and fatigue design of an aircraft. The calculated stresses and loads were compared with their same counterparts measured in flight. Their effects on fatigue values were quantified. This study was performed for the MIRAGE 2000 aircraft tracking and in service loads identification.   Author

N92-18586#   Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.).
THE OPERATIONAL LOADS MONITORING SYSTEM, OLMS
V. LADDA and H.-J. MEYER   In AGARD, Fatigue Management 14 p (SEE N92-18571 09-05)   Dec. 1991
(AGARD-CP-506) Copyright Avail: NTIS HC/MF A12;
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    The preservation of the damage tolerance qualities ensures the safe lifelong operation of aircraft. For this purpose and the assessment of fatigue life consumption, different methods have been developed to monitor the service experiences. Nowadays mainly two kinds of monitoring systems which are different in philosophy exist: first, the parametric system which records and processes only aircraft mission parameters, and second, the direct load/and or stress measurement system using strain gauges. The main advantages and disadvantages of both systems are discussed. A third possibility is to monitor the service experiences of aircraft by combining the advantages of both systems: this leads to the idea of Operational Loads Monitoring System (OLMS). In this contribution the advanced operational loads monitoring system OLMS, for a transport aircraft, is presented. Detailed descriptions are given concerning philosophy and realization. OLMS represents the on-board equipment for the Airframe Condition Monitoring Procedure (ACMP) which takes care of damage tolerance qualities and which will increase the efficiency of structural inspections. The OLMS as presented in this contribution is adaptable to all transport and combat aircraft with electronic flight control systems (EFCS). The verification has been performed on the test aircraft by means of strain gauge measurements. Results of the OLMS-computer simulation program as well as results of the flight test verification are presented.   Author

N92-18587#   Aeronautical Systems Div., Wright-Patterson AFB, OH.
LIFE MANAGEMENT APPROACH FOR USAF AIRCRAFT
JOHN W. LINCOLN   In AGARD, Fatigue Management 10 p (SEE N92-18571 09-05)   Dec. 1991
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    The USAF Aircraft Structural Integrity Program, that traces its origin to B-47 failures in 1958, was established based on the recognition that repeated loads were a threat to the safety of operational aircraft. Later, it was recognized that manufacturing and in-service damage also had the potential to degrade their safety. This threat has been successfully controlled through the adoption of the damage tolerance approach in 1975. This approach, also referred to as 'retirement for cause,' is used as a basis for an inspection/modification program to maintain safety throughout the life of the aircraft. However, when the aircraft structure has degraded to the point that multiple site damage has occurred, then the inspection program that was developed for the pristine structure needs to be changed. It is the purpose of this paper to review the occurrences of multiple site damage on USAF aircraft and how this has influenced their lives. This will be done through the experiences derived from the KC-135, C-5 and C-141 aircraft.   Author

N92-18588*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LARGE AREA QNDE INSPECTION FOR AIRFRAME INTEGRITY
WILLIAM P. WINFREE and JOSEPH S. HEYMAN *In* AGARD, Fatigue Management 5 p (SEE N92-18571 09-05) Dec. 1991
(AGARD-CP-506) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Quantitative Nondestructive Evaluation (QNDE) technology is being developed to provide new options for cost effective inspection of airframes. An R&D effort based on five NDE technologies is addressing questions of structural bonding assessment, corrosion detection, multisite damage detection, and fatigue characterization. The research/applications are being conducted by prioritized focussing and staging of the following technologies: (1) thermal NDE; (2) ultrasonic NDE; (3) coherent optical NDE; (4) magnetic imaging NDE; and (5) radiographic NDE. The focus here is on the most recent applications of thermal NDE technology to large area inspection of lap-joint and stiffener bonds. The approach is based on pulsed radiant heating of the airframe and measurement of the surface temperature of the structure with an infrared imager. Several advantages of the technique are that it is noncontacting, inspects one square meter area in a period of less than 2 minutes and has no difficulty inspecting typical curvatures of the fuselage. Numerical models of heat flow in these geometries are used to determine appropriate techniques for reduction of the infrared images, thereby delineating regions of disbonds. These models are also used to determine the optimum heating and measurement times for maximizing the contrast between bonded and unbonded structures. Good agreement is found between these results and experimental measurements, and a comparison of the two are presented. Also presented are results of measurements on samples with fabricated defects which show the technique is able to clearly indicate regions of disbonds. Measurements on an airframe also clearly image subsurface structure. Author

N92-18589*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RECENT FRACTURE MECHANICS RESULTS FROM NASA RESEARCH RELATED TO THE AGING COMMERCIAL TRANSPORT FLEET
CHARLES E. HARRIS *In* AGARD, Fatigue Management 6 p (SEE N92-18571 09-05) Dec. 1991
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NASA is conducting the Airframe Structural Integrity Program in support of the aging commercial transport fleet. This interdisciplinary program is being worked in cooperation with the U.S. airframe manufacturers, airline operators, and the FAA. Advanced analysis methods are under development to predict the fatigue crack growth in complex built-up shell structures. Innovative nondestructive examination technologies are also under development to provide large area inspection capability to detect corrosion, disbonds, and fatigue cracks. Recent fracture mechanics results applicable to predicting the growth of cracks initiating at the rivets of fuselage splice joints are reviewed. Author

N92-18590# Boeing Commercial Airplane Co., Seattle, WA.
STRUCTURAL AIRWORTHINESS OF AGING BOEING JET TRANSPORTS
JACK F. MCGUIRE and ULF G. GORANSON *In* AGARD, Fatigue Management 10 p (SEE N92-18571 09-05) Dec. 1991
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Boeing is dedicated to design and manufacture safe commercial jet transports. The successful accomplishment of this responsibility over the last three decades has contributed significantly to a position of industry leadership and reflects the top priority given to safety. This paper illustrates that the structural integrity assurance of commercial airplane structures is a serious and disciplined process. High standards must be maintained to ensure the safety of aging airplanes until economics dictate their retirement. Standard Boeing practices to ensure continuing structural integrity include providing structural maintenance programs, continuous communication through customer support

services, and recommendations for maintenance actions through service letters, structural item interim advisories, and service bulletins. To help identify potential problems associated with the aging jet transport fleet, Boeing has implemented additional activities: (1) supplemental structural inspection programs that require airlines to regularly inspect structurally significant items on selected older airplanes and report defects to Boeing for prompt fleet action; (2) teardown of older airframes to help identify corrosion and other structural service defects; (3) fatigue testing of older airframes to determine structural behavior in the presence of service-induced problems such as corrosion and repairs; and (4) an engineering assessment of the condition of a representative sample of older Boeing airplanes to observe effectiveness of corrosion prevention features and acquire additional data that might improve maintenance recommendations to the operators. Aging fleet concerns have also resulted in joint industry, airlines, and airworthiness authority actions. These initiatives have provided timely preventive structural maintenance recommendations and permit continued safe operation of aging jet transports until their retirement from service. Author

N92-18591# Ministry of Defence, London (England).
AIRCRAFT FATIGUE MANAGEMENT IN THE ROYAL AIR FORCE
M. E. J. RENDER and J. E. STEVENS (Royal Air Force, Dereham, England) *In* AGARD, Fatigue Management 14 p (SEE N92-18571 09-05) Dec. 1991
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An overview of how fatigue is managed for all of the Royal Air Force (RAF) Aircraft Fleets is presented. The main theme is the Tornado Aircraft since it represents the largest portion of the capital value of the RAF inventory. The RAF has three objectives for their aircraft structural integrity policy: to make aircraft operations as safe as is reasonably possible; to ensure that the aircraft are available to the front line; and to minimize the costs. Author

N92-18592# Bundesamt fuer Wehrtechnik und Beschaffung, Munich (Germany, F.R.).
TORNADO STRUCTURAL FATIGUE LIFE ASSESSMENT OF THE GERMAN AIR FORCE
PAUL FRAAS and AMBROS GOELLNER (Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn, Germany, F.R.) *In* AGARD, Fatigue Management 10 p (SEE N92-18571 09-05) Dec. 1991
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The structural development and the fatigue verification of the Tornado Program was completed. The majority of the aircraft were delivered to the German Air Force and some of them were in full operational use for a period of one decade. This is considered a suitable time to review the approach for ensuring the long-term structural airworthiness, from the users point of view. Author

N92-18593# Portuguese Air Force, Alfragide.
FATIGUE MANAGEMENT FOR THE A-7P
DANIEL SANTOS *In* AGARD, Fatigue Management 19 p (SEE N92-18571 09-05) Dec. 1991
(AGARD-CP-506) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

One objective of an Aircraft Structural Integrity Program (ASIP) is to ensure that all primary structure is both durable and damage tolerant, that is, it is able to resist both cracking and failure due to cracking. The heart of any durability and damage tolerance assessment is crack growth predictions. This requires a crack growth program, accurate stress intensity and load interaction models, and reliable material properties. With these tools, both durability analysis and damage tolerance analysis can be performed. All potentially critical locations were assumed to exhibit slow crack growth. No fail-safe concepts were used, although many locations have alternate load paths that carry the limit load. Author

N92-18594# Aeronautical Systems Div., Wright-Patterson AFB, OH. Structures Div.
MANAGING AIRBORNE ASSETS THROUGH LOADS MONITORING
R. MACH *In* AGARD, Fatigue Management 12 p (SEE N92-18571 09-05) Dec. 1991
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    Loads monitoring was a cornerstone of the Air Force Structural Integrity Program from its inception. But the high cost of new systems has provided a new need for the program. It provides the hard data that is required by the systems manager to determine the economic life of their aircraft and the most efficient allocation of aircraft to maintain optimum operation capability. Continued advances in solid state microprocessors and integrated software along with advances in storage media should enhance the capability of the overall program.   Author

N92-18595# Aeronautical Systems Div., Wright-Patterson AFB, OH. Loads and Dynamics Branch.
APPROACH TO CREW TRAINING IN SUPPORT OF THE USAF AIRCRAFT STRUCTURAL INTEGRITY PROGRAM (ASIP)
ALFONSO G. APONTE *In* AGARD, Fatigue Management 7 p (SEE N92-18571 09-05) Dec. 1991
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    Maintaining the safety and strength of an aircraft is dependent upon the capability of appropriate Air Force commands to perform maintenance and inspections throughout the service life of the aircraft. One of the maintenance actions involves the collection and reporting of operational usage data to support the loads/environment spectra survey (L/ESS) and Individual Aircraft Tracking (IAT) programs. The Air Force approach to training operational flight and ground crews about their responsibilities and the importance of this task which is an integral part of the Aircraft Structural Integrity Program (ASIP) is presented.   Author

N92-18778# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
MANOEUVRING AERODYNAMICS
Nov. 1991   287 p   In ENGLISH and FRENCH   Meeting held in Toulouse, France, 1-2 May 1991
(AGARD-CP-497; ISBN-92-835-0643-X) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from
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    This volume contains the 17 papers presented at the Advisory group for Aerospace Research & Development (AGARD) Fluid Dynamics Panel (FDP) Specialists' Meeting on Maneuvering Aerodynamics. In addition to these papers, the general discussion held at the end of the meeting and the Technical Evaluation Report are included. This FDP sponsored meeting and document reflect the growing interests in rapid, large-amplitude aircraft maneuvers at high angles of attack and highlights the importance of the unsteady separated, vortical and often nonlinear characteristics of the aerodynamic flows that exist under such conditions. Developments in pertinent experimental techniques, relevant aerodynamic data and their applications to flight behavior predictions, importance of time lags, methods for forebody vortex control, and flight tests of the X-31A aircraft are among the topics discussed. For individual titles, see N92-18779 through N92-18795.

N92-18779# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Deutsche Aerospace/Military Div.
X-31 ENHANCEMENT OF AERODYNAMICS FOR MANEUVERING BEYOND STALL
HANNES ROSS *In* AGARD, Manoeuvring Aerodynamics 12 p (SEE N92-18778 09-05) Nov. 1991
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    Current fighter aircraft are generally limited to angles of attack (AOA) below their maximum lift capability. Pilot inputs and aircraft maneuvering usually become limited when approaching the stall limited. Primary reasons for this situation are the degrading aerodynamic lateral/directional characteristics and reduced control power in the high AOA regime, often resulting in uncontrolled maneuvers/departures/spins. For these reasons, some aircraft reduced roll control inputs as well as Aileron-/Rudder-Interconnect (ARI) Systems installed to avoid uncoordinated flight conditions at higher AOA. Others have limitations as to the number of consecutive rolls they are allowed to fly even in the conventional AOA. Others have limitations as to the number of consecutive rolls that are allowed to fly even in the conventional AOA regime to prevent uncontrollable pitch-up/Beta excursions due to inertia coupling and engine gyroscopic moments. In the last ten years, new efforts have started to improve control capability in this flight regime. F-14, F-15, and F-18 have demonstrated AOA excursions up to about 65 degrees and the Su-27 and MIG-29 have performed impressive pitch maneuvers even exceeding AOA's of 90 degrees. However, all of the above mentioned maneuvers are performed in the pitch plane with little or no capability left for role control around the velocity vector. A number of experimental aircraft programs were initiated to explore the high AOA and the poststall regime to broaden the knowledge base. The flight test objectives range from basic understanding and investigation of aerodynamic flow phenomena (X-29, a/c no. 2 high AOA test vehicle, F-18 High AOA Research Vehicle (HARV)) to the incorporation of thrust vectoring capability (HARV) and finally to the demonstration of technical feasibility and tactical utility of high AOA maneuvering (X-31 A).   Author

N92-18780*# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
AERODYNAMIC AND FLOWFIELD HYSTERESIS OF SLENDER WING AIRCRAFT UNDERGOING LARGE-AMPLITUDE MOTIONS
ROBERT C. NELSON, ANDREW S. ARENA, JR., and SCOTT A. THOMPSON *In* AGARD, Manoeuvring Aerodynamics 11 p (SEE N92-18778 09-05) Nov. 1991
(Contract NCA2-406; NAG1-727; AF-AFOSR-0321-90)
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    The implication of maneuvers through large angles of incidence is discussed by examining the unsteady aerodynamic loads, surface pressures, vortical position, and breakdown on slender, flat plate delta wings. Two examples of large amplitude unsteady motions are presented. First, the unsteady characteristics of a 70 degree swept delta wing undergoing pitch oscillation from 0 to 60 degrees is examined. Data is presented that shows the relationship between vortex breakdown and the overshoot and undershoot of the aerodynamic loads and surface pressure distribution. The second example examines the leading edge vortical flow over an 80 degree swept wing undergoing a limit cycle roll oscillation commonly called wing rock.   Author

N92-18781# Alenia, Torino (Italy).
PREDICTION OF AERODYNAMIC PHENOMENA LIMITING AIRCRAFT MANOEUVRABILITY
A. FERRETTI, A. BARTOLI, and A. SALVATORE *In* AGARD, Manoeuvring Aerodynamics 10 p (SEE N92-18778 09-05) Nov. 1991
(AGARD-CP-497) Copyright Avail: NTIS HC/MF A13;
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    The synthesis of recent experiences concerning the effects of shock induced separation on conventional airplanes flying at high subsonic speeds are presented. Efforts were concentrated in synthesizing a prediction criterion for detecting onset of the wing aerodynamic phenomena leading to buffet and mishandling of such airplanes. Comparison of mishandling and buffet onset envelopes theoretically derived with those experimentally measured on an airplane is given evidencing the consistency of the methodology. For nonconventional, highly swept wings featuring leading edge vortical flow at high subsonic speed and moderate angle of attack, the analysis of wind tunnel results has allowed the definition of a prediction criterion for transition from attached to vortical flow. This change in the wing flow structure is responsible for remarkable nonlinearities in the aerodynamic coefficients of the aircraft and could limit maneuverability in certain areas of the flight envelope. Efforts in implementing these concepts in the aerodynamic design process of such wing planforms are stressed as well as the need

for further studies concerning a deeper understanding of the fluid dynamic conditions ruling the vortex breakdown.　　　Author

N92-18782#　　Aeronautica Macchi S.p.A., Varese (Italy). Aerodynamics Dept.
PARAMETRIC EFFECTS OF SOME AIRCRAFT COMPONENTS ON HIGH-ALPHA AERODYNAMIC CHARACTERISTICS
L. VISINTINI, R. PERTILE, and A. MENTASTI　　*In* AGARD, Manoeuvring Aerodynamics 11 p (SEE N92-18778 09-05)　Nov. 1991
(AGARD-CP-497)　Copyright　Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A wind tunnel test activity was performed with the purpose of defining and understanding the high angle of attack aerodynamic characteristics of an advanced trainer aircraft configuration. The tests included static and rotary balance measurements in the full 0 to 90 degree angle of attack range. The presentation includes a discussion of effects of model breakdown and of forebody finess ratio and cross section. Examples are also given about special difficulties related to subscale high angle of attack wind tunnel testing.　　　Author

N92-18784#　　General Dynamics Corp., Fort Worth, TX.
ANALYSIS OF UNSTEADY FORCE, PRESSURE, AND FLOW-VISUALIZATION DATA FOR A PITCHING STRAKED WING MODEL AT HIGH ANGLES OF ATTACK
A. M. CUNNINGHAM, JR. and R. G. DENBOER　　*In* AGARD, Manoeuvring Aerodynamics 16 p (SEE N92-18778 09-05)　Nov. 1991　Prepared in cooperation with National Aerospace Lab., Amsterdam, Netherlands
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Results are presented and discussed for the low speed test of a straked wing model oscillating in pitch that was conducted during 1986 The model was oscillated about mean angles of attack ranging from (-)4 deg to 48 deg with amplitudes varying from 2 deg to 18 deg for a maximum incidence range of (-)8 deg to 50 deg. It was also oscillated in pitch at side slip angles of (+)5 deg and (-)5 deg. Steady and unsteady pressure and flow-visualization data are used to provide a better understanding of the phenomena observed in the aerodynamic characteristics.　　　Author

N92-18785#　　Royal Aerospace Establishment, Bedford (England). Aerodynamics Dept.
MEASUREMENT OF DERIVATIVES DUE TO ACCELERATION IN HEAVE AND SIDESLIP
C. O. OLEARY, B. WEIR, and J. M. WALKER　　*In* AGARD, Manoeuvring Aerodynamics 11 p (SEE N92-18778 09-05)　Nov. 1991
(AGARD-CP-497)　Copyright　Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The paper describes the design of a new oscillatory rig, lightweight models, and tests in a low speed wind tunnel. Tests were made over a range of frequencies and model configurations. Derivatives due to acceleration in heave and sideslip, the alpha and beta first derivatives, have been measured for the two High Incidence Research Models (HIRM), HIRM1 and HIRM 2. Dynamic measurements were also made of the 'static' derivatives due to alpha and beta. Results showed that, at high angle-of-attack, derivatives due to acceleration in sideslip, in particular, are large and varied significantly with frequency of oscillation. Effects of model configuration are also presented. Dynamic effects on derivatives due to sideslip angle were significant.　　　Author

N92-18786#　　Aeronautical Research Inst. of Sweden, Bromma.
WIND TUNNEL FORCE MEASUREMENTS AND VISUALIZATION ON A 60-DEG DELTA WING IN OSCILLATION, STEPWISE MOTION, AND GUSTS
PER-AKE TORLUND　　*In* AGARD, Manoeuvring Aerodynamics 13 p (SEE N92-18778 09-05)　Nov. 1991
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A 60 deg delta wing has been tested in pitching motion in a low-speed wind tunnel. Harmonic oscillation tests with 4 and 8

deg amplitude at 0 to 35 deg angle of attack were carried out. The reduced frequency was between .003 and .195. Both dynamic aerodynamic derivatives and time histories of the normal force and pitching moment were recorded. The same model was also tested in a stepwise motion up to 90 deg angle of attack. The steps were positive and negative with 20 deg amplitude starting every 10 deg, also steps over the full 90 deg were made. The angle of attack rates were chosen to correspond to the oscillation tests, the maximum being 360 deg/s and the acceleration 13500 deg/s(exp 2). The tunnel speed was 57 m/s in most cases and the centerline chord was .5 m. The response to the step motion was compared to the response predicted from the results of the oscillation tests.　　　Author

N92-18787#　　Institut de Mecanique des Fluides de Lille (France).
CHARACTERIZATION OF UNSTEADY AERODYNAMIC PHENOMENA AT HIGH ANGLES [CARACTERISATION DE PHENOMENES AERODYNAMIQUES INSTATIONNAIRES A GRANDE INCIDENCE]
O. RENIER　　*In* AGARD, Manoeuvring Aerodynamics 21 p (SEE N92-18778 09-05)　Nov. 1991　In FRENCH; ENGLISH summary
(AGARD-CP-497)　Copyright　Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Dynamic maneuvers of an aircraft at high angles of attack are known to be the origin of unsteady, large amplitude aerodynamic phenomena. These phenomena cannot be neglected if the control of aircraft attitudes and movements has to be optimized. Such unsteady effects can be characterized on specific wind tunnel test facilities. Already effects of large incidence and sideslip variations of various aircraft geometries have been measured on the IMFL rotary balance during oscillatory coning motions. They have been globally taken into account in mathematical models using transfer functions. An original test apparatus was set up in the IMFL low speed wind tunnel. Various dynamic pitch and/or yaw motions can be carried out on an aircraft model: sinusoidal or constant angular rate motions or typical pointing maneuver attitude evolution. The large performance of this apparatus allows the characterization and analysis of small and large amplitude, high angles of attack aerodynamic phenomena. Those test facilities are described, their dynamic simulation potentialities illustrated by some results and modelization techniques used are presented.　　　Author

N92-18788#　　Aeronautical Research Labs., Melbourne (Australia).
SCALE MODEL MEASUREMENTS OF FIN BUFFET DUE TO VORTEX BURSTING ON F/A-18
C. A. MARTIN and D. H. THOMPSON　　*In* AGARD, Manoeuvring Aerodynamics 10 p (SEE N92-18778 09-05)　Nov. 1991
(AGARD-CP-497)　Copyright　Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Tests were carried out on scale models of the F-18 in a wind tunnel and in a water tunnel to study the characteristics of tail buffet due to bursting of the wing leading edge extension (LEX) vortices. The wind tunnel program covered the measurement of unsteady surface pressures and accelerations at the tail of a 1/9th scale model, for cases with and without the LEX fences fitted. Flow visualization of the vortex behavior was carried out using smoke and a laser light sheet. Extensive flow visualization tests were also carried out on a 1/4th scale model in a water tunnel to study the effects of engine intake flow and of the LEX fence on burst characteristics. Various aspects of these test programs are presented.　　　Author

N92-18789#　　Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
X-31: DISCUSSION OF STEADY STATE AND ROTARY DERIVATIVES
W. KRAUS　　*In* AGARD, Manoeuvring Aerodynamics 32 p (SEE N92-18778 09-05)　Nov. 1991
(AGARD-CP-497)　Copyright　Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The X-31A high agility airplane was designed to operate with excellent aerodynamic qualities not only in the normal flight regime,

but also at high angles of attack. The aircraft was designed to have natural aerodynamic stability about all three axis in the entire angle of attack range, except at small angle of attack, where the aircraft is unstable in pitch for performance reasons. In some critical regions in which the natural stability cannot be attained, the control power required to achieve stability is provided to the appropriate axis by artificial control, still leaving sufficient control power for maneuvers. In a basic wind tunnel development program, a configuration was tailored which fulfills most of the demanded requirements by aerodynamic means. Both the results and the method of obtaining these results is presented. Besides this static behavior, each aircraft has dynamic characteristics, which decide whether or not the aircraft will diverge. Additional wind tunnel tests was conducted in a spin tunnel to evaluate these characteristics. An analysis of the data is presented including steady state spin modes. Author

N92-18790# British Aerospace Public Ltd. Co., Preston (England). Military Aircraft Div.
USE OF STEPWISE REGRESSION TECHNIQUES AND KINEMATIC COMPATIBILITY FOR THE ANALYSIS OF EAP FLIGHT DATA
A. R. PERKINS *In* AGARD, Manoeuvring Aerodynamics 12 p (SEE N92-18778 09-05) Nov. 1991
(AGARD-CP-497) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An investigation is described into the capabilities and accuracy of an equation error method of aerodynamic parameter identification using stepwise regression techniques. The results of the method are presented for flight responses of the British Aerospace EAP aircraft which has multiple control surfaces and high levels of longitudinal instability together with significant nonlinearities in the aerodynamic data. The benefit of kinematic compatibility processing of the flight data is also presented. The EAP flight responses are analyzed up to an incidence of 30 deg using a technique for joining together several maneuvers to form larger data bases for analysis. The derivatives extracted by these techniques agree in general with the results of the wind tunnel measurements. Author

N92-18794# Dornier Luftfahrt G.m.b.H., Friedrichshafen (Germany, F.R.).
TRANSFORMATION OF FLIGHTMECHANICAL DESIGN REQUIREMENTS FOR MODERN FIGHTERS INTO AERODYNAMIC CHARACTERISTICS
PETER MANGOLD *In* AGARD, Manoeuvring Aerodynamics 15 p (SEE N92-18778 09-05) Nov. 1991
(AGARD-CP-497) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Recent experience in the design of highly augmented modern fighter aircraft with basically unstable characteristics in pitch have shown that the early integration of flightmechanical requirements into the aerodynamic optimization process is mandatory. Maximum allowable instabilities and control power requirements will set remarkable constraints to the freedom of aerodynamic design and influence essential components of the aircraft. Because of the complex aerodynamic effects at high angles of attack, it will be necessary to approach the 'basic configuration' by some optimization loops. During the whole process, specialists from flight mechanics, aerodynamics, and overall design departments have to form a close team in order to end up with an excellent, well balanced design. It was proven that a set of criteria which represents a platform of common discussion for the specialist groups 'aerodynamics', 'flight mechanics', and control law designers' within early phases of a new fighter project can be and must be established in order to avoid unexpected, time consuming and costly difficulties in later design phases. Author

N92-21951# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
AIRCRAFT SHIP OPERATIONS
Nov. 1991 340 p In ENGLISH and FRENCH Symposium held in Seville, Spain, 20-23 May 1991
(AGARD-CP-509; ISBN-92-835-0641-3) Copyright Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The Symposium considered problems of mutual interest connected with fixed and rotary wing aircraft operations from ships, and the application of new technology to enhance such operations. The topics covered included the ship environment in terms of wind, temperature, precipitation, turbulence, and deck motion; guidance, controls, and displays, primarily in the approach and landing phase; flight test and simulation techniques; launch, recovery, and handling systems developments; operational/pilot views; and future developments. For individual titles, see N92-21952 through N92-21974.

N92-21952# Naval Sea Systems Command, Washington, DC. Hull Form and Hydrodynamic Performance Div.
DECK MOTION CRITERIA FOR CARRIER AIRCRAFT OPERATIONS
J. H. PATTISON and R. R. BUSHWAY (Naval Air Systems Command, Washington, DC.) *In* AGARD, Aircraft Ship Operations 18 p (SEE N92-21951 12-05) Nov. 1991
(AGARD-CP-509) Copyright Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Updated ship motion criteria for conventional fixed wing aircraft launch, recovery, and handling operations are presented. The criteria were required to evaluate the effectiveness of proposed hull modifications for USS MIDWAY (CV41). A balanced approach was used to develop the criteria; including a review of existing criteria, an air department workshop, motion measurements during aircraft operations aboard USS MIDWAY and USS CONSTELLATION, flight simulations of aircraft recovery, and a study of the sensitivity of operability calculations to changes in the criteria. Deck attitude (list and trim) and wind limitations are discussed. Sample results are presented to show how the criteria are used to evaluate the effects of hull improvements in a typical operating area of the ocean. It is shown how the criteria may be used in onboard motion displays to guide the ship operator to best speeds and headings to avoid deck motion effects on operations. Author

N92-21956*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.
A NEW METHOD FOR SIMULATING ATMOSPHERIC TURBULENCE FOR ROTORCRAFT APPLICATIONS
J. RIAZ, J. V. R. PRASAD, D. P. SCHRAGE, and G. H. GAONKAR (Florida Atlantic Univ., Boca Raton.) *In* AGARD, Aircraft Ship Operations 6 p (SEE N92-21951 12-05) Nov. 1991 Previously announced in IAA as A92-14368
(Contract NCA2-512)
(AGARD-CP-509) Copyright Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01/3
Simulation of atmospheric turbulence as seen by a rotating blade element involves treatment of cyclostationary processes. Conventional filtering techniques do not lend themselves well to the generation of such turbulence sample functions as are required in rotorcraft flight dynamics simulation codes. A method to generate sample functions containing second order statistics of mean and covariance is presented. Compared to ensemble averaging involving excessive computer time, the novelty is to exploit cycloergodicity and thereby, replace ensemble averaging by averaging over a single path sample function of long duration. The method is validated by comparing its covariance results with the analytical and ensemble averaged results for a widely used 1-D turbulence approximation. Author

N92-21961# Kaman Aerospace Corp., Bloomfield, CT.
ANALYTICAL MODELING OF SH-2F HELICOPTER SHIPBOARD OPERATION
FU-SHANG WEI, ERICH BAITIS, and WILLIAM MYERS (David Taylor Research Center, Bethesda, MD.)   *In* AGARD, Aircraft Ship Operations 11 p (SEE N92-21951 12-05)   Nov. 1991
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An analysis of the shipboard characteristics of the SH-2F helicopter in response to prescribed deck motion, deck friction, and steady wind conditions was developed. The objective of deriving the SH-2F shipboard dynamic model is to define the safe conditions for launching and recovering the helicopter from the flight deck of Navy frigates and destroyers. Operational conditions of interest include helicopter and ship deck dynamic interactions which would potentially cause dangerous interference between the helicopter and the ship such as sliding or tipping of the helicopter. The wind condition, ship deck motion, helicopter rotor thrust, and friction coefficients between helicopter tires and flight deck surfaces are found to be important parameters which affect the helicopter shipboard operations. Four sets of aerodynamic characteristics are modeled in the analysis: one with the rotor operating at very low thrust; one for the rotor stopped and inoperative; one for rotor folded; and one for the fuselage. The ship motion data, including three linear translation and two angular rotation degrees of freedom (roll and pitch) are described in the time domain. The equations of motion of the shipboard dynamic model are derived using the energy method. These equations are solved in the quasi-steady fashion within one-third of a second refresher rate to the prescribed deck motion time histories and steady wind conditions.   Author

N92-21962# Canadair Ltd., Montreal (Quebec).   Surveillance Systems Div.
HELICOPTER/SHIP ANALYTIC DYNAMIC INTERFACE
BERNARD FERRIER, HENRY POLVI (National Defence Headquarters, Ottawa, Ontario), and FRANCOIS A. THIBODEAU   *In* AGARD, Aircraft Ship Operations 20 p (SEE N92-21951 12-05)   Nov. 1991
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An analytic approach to helicopter/ship dynamic interface testing is introduced. The development of dynamic interface from ship motion simulation is presented. A demonstration of a deck handling clearance study is performed for an EH101 helicopter and CPF ship model. Preliminary results of the Landing Period Designator Development Project are provided.   Author

N92-21963# Naval Air Test Center, Patuxent River, MD.   Strike Aircraft Test Directorate.
EVALUATING FIXED WING AIRCRAFT IN THE AIRCRAFT CARRIER ENVIRONMENT
C. P. SENN   *In* AGARD, Aircraft Ship Operations 9 p (SEE N92-21951 12-05)   Nov. 1991
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Operating fixed wing aircraft from today's modern aircraft carrier is a demanding task. Evaluation of aircraft/ship compatibility, both during the concept development phase and full scale development (FSD) ground and flight tests presents the evaluation team with unique challenges. The capabilities and characteristics of high performance carrier based tactical aircraft must be quantified for the catapult launch and subsequent flyaway, and the carrier approach and arrested landing tasks. Catapult launching involves determining the minimum safe launch airspeeds while maintaining acceptable flight characteristics in this low altitude, high angle of attack (AOA) regime. Approach and landing requires the slowest possible approach airspeeds while retaining the performance and handling qualities needed for precision glide slope control. Defining the lowest catapult launch and landing airspeeds reduces wind over deck (WOD) requirements, resulting in reduced ship's operating speed and increased operational flexibility. The tight operating confines of the flight and hanger decks, in conjunction with the large number of other aircraft, support equipment, and personnel dictate unique design requirements which must be considered in the earliest design stages of a new airplane. The

shore based and shipboard ground and flight tests which are conducted to assess the flying qualities, performance, and structural suitability of an airplane in the aircraft carrier environment are addressed.   Author

N92-21964# Agusta Sistemi S.p.A., Varese (Italy).   Flight Test Dept.
EH 101 SHIP INTERFACE TRIALS: FLIGHT TEST PROGRAMME AND PRELIMINARY RESULTS
R. LONGOBARDI, G. VISMARA, and B. PAGGI   *In* AGARD, Aircraft Ship Operations 7 p (SEE N92-21951 12-05)   Nov. 1991
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The development program of the EH 101 includes, for its naval variant, the investigation of the ship-helicopter interface characteristics to grant a preliminary release for helicopter operations on board Italian and British Navy units. The testing will be done according to the following scheme: (1) EH 101 handling qualities assessment while operating near a ship, during the final approach phase; (2) deck landings and take-offs for a preliminary identification of deck motion limits and wind envelope; (3) assessment of the deck landing technique with the use of landing aids; (4) assessment of the aircraft landing on the deck, rotors folding, refueling, armament loading, taxiing, tie downs, etc.; (5) assessment of helicopter operations in a heavy electromagnetic environment; and (6) assessment of the maintainability characteristics of the EH 101 in limited spaces (engine and gear boxes change). Additionally, the results of the preliminary sea trials carried out with the EH 101 prototypes will be presented. Author

N92-21965# National Aerospace Lab., Amsterdam (Netherlands).
DETERMINATION OF LIMITATIONS FOR HELICOPTER SHIP-BORNE OPERATIONS
R. FANG   *In* AGARD, Aircraft Ship Operations 9 p (SEE N92-21951 12-05)   Nov. 1991
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A brief outline of helicopter-ship qualification programs, as performed by the National Aerospace Laboratory NLR (the Netherlands), is given. The outline describes how detailed information about the helicopter's capabilities, the ship's motion characteristics, and the wind-climate above the ship's flight deck is used to set up and to execute a safe and efficient helicopter flight test program. The program leads to a safe and maximum operational availability of the helicopter on board the ship in terms of take-off and landing capabilities as functions of relative wind and sea-state.   Author

N92-21966# Aeroplane and Armament Experimental Establishment, Boscombe Down (England).   Rotary Wing Performance Section.
UNITED KINGDOM APPROACH TO DERIVING MILITARY SHIP HELICOPTER OPERATING LIMITS
B. A. FINLAY   *In* AGARD, Aircraft Ship Operations 14 p (SEE N92-21951 12-05)   Nov. 1991   Sponsored in part by Ministry of Defence
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In the United Kingdom the Aeroplane and Armament Experimental Establishment (A&AEE) is responsible for conducting trials to determine the limitations appropriate to military Ship Helicopter Operations. The philosophy behind these trials is presented. Additionally, the many considerations which play a part in successful trials are discussed. The tests which are carried out before trials at sea are described together with details of how trials are conducted with a helicopter and a ship to determine the widest possible operating envelopes. It is concluded that the methods used by the A&AEE establish envelopes for any particular combination of aircraft and ship that are both operationally valuable and safe.   Author

N92-21967# Aeronautical Research Labs., Melbourne (Australia). Flight Mechanics and Propulsion Div.

A REVIEW OF AUSTRALIAN ACTIVITY ON MODELLING THE HELICOPTER/SHIP DYNAMIC INTERFACE

A. M. ARNEY, J. BLACKWELL, L. P. ERM, and N. E. GILBERT *In* AGARD, Aircraft Ship Operations 13 p (SEE N92-21951 12-05) Nov. 1991 Sponsored by Royal Australian Navy
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The Aeronautical Research Laboratory (ARL) was tasked by the Royal Australian Navy (RAN) to develop a computer model of the S-70B-2 Seahawk/FFG-7 dynamic interface and to use this to investigate operational problems and limitations. An overview of the status of the task is presented, with particular emphasis on undercarriage dynamics and studies of the airwake in the region of the flight deck. For the undercarriage model, modification resulting from static trials, as well as plans for dynamic trials, are given. For the airwake studies, only preliminary results are available. These relate to full-scale airwake and ship motion trials aboard the FFG-7 class frigate HMAS Darwin, and 'mean flow' airwake studies in the low-speed wind tunnel at ARL using a 1/64th size model of an FFG-7.   Author

N92-21968# Naval Air Test Center, Patuxent River, MD. Strike Aircraft Test Directorate.

UNITED STATES NAVY SKI JUMP EXPERIENCE AND FUTURE APPLICATIONS

T. C. LEA, III, C. P. SENN, and J. W. CLARK, JR. (Naval Air Development Center, Warminster, PA.) *In* AGARD, Aircraft Ship Operations 15 p (SEE N92-21951 12-05) Nov. 1991
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The United States Navy has evaluated the performance benefits of using a ski jump during takeoff. The significant gains available with the use of Vertical and Short Takeoff and Landing (V/STOL) aircraft operating from a ski jump were documented many times in the past; however, the U.S. Navy has expanded the concept to include Conventional Takeoff and Landing (CTOL) aircraft. The results from a recent shipboard test are presented. The test was an evaluation of the AV-8B aboard the Spanish ski jump equipped ship PRINCIPE DE ASTURIAS, and a shore based flight test evaluation of CTOL aircraft operation from a ski jump ramp. The analytical tools developed during the CTOL phase of testing are used to project the benefits which could be realized by combining the steam powered catapult and a 'mini' ski jump ramp compatible with today's aircraft carriers.   Author

N92-21969# RDM Technology, Rotterdam (Netherlands).

HELICOPTER HANDLING: EXPERIENCE AND NEW DEVELOPMENTS

W. R. M. REIMERING and T. CRAIG (MacTaggart, Scott and Co. Ltd., Loanhead, Scotland) *In* AGARD, Aircraft Ship Operations 18 p (SEE N92-21951 12-05) Nov. 1991
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In the last 25 years, helicopter handling became a necessity in order to meet the mission requirements for operating helicopters from small ships. A survey of experiences and new developments in the field of helicopter handling is presented. The interface solutions, that are provided, take into consideration restrictions imposed by the airframe and the ship's construction. One set of solutions concentrates heavily on helicopter traversing systems. The other solutions discuss the landing grid and the design and construction of the decklock (sometimes referred to as the harpoon or talon).   Author

N92-21970# Dassault-Breguet Aviation, Saint Cloud (France). Direction General Technique.

DYNAMIC PERFORMANCE OF AN AIRCRAFT ON ITS LANDING GEAR: TEST AND EVALUATION ON A DIHEDRAL [COMPORTEMENT DYNAMIQUE D'UN AVION SUR SES ATTERRISSEURS: EXPERIMENTATION ET VALIDATION PAR FRANCHISSEMENT D'UN DIEDRE]

D. FLEYGNAC and E. BOURDAIS *In* AGARD, Aircraft Ship Operations 13 p (SEE N92-21951 12-05) Nov. 1991 In FRENCH
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The essential role of the dynamic performance of landing gear in this study of instances of contact with the ground and, more particularly, the analysis of catapulting marine aircraft has justified the desire to validate the models used in the design phase of existing aircraft. Described here is the preparation, installation, and use of a dihedral to launch a MIRAGE 2000. These trials permitted a detailed identification of the performance characteristics of landing gear in a particular dynamic phase that is fairly representative of the conditions encountered when catapulting, as well as the aerodynamic effectiveness of control surfaces with ground effect.   Author

N92-21971# British Aerospace Public Ltd. Co., Lancashire (England). Advanced Studies Dept.

SOME IMPLICATIONS FOR ADVANCED STOVL OPERATION FROM INVINCIBLE CLASS SHIPS

K. AINSCOW and P. G. KNOTT *In* AGARD, Aircraft Ship Operations 10 p (SEE N92-21951 12-05) Nov. 1991
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Replacing the Sea Harrier with a high performance Advanced Short Takeoff and Vertical Landing (ASTOVL) design for use on Invincible class ships was studied. Four different ASTOVL propulsion concepts are discussed. The integration of these larger, heavier aircraft with the small ship carrying EH101 helicopters is discussed. It is shown that the constraints of the ship and the size and performance of the aircraft require some changes in operational procedures when compared with Sea Harrier practice. The higher takeoff thrust to weight ratio and more hostile exhaust plumes suggest the use of the aft deck for recovery, a shorter deck run with the sky ramp for launching, and a blast deflector between the two areas. A study of the deck environment generated by the ASTOVL aircraft indicates that a delicate balance among size, mass, performance and exhaust environment will need to be struck in future Sea Harrier replacement studies for small ship operation.   Author

N92-21973# Stato Maggiore Marina, Rome (Italy).

LIMITATIONS ON HELICOPTER OPERATIONS IN THE AERONAVAL ENVIRONMENT [LIMITATIONS DES OPERATIONS DES HELICOPTERES DANS LE MILIEU AERONAVAL]

D. FALCINELLI *In* AGARD, Aircraft Ship Operations 6 p (SEE N92-21951 12-05) Nov. 1991 In FRENCH
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The particular problems faced by pilots during flight activities onboard military ships are discussed. Problems include limited space, motion of the flight deck, wind, and turbulence. Various situations were studied using helicopters, but the results can be generalized to other types of aircraft. Problems of approach and landing are of special interest. Limitations of the environment, systems that help flight operations, markings and visual cues, landing and relocation systems, and approach systems are briefly discussed.   Author

N92-21974# Atlantic Research Corp., Landover, MD.
REVOLUTION AT SEA: AIRCRAFT OPTIONS FOR THE YEAR 2030
JAMES C. BIGGERS and PETER A. SILVIA (David Taylor Research Center, Bethesda, MD.)   *In* AGARD, Aircraft Ship Operations 12 p (SEE N92-21951 12-05)   Nov. 1991
(AGARD-CP-509)   Copyright   Avail: NTIS HC/MF A15;
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Some innovative options for future aircraft and a revolutionary approach to the ships from which they operate are presented. Some options have been explored through the preliminary design stage, some are only at the conceptual design stage, and others are mere speculation. The limitations of the present fleet are noted, along with some possible solutions. All options assume the integration of ships and aircraft in more depth than previously. The objective here is to create in the reader a vision of the future surface and air fleet that is significantly different from today's Navy, and to get the reader involved in bringing this vision to reality.   Author

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

N89-27650# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
SYSTEMS ENGINEERING
May 1989   132 p   In ENGLISH and FRENCH   Lecture series held in Kettering, OH, 15-16 May 1989, in Delft, Netherlands, 22-23 May 1989, and in Rome, Italy, 25-26 May 1989
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Recent AGARD activities have indicated a strong need for more effective avionics system engineering. There is a growing need for reducing development time, effecting savings in costs of ownership, and in extending the life-time of avionics systems. This must be accomplished along with meeting needs of the user faced with a growing threat. With the growing complexity of avionics systems (as well as other systems), it is important to develop and maintain expertise in system planning, architecture, and management. The important systems engineering aspects of requirements, system integration, prototyping, and design are addressed. In addition, the impact of technology on system architecture are discussed. Methodologies are described and actual case histories will serve as practical examples of modern systems engineering. For individual titles, see N89-27651 through N89-27658.

N89-27651# Rome Air Development Center, Griffiss AFB, NY.
AVIONICS SYSTEM ENGINEERING: AN INTRODUCTION
FRED I. DIAMOND   *In* AGARD, Systems Engineering 6 p (SEE N89-27650 22-06)   May 1989
(AGARD-LS-164)   Copyright   Avail: NTIS HC A07/MF A01

System engineering is the process used in the evolution of systems from identification of a need through construction and/or production and deployment in an operational environment. It is a process that involves the application of appropriate scientific and technical knowledge to transform an operational need into a system configuration with defined parameters, through an iterative process of analysis, design, test, and evaluation; to integrate all performance requirements, including reliability, maintainability, and supportability into the total engineering effort; and to integrate related components to insure interoperability and optimum system performance. It is a process that also considers economic factors such as development and life cycle costs. The life cycle process involves several key steps, many iterative, but in an orderly and controlled manner. These steps include requirements, architecture specification, design, development/construction, test and evaluation, and operational use. With the growing complexity of avionics systems, effective systems engineering is critical. Therefore, greater emphasis is placed on architectures, subsystem design, and interfaces and system integration. Only through a total

systems engineering approach from the very initial phases of the system life cycle can a well-engineered system be achieved. The payoff will be reduced cost of ownership and greater mission effectiveness.   Author

N89-27652# Westinghouse Electric Corp., Baltimore, MD.
AVIONIC SYSTEM REQUIREMENTS
HARVEY M. PASKIN   *In* AGARD, Systems Engineering 6 p (SEE N89-27650 22-06)   May 1989
(AGARD-LS-164)   Copyright   Avail: NTIS HC A07/MF A01

Avionics system requirements are addressed at the conceptual level in light of changing threats, acquisition strategies, technology, and business environments. The objective is to provide a perspective of total integrated avionics system performance which illuminates broad requirement issues rather than specific subsystem specifications. The fundamental tenet is that although parametric and functional avionic system requirements can be related intuitively to mission related activities, a more global view is necessary to ensure that system requirements aptly address the gamut of factors which relentlessly bear on the ultimate system design, development, production, and support. The premise is that avionics requirements are driven by four factors: information and data sources, control opportunities and information needs; concepts and algorithmic techniques; and realization technologies. These four factors are set in a generic systems structure which shows their interrelationships and provides the framework for conceptualizing avionic system solutions to meet particular mission needs. The structure focuses on the role of avionics in providing situation assessment, response selection, response implementation, and communications. With this structures in place, avionic system requirements are then examined within the context of architecture, techniques, technology, producibility, and supportability.   Author

N89-27653# British Aircraft Corp., Preston (England).
A STRUCTURED APPROACH TO WEAPON SYSTEM DESIGN
J. D. ROWLEY   *In* AGARD, Systems Engineering 7 p (SEE N89-27650 22-06)   May 1989
(AGARD-LS-164)   Copyright   Avail: NTIS HC A07/MF A01

A structured approach is described for the design of a weapon system which British Aerospace (BAe) was able to develop and prove during the design of the avionics system for the Experimental Aircraft Program (EAP) demonstrator aircraft. Brief descriptions are given of the EAP avionics system, the main system design tools used, the activities carried out during the systems design process, and the management and control procedures adopted. In addition a series of observations highlighting some of the findings of the project and providing pointers to the design of future weapon systems are given.   Author

N89-27654# Aeronautical Systems Div., Wright-Patterson AFB, OH. Directorate of Design Analysis.
INTEGRATED AVIONICS: CONCEPTUAL DESIGN
MICHAEL J. BREZA   *In* AGARD, Systems Engineering 3 p (SEE N89-27650 22-06)   May 1989
(AGARD-LS-164)   Copyright   Avail: NTIS HC A07/MF A01

Avionics of modern military aircraft is essential for maximizing performance realization of the total aeronautical system. In the early conceptual phase, aeronautical systems designers give scant attention to the interaction of avionics components. The aircraft design team generally provides weight, volume, and power considerations for the desired avionics functions and assumes that an avionics suite can eventually be assembled. Even less attention is given to the potential synergistic effect avionics can have with the aircraft design process. In contrast, the designers expend a large effort on finding the best balanced combination of airframe and propulsion components which satisfy the design objectives. An attempt is made to show why avionics must be a co-equal member of the aeronautical system along with airframe, propulsion, and armament. In becoming a co-equal partner, avionics must be an element of the system design analysis, commencing with the early conceptual design phase of a new aeronautical system.   Author

N89-27655# Air Force Avionics Lab., Wright-Patterson AFB, OH.
THE EVOLUTION OF DIGITAL AVIONICS ARCHITECTURES/SYSTEMS
JOHN C. OSTGAARD and D. REED MORGAN *In* AGARD, Systems Engineering 22 p (SEE N89-27650 22-06) May 1989
(AGARD-LS-164) Copyright Avail: NTIS HC A07/MF A01
The evolutionary design/development of modern-day digital information systems is examined. Included are the initial attempts at using digital technology in the early 1970s, the system integration thrusts of the 1980s, and the continued system technology revolution of the 1990s. Author

N89-27656# GEC Avionics Ltd., Rochester (England).
AVIONIC SYSTEM DESIGN METHODOLOGY
M. J. TOOZE *In* AGARD, Systems Engineering 9 p (SEE N89-27650 22-06) May 1989
(AGARD-LS-164) Copyright Avail: NTIS HC A07/MF A01
An approach is described for an avionic system design and its application to modular avionic architecture. The approach is to test various candidate architectures using a common functional requirement. The method commences with a requirement analysis carried out in a top-down fashion to arrive at a full functional description. A parallel phase determines the technological base and defines a number of candidate architectures and corresponding component sets (module sets in the case of modular architecture). Thus technological performance and in-place equipment limitations are included at an early stage independent of the requirement. Hence top-down means bottom-up, by taking various architecture candidates and corresponding modular sets and applying the functional description of the requirement, so each architecture may be investigated for its capability to cope with the trial or application system. Assessment of reliability and performance objectives is discussed. Also included is reference to the areas of operating systems and BITE which may form part of the system but are not necessarily directly represented at the boundaries of the system. The philosophy of the approach is evaluated and does not extend to application of the various CASE design tools which exist (or may be specified) in order to carry out such a project in practice. Author

N89-27657# Aeritalia S.p.A., Caselle Torinese (Italy). Gruppo Sistemi e Teleguidati.
RAPID PROTOTYPING OF COMPLEX AVIONICS SYSTEMS
L. BERARDI *In* AGARD, Systems Engineering 18 p (SEE N89-27650 22-06) May 1989
(AGARD-LS-164) Copyright Avail: NTIS HC A07/MF A01
The use of a rapid prototyping approach in the initial stages of complex avionics system design can complement some traditional computer design methods. In fact most of the computer aids in engineering and design are aimed to a better, coherent and, as far as possible, complete description of the project, but not too much is done on the verification of the proposed concept implementation. The advantage of having in the early design a software prototype of the system to highlight undesirable characteristics or possible improvements when the system has a high degree of complexity is discussed. Then a design tool called Expert Consultant for Avionics System Transformation Exploitation (ECATE) is described. ECATE is an expert system that prototypes the information handling architecture of an avionics system. The use of knowledge engineering and, in general, artificial intelligence approach for the rapid prototyping has proven very effective, because of the high flexibility, complex domain mastering capability, and heuristic methods typical of these techniques. Finally a description of a complete, integrated environment for the rapid development of prototypes of avionics systems, by using artificial intelligence and computer tools, is given. Author

N89-27658# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
MODELING FUNCTIONAL SPECIFICATIONS FOR ONBOARD SOFTWARE [MAQUETTAGE DES SPECIFICATIONS FONCTIONNELLES DU LOGICIEL EMBARQUE]
PATRICK SCHIRLE *In* AGARD, Systems Engineering 19 p (SEE N89-27650 22-06) May 1989 In FRENCH
(AGARD-LS-164) Copyright Avail: NTIS HC A07/MF A01
Software development for military avionics requires extensive documentation of functional and contractual specifications. The modeling of specifications permits: (1) improvement of the formal quality of specifications; (2) functional validation throughout the entire software life cycle; (3) generation of acceptance criteria; and (4) establishment of a functional reference for system integration. The role of specifications modeling in the software development process is discussed and experiences with the Rafale A and Mirage 2000 NC avionics systems are described.
Transl. by M.G.

N90-27448# Army Avionics Lab., Fort Monmouth, NJ.
HOVER POSITION SENSING SYSTEM
STEPHEN P. AHRENS and JOSEPH MCGOWAN (Intermetrics, Inc., Oceanport, NJ.) *In* AGARD, Tactical Applications of Space Systems 8 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The U.S. Army Light Helicopter Experimental (LHX) aircraft has a requirement for a Hover Hold System with a desired accuracy of 1 meter RMS for a 3 minute period. AVRADA (Avionics Research and Development Activity) recently completed a demonstration program which indicated that an error of 0.6 meter or less is achievable with the LHX navigation sensor suite. The demonstration program and results are presented. Author

N91-12686# Draper (Charles Stark) Lab., Inc., Cambridge, MA. Fault-Tolerant Systems Div.
TECHNIQUES FOR TRANSIENT ERROR RECOVERY AND AVOIDANCE IN REDUNDANT PROCESSING SYSTEMS
STUART ADAMS and MARK DZWONCZYK *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 9 p (SEE N91-12682 04-08) Apr. 1990
(AGARD-CP-456) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
As the trend for increased storage in reliable, high-performance guidance, navigation, and control systems continues, coverage of transient memory failures becomes an increasingly critical problem. New techniques of recovery from such failures are discussed in redundant processing systems which perform high-frequency iterative control algorithms for flight critical GN and C. Two approaches are presented. The first employs hardware assisted recovery techniques to detect which memory segments in the failed processor need to be restored, so that recovery can be accomplished incrementally, by only restoring segments of memory which were corrupted. The second approach is to utilize a common fault-tolerant memory which allows errors to be masked and corrected on-the-fly eliminating the need for recovery. Author

N91-12698# Crouzet Aerospace and Systems, Valence (France).
BREAKDOWN METHODOLOGY FOR FLIGHT CRITICAL APPLICATIONS INTO ELEMENTARY COMPONENTS
BERNARD CHAVANA and FRANCOIS DESAINTEMARESVILLE *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 9 p (SEE N91-12682 04-08) Apr. 1990 In FRENCH
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The objective is to explain the steps in specification/conception used in the case of critical product development for aircraft safety. The explanation does not approach from the design aspect, but in the specification sense from the middle of the design (coding, testing....). At each stage, it is shown how a simple step is discovered for assuming project limits. Transl. by E.R.

N91-15154# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
ADVANCES IN COMPONENTS FOR ACTIVE AND PASSIVE AIRBORNE SENSORS
Sep. 1990   191 p   Meeting held in Bath, England, 9-10 May 1990
(AGARD-CP-482; ISBN-92-835-0584-0; AD-A229641) Copyright
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The survivability of aircraft and their capability of carrying out different missions rely on numerous sensor systems such as radar, altermeters, radio navigation, measure, and countermeasure equipment. It is very important that the most advanced semiconductor technologies be used in those systems as early as possible, because avionic equipment performance is limited by available components. Emerging semiconductor components and sensor technologies are examined in the proceedings from this workshop. For individual titles, see N91-15155 through N91-15170.

N91-15155# Thomson Composants, Saint Egreve (France). Militaires et Spatiaux.
SPECIFIC ASPECTS OF ADVANCED COMPONENTS FOR AIRBORNE APPLICATIONS
JEAN-MICHEL BRICE *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 6 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Some of the important specific aspects are presented of electronic components, mainly high speed, high performance integrated circuits used for airborne applications. It is shown that the requirements such as complexity, performance, power consumption, are more stringent for airborne components than for other components, civil ones in particular. In addition, the long lifetime of airborne equipments, typically 25 to 30 years, requires specific arrangement to assure the long term availability of the stratogic components, as the semiconductor technologies don't survive more than 10 years. The antinomy, use of standard and mature technologies for low cost and large product base but necessity to get access to specific or advanced technologies for specific performance requirements, can be solved by the add-on military concept, where civil technologies are used whenever possible, but specific developments are undertaken to fulfill the military airborne specifications.   Author

N91-15156# Thomson Composants, Orsay (France).
MICROWAVE AND MILLIMETER WAVE COMPONENTS: PERFORMANCES, PERSPECTIVES, AND APPLICATIONS TO AVIONICS
PIERRE BRIERE and DOMINIQUE PONS (Thomson-CSF, Orsay, France) *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 7 p (SEE N91-15154 07-06)   Sep. 1990
(AGARD-CP-482) Copyright Avail. NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Significant advances in microwave and millimeter wave three terminal devices have been obtained in the last few years, leading to great performance gains in noise figure power gain, and power output up to 100 GHz. Great improvements in materials growth, heterojunction device structures and processing technology have resulted in noise figure as low as 1.4 dB and power output in excess of 50 mw, both at 94 GHz. In addition, the emergence of Heterojunction Bipolar Transistor (HBT) based Monolithic Microwave Integrated Circuit's (MMIC's) opens new possibilities for high power and high efficiency circuits, low phase noise Voltage Controlled Oscillators (VCOs) and others. The different types of these advanced devices are reviewed and their performance characteristics in low noise and power applications are examined. Potential applications of such devices with their specific advantages in electronic airborne equipment are also studied.   Author

N91-15159# Army Electronics Technology and Devices Lab., Fort Monmouth, NJ.
LOW-NOISE OSCILLATORS FOR AIRBORNE RADAR APPLICATIONS
RAYMOND L. FILLER and JOHN R. VIG *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 16 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Vibration effects are a significant problem in modern communication, navigation, and radar systems. Vibration induced phase noise can change the probability of detection of moving target indicator (MTI) radar from near 100 percent to 0. Oscillators that are capable of meeting the requirements of MTI radar systems in a quiet environment are readily available. In the vibrating environments of airborne platforms, however, the phase noise of oscillators will degrade to a large degree. High stability frequency sources, including atomic standards, contain quartz crystal resonators. One result of the evolution of electronics, i.e., the transition from tubes to transistors, and from point-to-point wiring to printed circuits, is the establishment of the quartz crystal resonator as the most acceleration sensitive component in frequency sources. The causes and effects of acceleration sensitivity of bulkwave quartz crystal resonators are reviewed along with the methods that reduce or compensate for that sensitivity. Most of what is discussed is relevant to most microwave oscillators.   Author

N91-15160# Siemens A.G., Munich (Germany, F.R.). Components Group.
GAAS MMICS IN SELFALIGNED GATE TECHNOLOGY FOR PHASED ARRAY RADAR APPLICATION
E. PETTENPAUL and U. FREYER (Siemens A.G., Unterschleissheim, Germany, F.R.) *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 10 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Design and performance data of GaAs Monolithic Microwave Integrated Circuits (MMICs) for C and X band Transmitter/Receiver (T/R) Radar Antenna Modules and broadband Electronic Countermeasure application are described. The devices considered are low noise amplifiers, medium power amplifiers, 3 W high power amplifiers, 4 and 6 bit attenuators, 4 and 6 bit phase shifters, and distributed amplifiers. The devices are fabricated on a high volume pilot line with only one standard high yield process. The main steps in the process are given. In comparison to other standard MMIC process lines it is specific, that a Selfaligned Gate Technique, the so called DIOM (Double Ge/Si contact Implantation, One Metallization) process, is used for production. Thereupon is another specific aspect that an advanced inhouse computer aided design package for GaAs MMICs and a very accurate cell library based on on-wafer RF measurements is operational. Highlights are the very accurate and low noise 6 bit attenuators and phase shifters and especially a high power amplifier MMIC with 3.6 W output power and 31 percent added efficiency at C band.   Author

N91-15164# Naval Weapons Center, China Lake, CA.
LOGARITHMIC AMPLIFICATION FOR PASSIVE AIRBORNE DIRECTION FINDING IN THE 1990S
RICHARD SMITH HUGHES *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 15 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Logarithmic amplifiers (log amps) are indepensable parts in most airborne passive direction finding (DF) sensors, including both antiradiation missiles (ARMs) and radar warning receivers (RWRs) on aircraft. The modern early warning (EW) threat necessitates covering increased instantaneous radio frequency (RF) bandwidths and processing increasing pulse densities, coupled with needs for lower power dissipation, smaller size, and lower cost. Because of these constraints, the log amp designer is often at a loss. Successive detection log intermediate frequency amps (SDLAs) and Detector/log video amps (DLVAs) have disadvantages. The

log amps of the 1970s through mid 80s will not meet the stringent requirement of the 90s. A historical perspective is presented of the why's and how's of modern log amps, with emphasis on their application specific strong and weak points. New circuit elements and topologies are presented that may well determine where the log amps of the 90s are headed. *Author*

N91-15166# Rome Air Development Center, Griffiss AFB, NY.
MMIC IMPACT ON AIRBORNE AVIONIC SYSTEMS
EDWARD J. JONES and WILLIAM J. BOCCHI, JR. *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 7 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09;
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The latest advances in Monolithic Microwave Integrated Circuit (MMIC) technology and its impact on airborne avionic systems, along with a unique technique for designing reliability into MMIC devices, is described. Current MMIC transmit/receive (T/R) module performance is presented along with current hybrid module results for comparison. For example, typical RMS phase error for a 10 GHz T/R MMIC module is about one half of a hybrid module, which can increase antenna performance by 5 dB. Work in developing and applying finite element analysis (FEA) techniques to MMIC T/R modules to determine temperature and stress levels within microscopic regions of these devices is also examined. It is now possible to assess the reliability of new MMIC designs using this analytical tool which makes it possible to avoid time consuming and costly after-the-fact test and redesign of a given development. *Author*

N91-15169# Naval Weapons Center, China Lake, CA. Targeting and Fire Control Div.
LASER OBSTACLE AND CABLE UPDATE SENSOR
C. K. BULLOCK, R. T. HINTZ, and W. TANAKA *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 21 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09,
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The real night foreign weapon evaluation (FWE) program was evaluating an integrated night attack avionics suite for an A-6E aircraft. The most recent addition to this avionics suite is a CO2 laser terrain following/obstacle avoidance (TF/OA) sensor. The requirements are described for this type of sensor along with the characteristics of the system, and some preliminary test results gathered during A-6 flights. *Author*

N91-18073# Military Airlift Command, Scott AFB, IL. Reliability and Maintainability Technology Div.
C-130 ELECTRONIC COCKPIT: RELIABILITY AND MAINTAINABILITY TECHNOLOGY INSERTION PROGRAM (RAMTIP)
ROBERT L. RUSSELL *In* AGARD, Progress in Military Airlift 6 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
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The Reliability and Maintainability Technology Insertion Program (RAMTIP) is aimed at accelerating new technologies from the laboratory and applying them to Air Force weapon systems in an effort to improve reliability and maintainability (R and M). This RAMTIP project will replace some sixty analog type cockpit instruments in a Military Airlift Command (MAC) C-130E with six liquid crystal flat panel displays. Five displays are installed on the pilot's/copilot's instrument panel with a sixth display installed at the navigator's station. Designed in the mid-1950s, the C-130 has remained highly cost effective to procure and operate. This is due largely to the simplicity of its systems and the fact that its design and tooling costs have long since been amortized. The aircraft performs a diversity of missions quite well, but the repairing and stocking of obsolete analog type instruments has become logistically difficult and costly. The purpose is to demonstrate the operational effectiveness and suitability of active matrix liquid crystal flat panel displays in the C-130 and to validate the projected R and M improvements of this technology over electromechanical analog instruments and cathode ray tubes (CRT). Although work is still in progress, the successful development and integration of

this technology offers significant potential improvement in R and M, redundancy with graceful degradation, and enhanced operational effectiveness. Once proven, this technology can be applied to a wide variety of other aircraft throughout the Air Force inventory and other Department of Defense services, as well as that of the commercial aircraft industry. *Author*

N91-21135*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DIGITAL SIGNAL CONDITIONING FOR FLIGHT TEST INSTRUMENTATION
GLENN A. BEVER Mar. 1991 81 p Sponsored by AGARD Flight Mechanics Panel, Flight Test Techniques Working Group
(NASA-TM-101739; H-1695; NAS 1.15:101739;
AGARDOGRAPH-160) Avail: NTIS HC/MF A05 CSCL 01/4

An introduction to digital measurement processes on aircraft is provided. Flight test instrumentation systems are rapidly evolving from analog-intensive to digital intensive systems, including the use of onboard digital computers. The topics include measurements that are digital in origin, as well as sampling, encoding, transmitting, and storing data. Particular emphasis is placed on modern avionic data bus architectures and what to be aware of when extracting data from them. Examples of data extraction techniques are given. Tradeoffs between digital logic families, trends in digital development, and design testing techniques are discussed. An introduction to digital filtering is also covered. *Author*

N91-25138# McDonnell Aircraft Co., Saint Louis, MO.
INTEGRATED CONTROL AND AVIONICS FOR AIR SUPERIORITY: A KNOWLEDGE-BASED DECISION AIDING SYSTEM
DONALD J. HALSKI, ROBERT J. LANDY, and JAMES A. KOCHER (Wright Research Development Center, Wright-Patterson AFB, OH.) *In* AGARD, Knowledge Based System Applications for Guidance and Control 9 p (SEE N91-25121 17-04) Apr. 1991
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An ongoing program is described in which is developed an effective, real time, knowledge based, decision aiding system for air combat. The Integrated Control and Avionics for Air Superiority (ICAAS) program is used to develop, integrate, and demonstrate critical technologies which will enable USAF tactical fighter aircraft to kill and survive when outnumbered as much as four to one by enemy aircraft during air combat. Primary emphasis is placed upon beyond visual range (BVR) multiple target attack capability with provisions for effective transition to close-in combat. Knowledge based pilot decision aiding techniques and expert system methods are used to achieve substantially enhanced offensive and defensive capabilities compared to current operational systems. Situation awareness information and recommended actions are computed to aid the pilot in selecting the most effective attack and defend engagement options. The system maximizes opportunities for missile launch against multiple enemy aircraft while maintaining options to defend when necessary. Sufficient integration and automation are provided for application to a single seat fighter. *Author*

N92-12531# Wright Lab., Wright-Patterson AFB, OH.
PILOT'S ASSOCIATE: EVOLUTION OF A FUNCTIONAL PROTOTYPE
CARL S. LIZZA, SHEILA B. BANKS, and MICHAEL A. WHELAN *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 12 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499) Copyright Avail: NTIS HC/MF A14;
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The Pilot's Associate Program has completed its first phase of functional development which included two significant program milestones. The early successful development of complex, knowledge based, decision aiding systems allowed the program to shift focus to a more near term, embedded avionics application of the technology. This change in philosophy forced an evolution away from a program designed to explore artificial intelligence without processing bounds, towards a more consistent with, and constrained by, the realities of an avionics processing architecture of an actual aircraft. One of the developmental approaches is focused on, the technical progress made through this phase of

the program, and the accomplishments and disappointments with the design approach. Lastly, a brief look into the lessons learned as artificial intelligence technology was applied to a dynamic and complicated domain is presented. Author

N92-12532# British Aerospace Public Ltd. Co, Preston (England).
DEVELOPMENT OF TACTICAL DECISION AIDS
W. G. SEMPLE In AGARD, Machine Intelligence for Aerospace Electronic Systems 6 p (SEE N92-12517 03-63) Sep. 1991
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British Aerospace is pursuing a program of research and development of computer aids (mission management aids) to assist the pilot in the management of combat missions. In addition to algorithms, many aids will have to exploit new concepts from software engineering to artificial intelligence. We have these new tools by which we expect that we can meet the new requirements. However, many of the conventional solutions are new to our experience, at least within the stringent requirements of real-time airborne computing, and many of the new tools are only partly developed or partly understood. This is especially true for some tactical MMAs. Author

N92-12535# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.
A THREAT MANAGEMENT SYSTEM
K. HOLLA and B. BENNINGHOFEN In AGARD, Machine Intelligence for Aerospace Electronic Systems 6 p (SEE N92-12517 03-63) Sep. 1991
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The Threat Management System (TMS) is a company prototype development of a support system for the crew of fighter bombers at low level flight. In particular, TMS is supposed to provide support in high dense groundbased air defence scenarios during the preparation phase, the penetration phase, and the attack phase of a mission, applying methods of terrain and threat avoidance combined with sensor information fusion. Author

N92-12536# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.
EXPERT SYSTEM FOR THE TORNADO GROUND-BASED CHECK-OUT SYSTEM
J. FEY, J. MARANGOS, M. MERX, and W. MANSEL In AGARD, Machine Intelligence for Aerospace Electronic Systems 5 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499) Copyright Avail: NTIS HC/MF A14;
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A technology demonstrator, supporting the TORNADO check-out system for aircraft was developed and tested. The expert system, called TORRES (TORNADO Radar Readiness Expert System), supports debriefing staff with various levels of experience. The scope of the error detection encompasses the TORNADO Terrain Following and Ground Mapping Radar system down to the module level. The main task of TORRES is the identification and isolation of errors that occurred during the previous flight. The expert system is also able to exclude errors that were generated by other systems capable of changing the state of the radar system and isolate the cause. Other influences, like EMC, exceeding avionic systems acceleration limits, and weather effects are taken under consideration and reported. If an error run is left without an associated case, special test runs are suggested. An explanation facility generates detailed debriefing reports. Author

N92-12539# Wright Lab., Wright-Patterson AFB, OH.
INTEGRATED COMMUNICATIONS, NAVIGATION, IDENTIFICATION, AVIONICS (ICNIA) EXPERT SYSTEM FOR FAULT TOLERANT AVIONICS
MARK E. MINGES In AGARD, Machine Intelligence for Aerospace Electronic Systems 15 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499) Copyright Avail: NTIS HC/MF A14;
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Embedded avionic systems for aircraft are becoming increasingly more complex. Very High Speed Integrated Circuits (VHSIC) and semi-custom devices are used to gain many-fold increases in processing power and capability. Mission and operational requirements dictate a high availability and fault detection capability defined quantitatively as 98 percent detection of all faults and isolation of 90 percent of those faults to a line replaceable module (LRM), or 95 percent of the faults to two LRM's. The Integrated Communications, Navigation, Identification Avionics (ICNIA) Program utilizes a module maintenance node (MN) which aids high speed testing of the LRM, and gives the ability to isolate the fault(s) to one or more modules. The MN uses the concepts of set scan design, pseudo-random test vector generation, output response compression, and separate set scan loops to test the small scale integration-medium scale integration logic on the LRM. The resultant data is made available to the expert system within ICNIA so that real-time fault detection and isolation can be achieved. The objective of the expert system within ICNIA is to detect and isolate faults in near real-time and minimize the false alarm rate. Other aspects of the system are addressed. Author

N92-12540# Wright Lab., Wright-Patterson AFB, OH.
A DEVELOPMENT-MEMORY APPROACH FOR ENHANCING AVIONICS SOFTWARE LOGISTICS
MARC J. PITARYS In AGARD, Machine Intelligence for Aerospace Electronic Systems 5 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499) Copyright Avail: NTIS HC/MF A14;
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Advanced avionics systems will execute Ada software on multiple parallel computers. The size and complexity of the avionics software will be massive. Of particular importance is how the software will be supported once it is delivered to the Air Force. Software support is that part of the avionics software life-cycle that deals with the correction of deficiencies and the addition of enhancements to the avionics software. Much of the time spent by personnel is information searching and inferencing. These tasks are made more complicated when information that was useful to the developer is not included in the software documentation that is delivered with the weapon system. The challenges facing avionics software support personnel are covered, and an advanced software support concept called Development-Memory (DM) is addressed.
Author

N92-14046# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
THE CONFLICTING FORCES DRIVING FUTURE AVIONICS ACQUISITION
Sep. 1991 207 p In ENGLISH and FRENCH Lecture series held in Kettering, MD, 16-17 Oct. 1991, in London, England, 4-5 Nov. 1991, and in Madrid, Spain, 7-8 Nov. 1991
(AGARD-LS-176; ISBN-32-835-0636-7; AD-A244244) Copyright Avail: NTIS HC/MF A10; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

There is a growing need to develop flexible/robust avionics to meet ever changing mission needs of the operational forces. Such needs may conflict with other required characteristics such as standardization, increased reliability, durability, and integrity. Weapon system costs and associated avionics costs continue to increase while military budgets continue to shrink due to the changing world conditions. Thus, it is even more important to intelligently resolve these often conflicting forces driving development efforts. These evolving trends, conflicts, and challenges are examined with a view to enhancing dialogue, understanding, and improved planning. For individual titles, see N92-14047 through N92-14058.

N92-14047# Aeronautical Systems Div., Wright-Patterson AFB, OH.
EVOLUTION OF AVIONIC SYSTEMS ARCHITECTURE, FROM THE 1950'S TO THE PRESENT
GARY L. LUDWIG *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 7 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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      The evolution of the avionic systems architectures in the U.S. Air Force fighter aircraft is described, beginning with the system design typical of the Century Series aircraft (the F-100, F-101, etc.) and progressing on through the long list of fielded aircraft to the front-line fighters of today and beyond to the system currently under development at the Aeronautical Systems Division. In parallel with this description, the forcing functions and catalysts for change of avionic systems architecture are also noted. In this regard, the rapid shift to digital avionics made possible by the transistor and the integrated circuit, wafer-scale integration, and high-density mass memory devices has rapidly driven the evolution of avionic system architecture. Attendant with such technology advancements, pilot interface associated with each new generation of avionic subsystem has also continued to mature and this also has had a major impact on system design. With the ever-increasing capabilities of weapons systems, pilot workload has increased dramatically. The need for simplification, integration, and automation of operator functions has become abundantly clear. The evolution of system design features intended to ease the operator's burden have greatly influenced system design, and these impacts are also reviewed. In conclusion, a quick glimpse at future means of supporting the pilot is provided, and the implications on future avionic system design are reviewed.   Author

N92-14048# Aeronautical Systems Div., Wright-Patterson AFB, OH.
AVIONICS STANDARDIZATION IN THE USAF: 1980 TO 1990
NANCY L. CLEMENTS *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 9 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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      A review of avionics standardization from 1980-1990 is presented. Background, definitions, and anticipated benefits of avionics standardization are presented followed by the current extent of standards application and associated cost avoidance summaries. Lessons learned from the past 10 years are highlighted along with efforts underway to define a set of standardization, application, and implementation criteria designed to identify future avionics standardization initiatives and quantify anticipated benefits.   Author

N92-14049# Boeing Military Airplane Development, Seattle, WA. Avionics Technology Div.
HISTORICAL PERSPECTIVE ON THE EVOLUTION OF AVIONICS STANDARDS
JOHN C. RUTH *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 12 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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      An Avionics Laboratory major program, the Digital Avionics Information System (DAIS), played a key role in the evolution of interface standards from the late 1960's to the middle 1980's. The DAIS program considered interface standards in its basic concept and the cornerstones of the DAIS concept were: (1) A digital multiplex distribution system; (2) Functional software coded in a Higher Order Language; (3) A functional interface standard for processors in the form of a common instructional set architecture; and (4) A glass cockpit with interactive displays. The DAIS hypothesis was that significant ownership savings could be obtained on an aircraft and other weapon systems if some type of standard interfaces were established. Commonality of hardware was not the driving issue, but standards which defined the key interfaces and did not inhibit creative and innovative technology upgrades were imperative. The DAIS program endorsed many of

the standards, 1553, 1589, 1750, and 1760, by which avionics designers now design highly integrated systems.   Author

N92-14050# Ministry of Defence, Paris (France). Integration Div.
AVIONICS STANDARDIZATION IN EUROPE
L. GUIBERT *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 15 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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      Avionics standardization in Europe has relied upon common standards, such as Stanags. That approach is not rigid enough to ensure real interoperability, as will be demonstrated with the Link 16 example. It is foreseen that one of the major challenges for future avionics standardization will be the modularity. For some reasons, there must be international commonality in order to obtain minimization of costs. One important issue is the applicability of modular avionics on board European aircraft. This has been studied in France with relation to the Rafale. The results of that study will be discussed in some details. Another issue is the standardization of Instruction Set Architectures (ISA) in the field of data processing. That concept helps to solve some problems, such as software interchangeability and reconfigurability, but it also has drawbacks. A solution to the problem which does not imply common ISAs is predicted in France: the software bus. That concept, related to the Real Time Ada Extension program is proposed. It is clearly understood in Europe that modular avionics will gain maximum advantage if its F31 specifications are common to the different nations and services within NATO. This enforces the need for cooperation at both governmental and industrial levels. Europe has launched two multinational programs in order to define and validate a common avionics architecture for application in the next century: the ASAAC and the EUCLID CEPA 4. The scope and content of the first phase of these programs will be described.
                                                     Author

N92-14051# Thomson-CSF, Malakoff (France). Radar and Counter-Measures Div.
MIXED APPROACH TOWARDS MODULAR AVIONICS CONFLICTING REQUIREMENTS
J. P. LACROIX *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 10 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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      New development efforts like PAVE-PILLAR and PAVE-PACE in the US, EUCLID CEPA 4 in Europe, aim at architecture selection or standards recommendations in order to satisfy at least three requirement domains: LCC (life cycle cost) requirements; performance requirements, and availability requirements. A tool is described (graphic capture and simulation) which aims to bring some methodological help for designing modular integrated avionics systems, by allowing a more accurate analysis of their dynamical behavior. The refinement of the system modelization is tightly dependent on the performance of the simulation package.
                                                     Author

N92-14052# Ministry of Defence, London (England).
AVIONICS SOFTWARE EVOLUTION
JOHN A. TURTON *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 17 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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      The critical software related aspects are reviewed, where thorough planning and implementation of philosophies and principles are needed, in order to be able to develop software based avionic systems to meet target timescales and budgets. Some of the critical software technologies are identified that will facilitate this process, both today and in the near future. The implications are described for software resulting from the currently emerging modular avionic architectures. A central theme is that the system and software generation process should be placed on as formal a theoretical basis as possible. This is in order to be able to deal effectively with the complexity of the software based avionic systems that are just around the corner.   Author

06 AIRCRAFT INSTRUMENTATION

N92-14053# Aeronautical Systems Div., Wright-Patterson AFB, OH.
COMMON AVIONICS BASELINE: THE PRODUCT OF THE JOINT INTEGRATED AVIONICS WORKING GROUP
CHRISTOPHER L. BLAKE *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 12 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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The JIAWG CAB is expected to have enormous influence on the entire next generation of avionic systems. It is imperative that good standardization decisions, based on a credible data base of design, test, and analysis, be used as the basis for CAB definition. Premature publication of specifications and standards whose content is not well founded and likely to change could cause resources to be wasted by the industry and could fatally undermine the credibility of this DOD avionics commonality thrust. The CAB development is concurrent with the development phases of the Light Helicopter and Advanced Tactical Fighter programs from which the data needed to close remaining technical issues will be derived. The JIAWG process provides a systematic way to define technical issues and alternative solutions and to draw on all valid data sources in establishing the preferred resolution of each issue. This process will be tightly coordinated with the weapon system programs to ensure specifications and standards incorporate adequate and current data from analysis and testing to complete each version of the CAB as part of planned weapon system development milestones. Author

N92-14054# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Systems Engineering Branch.
AVIONICS SYSTEMS DEVELOPMENT: TECHNOLOGICAL TRENDS, CONFLICTS, AND COST ISSUES IN A CHANGING EUROPEAN ENVIRONMENT
HELMUT RAPP *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 15 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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Presented here is an overview of German research and development projects generally known as modular avionics and their relationship to international initiatives. Growing system software complexity as well as rising software problems and cost have forced software development into rigid development methods and high order languages, and towards increasing standardization. Focussed upon are equipment standards that allow technology growth, maximize competition, and promote reusability of designs, and the avionics system software evolution and the experiences gained in the German TORNADO and F-4F upgrade programs. Author

N92-14055# Aeronautical Systems Div., Wright-Patterson AFB, OH.
AVIONICS MODERNIZATION/UPGRADES IN THE LATE 1990S
RONALD S. VOKITS *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 5 p (SEE N92-14046 05-06) Sep. 1991
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A number of issues relative to avionics upgrading are briefly discussed. Capability and supportability improvements; maintenance philosophy; availability, diagnostics, software, and packaging improvements; mixing of old and new technologies; standards; life cycles; and predictions are among the topics covered. Author

N92-14056# Aeronautical Systems Div., Wright-Patterson AFB, OH. Integrated Engineering and Technical Management Div.
AVIONICS RELIABILITY, DURABILITY, AND INTEGRITY: CAN THEY BE INDEPENDENT OF APPLICATION?
HAROLD W. UNDERWOOD *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 22 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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The development of avionics through the application of traditional MIL-STD-785, Reliability Program for Systems and Equipment Development and Production development processes for avionic reliability has been proven to have several advantages, disadvantages, and limitations. This process is contrasted to the Avionics Integrity process which is based upon the knowledge of how the equipment is to be used, the actual environments of the operating equipment, and the application of fatigue theory and life laws to design. The process is based upon a detailed understanding of the characteristics of the parts, materials, and associated processes used in its manufacture, and the tailoring of the process controls, inspection, and test requirements. The outcome of the process will be avionics with a minimum life that is dependent upon the operational stresses applied. Additionally, a number of conflicts associated with the use of standard environments, standard parts, the use of redundancy, who is responsible for reliability, MIL-SPEC design criteria, mean time between failure as a metric, and warranties are also addressed. Author

N92-14057# Westinghouse Electric Corp., Baltimore, MD. Digital Systems Dept.
IMPLICATIONS OF INTEROPERABILITY AND STANDARDIZATION FOR THE INDUSTRIAL BASE
JOHN C. STUELPNAGEL *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 6 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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A persistent problem for North Atlantic Treaty Organization (NATO) forces has been the difficulty of standardization and interoperability, due to conflicting political, economic, national, and industrial pressures. One approach to better accomplish standardization objectives has been the establishment of co-development programs, such as the Very High Speed Integrated Circuit (VHSIC) Avionics Modular Processor Program, in which the French and United States Governments have initiated the development of interoperable digital processing modules. However, conflicts in timing between development efforts and schedules for production and deployment of aircraft platforms has resulted in limited use of such modules in major aircraft programs. Several models for NATO standardization organizations are discussed which could address this problem and achieve significantly higher levels of interoperability in operational NATO equipment. Author

N92-14058# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Systems Integration Div.
AVIONICS TECHNOLOGY BEYOND 2000
LESTER MCFAWN and D. R. MORGAN *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 27 p (SEE N92-14046 05-06) Sep. 1991
(AGARD-LS-176) Copyright Avail: NTIS HC/MF A10;
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If current trends continue, military avionics will face a very difficult situation at the turn of the century. This situation is predicted despite the impressive strides made in avionics performance, reduced weight per function, reduced cost per function, and a steady improvement in hardware reliability over the past 20 years. If we are unable to achieve a reasonably balanced affordability/availability/performance capability triad, there will be no other option than to substantially reduce either the number of weapon systems or their war-fighting capability. The basic architectural framework and modular avionics strategy needed to achieve this triad will soon be in place. Most of the needed enabling technologies are under development. The next step will be to carefully exploit, integrate, and validate these technologies in bold, innovative ways. Dramatic change will be needed in the way we

integrate and share sensor functions; in the way we develop and support software; and in the design environments we use. Projected factors that will fundamentally impact future avionics systems and the implications of these factors are discussed along with avionics architecture, 21st century avionics software, and the future avionic system design environment. Author

07

AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and onboard auxiliary power plants for aircraft.

N89-22659# Ministry of Defence, London (England).
FUTURE ADVANCED AERO-ENGINES: THE MATERIALS CHALLENGE
D. R. HIGHTON and W. J. CHRISPIN *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 10 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02

A balanced program of aero-engine advanced engineering is pursued in the UK, and an important and growing element of this program is that devoted to materials and processing technology. The quest for more capable materials is an essential element of that program. The powerplant continues to be a critical factor in improving vehicle capability in all military and civil applications. A position has been reached where further improvements in propulsion depend not only on maintaining current effort in aerothermodynamic technology, but also making substantial investments in new high risk materials technology. E.R.

N89-26854# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
MEASUREMENT UNCERTAINTY WITHIN THE UNIFORM ENGINE TEST PROGRAMME
J. P. K. VLEGHERT, ed. (National Aerospace Lab., Amsterdam, Netherlands) May 1989 77 p
(AGARD-AG-307; ISBN-92-835-0508-5; AD-A211105) Copyright Avail: NTIS HC A05/MF A01

This AGARDograph is an outcome of the Propulsion and Energetics Panel Working Group 15 on, Uniform Engine Testing Programme (AGARD AR 248). During the performance of this Group it appeared that the results of some test runs were somewhat scattered, without an obvious explanation. The Group, therefore, formed a sub-Group with the task of carefully assessing the uncertainties of the measured data in order to find out whether the scattering was within the expected uncertainty or whether an explanation must be found. Since the results of the efforts of the sub-Group have some importance beyond the Working Group 15 tests, it was decided to report them in the form of an AGARDograph. In Chapter 5 the different uncertainties are estimated. The discussion on the uncertainties appears in Chapter 6 and in the following Chapter 7, ten conclusions are drawn from the efforts. This AGARDograph was prepared at the request of the Propulsion and Energetics Panel of AGARD. Author

N89-27661# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
BLADING DESIGN FOR AXIAL TURBOMACHINES
May 1989 212 p Lecture series held in Toronto, Ontario, 1-2 Jun. 1989, in Cologne, Fed. Republic of Germany, 15-16 Jun. 1989, and in Ecully, France, 19-20 Jun. 1989
(AGARD-LS-167; ISBN-92-835-0512-3; AD-A211103) Copyright Avail: NTIS HC A10/MF A02

The efficiency and performance of the turbomachinery components of future aero engines can considerably be improved by applying recent advances in understanding the flow behavior of axial compressor and turbine bladings. Thus, the optimal profile pressure distribution as input for new blading design methods has an important effect on losses and flow deflection. The boundary-layer behavior has to be carefully taken into account with respect to laminar/turbulent transition, shock/boundary-layer

interaction and separation effects. In addition to these aerodynamical questiona, unsteady effects and the limitations from structural and vibrational conditions also have to be taken into account. Two main topics are discussed: design methods and their principles and limitations, and application to axial compressors and turbines. For individual titles, see N89-27662 through N89-27669.

N89-27662# Hochschule der Bundeswehr, Munich (Germany, F.R.). Inst. fuer Strahlantriebe.
REVIEW ON TURBOMACHINERY BLADING DESIGN PROBLEMS
L. FOTTNER *In* AGARD, Blading Design for Axial Turbomachines 13 p (SEE N89-27661 22-07) May 1989
(AGARD-LS-167) Copyright Avail: NTIS HC A10/MF A02

Based on the design objectives for the bladings of highly-loaded, high Mach number turbocomponents the main problem areas to be taken into account during the design process are derived. These refer to the flow field conditions with respect to the effect of the Mach number on the profile contour shape, the aerodynamic loading, especially compressor bladings, and the boundary-layer behavior. In addition, blading design has to account for the secondary flow effects and unsteady flow conditions. Author

N89-27663# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.
DESIGN CRITERIA FOR OPTIMAL BLADING DESIGN
HANS STARKEN *In* AGARD, Blading Design for Axial Turbomachines 17 p (SEE N89-27661 22-07) May 1989
(AGARD-LS-1[r] opyright Avail: NTIS HC A10/MF A02

Since arou J/o numerical methods are available to compute cascade blade shapes from prescribed surface velocity distributions in compressible flow range. Two-dimensional or quasi three-dimenstional inverse or design methods enabled thereby the improvement of compressor and turbine cascades via an optimized blade pressure distribution. The theoretical and experimental development of such pressure distributions is described for the subsonic, supercritical, transonic, and supersonic velocity range of the compressor cascades. The equivalent problems in turbine cascades are indicated. Author

N89-27664# Office National d'Etudes et de Recherches Aeronautiqu:3s, Paris (France).
OVERVIEW ON BLADING DESIGN METHODS
G. MEAUZE *In* AGARD, Blading Design for Axial Turbomachines 20 p (SEE N89-27661 22-07) May 1989
(AGARD-LS-167) Copyright Avail: NTIS HC A10/MF A02

Rather than presenting an exhaustive catalog on the design method calculations, the possible ways to use the calculation methods are discussed, as well as the problems of their practical applications. The complexity of the flow behavior is recalled through a turbomachine and the simplifications which must be adopter, i.e., a mean axisymmetric steady through flow hypothesis. The particular case of an isolated blade row with the possible use of a full 3-D design approach is presented. The well-known quasi 3-D approach combining the mean through flow and the blade-to-blade calculations is discussed where some details are given on direct and inverse methods for both through flow and cascade flow. Author

N89-27665# Iowa State Univ. of Science and Technology, Ames. Dept. of Mechanical Engineering.
PERFORMANCE PREDICTION FOR AXIAL-FLOW COMPRESSOR AND TURBINE BLADING
GEORGE K. SEROVY *In* AGARD, Blading Design for Axial Turbomachines 19 p (SEE N89-27661 22-07) May 1989
(AGARD-LS-167) Copyright Avail: NTIS HC A10/MF A02

The performance of compressor and turbine blading must be predicted in all levels of a conventional design system, beginning in the preliminary design phase before blade row geometry is defined. Because of this requirement, many levels of complexity exist in both input and output of prediction methods, and alternative methods exist within each phase of design. A brief review of performance prediction problems and current solutions is presented. Because details of equations and methods cannot and should not be included, reference to original documents in readily available sources are classified according to their place in

configuration design and analysis. It is concluded that both quasi-three-dimensional and three-dimensional computation methods have a potential for future development in terms of configuration optimization. Additionally, it is concluded that experimental data correlation is not dead, and that improvement potential exists in every area of the performance estimation problem. Author

N89-27666# Rolls-Royce Ltd., Derby (England).
BLADING DESIGN FOR MULTI-STAGE HP COMPRESSORS
P. STOW   In AGARD, Blading Design for Axial Turbomachines 29 p (SEE N89-27661 22-07)   May 1989
(AGARD-LS-167)   Copyright   Avail: NTIS HC A10/MF A02
    Computer aided turbomachinery blade design is discussed with the emphasis on the mathematical models that are needed in order to account for the important physical phenomena. The various aspects of a typical balde design system are presented covering through-flow and blade-to-blade analysis. The through-flow discussion coveres linked through-flow-blade-to-blade analysis, blade loss models, end-wall boundary layers, secondary flow analysis, and spanwise mixing models. Blade section design using mixed design and analysis methods is covered together with loss prediction using coupled inviscid boundary layer approaches. Limitations of the coupled approach are discussed together with the emerging role of Reynolds averaged Navier-Stokes methods aimed at removing these limitations. The need for fully three-dimensional methods is covered together with their incorporation into the design system. Finally areas for future development and application are discussed. Author

N89-27667#   Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
TRANSONIC AND SUPERSONIC COMPRESSOR BLADING DESIGN
A. J. WENNERSTROM   In AGARD, Blading Design for Axial Turbomachines 22 p (SEE N89-27661 22-07)   May 1989
(AGARD-LS-167)   Copyright   Avail: NTIS HC A10/MF A02
    A design is presented for axial compressor stages for which the achievement of high performance is both critical from the standpoint of a thermodynamic cycle and also difficult because of high aerodynamic loading, Mach number, or both. The type of method of interest is often termed a through-blade design procedure. The general methodology employed is covered including the computational framework. The kinds of information derived from empiricism is discussed, followed by those areas where design guidance is lacking and logical assumptions are used. The foregoing can theoretically result in an infinite range of solutions. An optimization critieria is presented through striving to obtain the one best solution. Three examples are shown covering the Mach number range of about 0.7 to 1.6 to illustrate the success of the approach. Several other factors which must be taken into account in a design are mentioned. Also, several glaring weaknesses in the present design methods are identified. The lecture concludes with some comments on current design trends and computational goals. Author

N89-27668# Centre de Villaroche, Moissy (France).
BLADING DESIGN FOR COOLED HIGH-PRESSURE TURBINES
P. F. BRY   In AGARD, Blading Design for Axial Turbomachines 42 p (SEE N89-27661 22-07)   May 1989
(AGARD-LS-167)   Copyright   Avail: NTIS HC A10/MF A02
    The past fifty years have seen the tremendous development of jet engine propulsion. Testing has become very complex and has paralleled the increasing complexity observed in the domain of computational methods. The best compromise must be found for the inner and outer shapes of the nozzles and blades. This can only be achieved if internal and external designs are performed by an integrated team of specialists. Tools are described that are available for helping design engineers to reach this objective. Examples of what can be achieved are presented. Both theoretical and experimental aspects are addressed since they are an integral part of the design process. Author

N89-27669#   Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
AERODYNAMIC DESIGN OF LOW PRESSURE TURBINES
J. HOURMOUZIADIS   In AGARD, Blading Design for Axial Turbomachines 40 p (SEE N89-27661 22-07)   May 1989
(AGARD-LS-167)   Copyright   Avail: NTIS HC A10/MF A02
    The aerodynamic requirements for low pressure (LP) turbines covering a wide range of Mach and Reynolds numbers are derived from the applications for turbofan, shaft, and propfan engines. Designing turbines for high performance levels is based on extensive experience and modern prediction techniques. Methodology, experimental background, measurement techniques, and design systems are reviewed. The merits and limitations of present computation procedures are discussed. The close interaction between research and industrial development is discussed and the differences are pointed out. Two-dimensional pressure distributions can be predicted by a variety of very efficient inviscid methods. Boundary layer prediction is handicapped by complexity including separation and transition. The characteristic of the Prandtl boundary layer is developed and the physical model leading to the concept of Controlled Boundary Layer (CBL) design is presented. The effects of unsteadiness and turbulence in turbomachinery as well as the extension to transonic flow are considered. The understanding of the inviscid 3-D aerodynamics and their introduction in the design systems is presented. Secondary flows and their direct and indirect effects on losses are discussed. The problems to be addressed in the intermediate and long term research and development work are listed and their significance commented upon. Author

N90-10195#   General Electric Co., Cincinnati, OH.   Aircraft Engines.
DYNAMIC INSTABILITY CHARACTERISTICS OF AIRCRAFT TURBINE ENGINE COMBUSTORS
M. J. KENWORTHY, D. W. BAHR, P. MUNGUR, D. L. BURRUS, J. M. MEHTA, and ANTHONY J. CIFONE (Naval Air Propulsion Test Center, Trenton, NJ.)   In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 13 p (SEE N90-10191 01-25)   Apr. 1989
(AGARD-CP-450)   Copyright   Avail: NTIS HC A14/MF A02
    Many aircraft turbine engine combustors exhibit dynamic instabilities at subidle and idle operating conditions. These instabilities can result in objectionable noise and, in some instances, compressor stall problems. To permit analytical assessments of these phenomena, an aeroacoustic model of these combustor instabilities was developed. To calibrate and validate this model, sector rig tests of the CF6-80A engine combustor were conducted. In these tests, the frequencies and amplitudes of the instabilities and the acoustic characteristics of the combustor were measured. Additional tests in a F101/F110/CFM56 sector combustor rig are planned. The test results compare well with the theory. The following conclusions are drawn from the portion of the work completed to date: (1) audible noise is a resonant acoustic wave within the cavity as predicted by the analytical model; (2) the acoustic wave responds strongly at the fuel-air ratio with the optimum time lag between the fuel injector and the heat release region, consistent with the analytical model; and (3) the analytical model predictions are in generally good agreement with the CF6-80A combustor test data, but further experiments with better defined end conditions are being obtained for a more complete validation. Author

N90-10198#   Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
EFFECTS OF LOW-FREQUENCY INSTABILITIES ON THE OPERATION OF RAMJET AIR INLETS [EFFETS DES INSTABILITES DE BASSE FREQUENCE SUR LE FONCTIONNEMENT DES PRISES D'AIR DE STATOREACTEUR]
C. SANS   In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 12 p (SEE N90-10191 01-25)   Apr. 1989   In FRENCH; ENGLISH summary   Previously announced in IAA as A89-29285
(AGARD-CP-450)   Copyright   Avail: NTIS HC A14/MF A02
    The effect of low-frequency instabilities on ramjet air inlet performance was experimentally studied using an axisymmetric inlet equipped with a device providing large-pressure fluctuations of between 0 and 200 Hz. Results obtained at Mach 2 demonstrate

that the instabilities do not interfere with the operation of the inlet, except for the case of subcritical conditions. The internal boundary-layer intake is shown to drastically reduce the pressure fluctuations.　　　　　　　　　　　　　　　　　　　　　IAA

N90-10199#　　Naval Weapons Center, China Lake, CA. Airbreathing Propulsion Branch.
RECENT DEVELOPMENTS IN RAMJET PRESSURE OSCILLATION TECHNOLOGY
P. A. CHUN, J. A. LOUNDAGIN, J. A. NABITY, and S. E. AYLER *In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 13 p (SEE N90-10191 01-25)　Apr. 1989
(AGARD-CP-450)　Copyright　Avail: NTIS HC A14/MF A02
　　　Dynamic matching of a supersonic inlet and combustor is a major consideration in ramjet propulsion development. The inlet shock system present under supersonic speeds must be kept stable under all engine operating conditions. An unstable shock system could result in inlet unstart and/or buzz and undesirable pressure oscillations in the ramjet engine. To date, there is no technique for determining if a particular ramjet engine configuration will have combustion-induced pressure oscillations. Current experimental and theoretical techniques applied to the characterization of liquid fuel ramjet combustors are summarized. Comparisons between steady-state and dynamic data are provided to show how both types of information are used to interpret engine behavior.
　　　　　　　　　　　　　　　　　　　　　　　　　Author

N90-10200#　Cambridge Univ (England). Dept. of Engineering.
REHEAT BUZZ: AN ACOUSTICALLY COUPLED COMBUSTION INSTABILITY
A. P. DOWLING　　　*In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 16 p (SEE N90-10191 01-25) Apr. 1989
(AGARD-CP-450)　Copyright　Avail: NTIS HC A14/MF A02
　　　Reheat buzz is a low frequency instability of afterburners. It is caused by the interaction of combustion and acoustic waves within the reheat duct. The acoustic waves perturb the combustion, while the unsteady combustion generates yet more sound leading to the possibility of instability. A simple theory was developed and tested by comparison with results obtained on a premixed rig. The theory is able to predict the frequency of the instability and the mode shape, accurately reproducing the effect of changes in flow rate, inlet temperature, duct length and fuel-air ratio.　Author

N90-10201#　　Otago Univ., Dunedin (New Zealand).　Dept. of Physics.
ATTENUATION OF REHEAT BUZZ BY ACTIVE CONTROL
P. J. LANGHORNE and N. HOOPER (Cambridge Univ., England)
In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 17 p (SEE N90-10191 01-25)　Apr. 1989　Sponsored in part by Rolls-Royce plc, London, England
(AGARD-CP-450)　Copyright　Avail: NTIS HC A14/MF A02
　　　Reheat buzz is a low frequency longitudinal pressure fluctuation which can be excited by flame/sound field interaction in the afterburner of a jet aeroengine operating at high fuel to air ratios. Active control techniques were already applied to control a similar combustion instability on a rig. In this previous case the controller modified the upstream boundary condition by unsteadily altering the mass flow of premixed gas. This method is not readily applicable to an engine. It is demonstrated that similar achievements are possible with the suitably-phased addition of extra fuel. The mechanical power requirements of this controller are modest and the system is easy to implement.　　　　　　　　Author

N90-10202*#　Flow Research, Inc., Kent, WA.
NUMERICAL SIMULATION OF PRESSURE OSCILLATIONS IN A RAMJET COMBUSTOR
WEN-HUEI JOU and SURESH MENON　*In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 25 p (SEE N90-10191 01-25)　Apr. 1989　Sponsored in part by NASA. Lewis Research Center; and by NASA. Ames Research Center
(Contract N00014-84-C-0359)
(AGARD-CP-450)　Copyright　Avail: NTIS HC A14/MF A02 CSCL 21/5
　　　Large-eddy simulations of compressible cold flow in a ramjet combustor configuration were performed. The objectives were to investigate the mechanisms for vortex-acoustic interaction in such a device and to develop a simulation method that can be extended

to cases with combustion heat release to study combustion instability. From the simulation, it was found that the separated shear layer rolls up into concentrated vortices that merge to form large coherent structures. These vortices interact with the choked nozzle downstream to produce an axial acoustic dipole. The spectrum of the pressure fluctuation at the base of the backward-facing step shows that there are two types of oscillations: an acoustic resonant mode and a vortex-acoustic coupled mode. Based on the flow physics observed in the simulations, a simple one-dimensional model for the vortex-acoustic coupled mode was proposed. The eigenvalue problem based on this model was solved to obtain the frequency of the coupled mode.　　　　Author

N90-10203#　　Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NUMERICAL SIMULATION OF UNSTEADY COMBUSTION IN A DUMP COMBUSTOR [SIMULATION NUMERIQUE DU FONCTIONNEMENT INSTATIONNAIRE D'UN FOYER A ELARGISSEMENT BRUSQUE]
F. GARNIER, B. LABEGORRE, M. SERRANO, and A. LAVERDANT　*In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 28 p (SEE N90-10191 01-25)　Apr. 1989　In FRENCH; ENGLISH summary
(AGARD-CP-450)　Copyright　Avail: NTIS HC A14/MF A02
　　　Basic investigations can be of great interest in the control of high frequency combustion instability in ramjets, in particular by identification of amplifying and damping mechanism of instabilities and of their coupling. With the advent of vectorized computers and the progress of numerical methods, simulation of unsteady, biphasic and three-dimensional combustion is now possible. In this perspective, ONERA has undertaken the adaptation of a computer code, KIVA, precedently developed by the Los Alamos National Laboratory for diesel engines study; this adaptation is essentially concerned with the introduction of inflow and outflow. The application is made on a dump combustor with liquid fuel injection. A detailed description of physico-chemical mechanism involved is presented and the first numerical results obtained are compared with similar ones.　　　　　　　　　　　　　Author

N90-10204#　　California State Univ., Sacramento.　Dept. of Mechanical Engineering.
VERY-LOW-FREQUENCY OSCILLATIONS IN LIQUID-FUELED RAMJETS
FREDERICK H. REARDON　*In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 12 p (SEE N90-10191 01-25)　Apr. 1989
(Contract F33615-81-C-2078)
(AGARD-CP-450)　Copyright　Avail: NTIS HC A14/MF A02
　　　Very-low-frequency (bulk-mode) oscillations were studied, making use of experimental data gathered at the Air Force Wright Aeronautical Laboratories. Only those oscillations in which the acoustic resonance characteristics of the combustor were not excited were considered. More than 200 cases of such oscillations in coaxial-dump combustors were examined. Correlations of oscillation incidence, frequency and amplitude were made in terms of design and operating parameters, including inlet diameter and length, combustor diameter and length-to-diameter ratio, air inlet temperature and fuel-air ratio. An analytical model was developed with which the effects of various oscillation driving mechanisms were examined and compared with the experimental data. Mechanisms considered were: combustion rate fluctuations resulting from fluctuating flow rates of fuel and air, combustion energy release rate variations due to pressure and temperature fluctuations in the flame zone, distortion of the flame zone by vortices shed at the dump plane, generation of an oscillating pressure field by vortex shedding at the dump plane interacting with the exhaust nozzle contraction, and entropy (convective) waves, resulting from fuel/air ratio oscillations, that reflect from the nozzle as pressure waves. Calculations using the analytical model showed agreement with experimental results for nearly 70 percent of the tests examined. The vortex and entropy wave mechanisms did not substantially improve the model's predictive ability.　　　　　　　　　　　　　　　　　　　Author

N90-10206# Naval Research Lab., Washington, DC. Lab. for Computational Physics and Fluid Dynamics.
ACOUSTIC-VORTEX-CHEMICAL INTERACTIONS IN AN IDEALIZED RAMJET
K. KAILASANATH, J. H. GARDNER, J. P. BORIS, and ELAINE S. ORAN *In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 13 p (SEE N90-10191 01-25)   Apr. 1989 Sponsored in part by Navy
(AGARD-CP-450) Copyright Avail: NTIS HC A14/MF A02

A potentially important source of large pressure oscillations in combustors is an instability induced by the interactions between large-scale vortex structures, acoustic waves, and chemical energy release. To study these interactions, time-dependent, compressible numerical simulations of the flow field in an idealized ramjet consisting of an axisymmetric inlet and combustor and a choked nozzle were performed. These simulations have allowed the isolation of the interactions between acoustic waves and large-scale vortex structures and then to study the effects of energy release on the flow field. A number of parameters such as inflow Mach number, inlet and combustor acoustics and energy release rates have been systematically varied in the simulations. A summary of the observations from these various simulations are presented in this paper. The nonreactive flow calculations show complex interactions among the natural instability frequency of the shear layer at the inlet-combustor junction and the acoustics of both the inlet and the combustor. Vortex shedding usually occurs at the natural instability frequency of the initially laminar shear layer but vortex mergings are affected by the acoustic frequencies of the ramjet. When the frequency of the first longitudinal acoustic mode of the combustor is near the natural instability frequency of the shear layer, then vortex shedding is observed at the acoustic frequency. In many cases the entire flow oscillates at a low frequency which corresponds to that of a quarter-wave mode in the inlet. In these cases, the vortex-merging patterns in the combustor can be explained on the basis of an interaction between the acoustics of the inlet and the combustor. For the particular reactive flow case discussed, energy release alters the flow field substantially. In the first cycle after ignition, fluid expansion due to energy release quickly destroys the pattern of vortex mergings observed in the cold flow and a new pattern emerges that is dominated by a large vortex. In subsequent cycles, most of the energy release occurs after vortex mergings have produced this large vortex. Energy release in this large vortex is in phase with the pressure oscillation over a substantial region of the combustor. This results in the observed amplification of the low-frequency oscillations and leads to combustion instability.   Author

N90-18396# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Structures and Materials.
AGARD/SMP REVIEW: DAMAGE TOLERANCE FOR ENGINE STRUCTURES. 2: DEFECTS AND QUANTITATIVE MATERIALS BEHAVIOUR
Aug. 1989   105 p   In ENGLISH and FRENCH   Meeting held in Mierlo, Netherlands, 2-7 Oct. 1988
(AGARD-R-769; ISBN-92-835-0518-2) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Most current military and all civil engines are operated under safe life procedures for their critical components. Experience has shown that this philosophy presented two drawbacks: the move towards designs allowing higher operational stresses, and the use of advanced high strength alloys make it likely that a disc burst could happen (followed by a rapid crack growth) well before the statistically-based safe life was achieved; and it is potentially wasteful of expensive components, since it was estimated that over 80 percent of engine discs have ten or more low cycle fatigue lives remaining when discarded under safe life rules. Damage tolerance being an alternative life philosophy, it was therefore decided to conduct a series of four workshops addressing the areas critical to damage tolerance design of engine parts. For individual titles, see N90-18397 through N90-18404.

N90-18402# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).
REVIEW OF MODELLING METHODS TO TAKE ACCOUNT OF MATERIAL STRUCTURE AND DEFECTS
R. N. TADROS and K. REZAI *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 2: Defects and Quantitative Materials Behaviour 15 p (SEE N90-18396 11-07) Aug. 1989
(AGARD-R-769) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Among the many requirements for the design of gas turbine engine components, understanding the behavior of these components and the alloys used to make them is fundamental in order to ensure structural integrity and safe operation of the engines. The conventional Safe Life Approach is discussed together with an overview of crack growth modeling used at Pratt and Whitney Canada. The intention is not to compare the two approaches, but rather to highlight their applications and required improvement for the design and production of next generation gas turbine engines.   Author

N90-18403# Utah Univ., Salt Lake City. Dept. of Mechanical Engineering.
FUTURE TECHNOLOGY REQUIREMENTS (RELATED TO DEFECTS AND QUANTITATIVE MATERIAL BEHAVIOR TO AID IN IMPLEMENTATION OF DAMAGE TOLERANCE FOR DESIGN OF ENGINE STRUCTURES)
DAVID W. HOEPPNER *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 2: Defects and Quantitative Materials Behaviour 11 p (SEE N90-18396 11-07) Aug. 1989
(AGARD-R-769) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Issues are presented that are viewed as critical to an increased rate if implementation of damage tolerance concepts to the design of critical engine components. Areas emphasized are defect definition, inspection, modeling of discontinuities, evaluation of subcritical crack propagation behavior, development of material properties data banks, increasing the understanding of microstructural influences on material behavior, methods of comparing materials and various processing methods for modifying defect tolerance, and development of lifting methods that will enable designers, operators, and maintenance personnel to understand and incorporate all the concepts necessary to assure integrity of critical engine components. Various conclusions, including suggestions for expanding knowledge, are presented.   Author

N90-18404# Centre d'Essais Aeronautique Toulouse (France). Groupe Materiaux et Technologies.
THE NEED FOR A COMMON APPROACH WITHIN AGARD [LE BESOIN D'ACTIONS CONCERTEES AU SEIN DE L'AGARD]
TH. PARDESSUS *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 2: Defects and Quantitative Materials Behaviour 5 p (SEE N90-18396 11-07) Aug. 1989 In FRENCH
(AGARD-R-769) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The need for agreement within AGARD on what constitutes a fully integrated material specification for damage tolerance is addressed. Suggestions are made regarding a test procedure that would help define more precisely defect sizes and populations. Test methods, the role of materials behavior modeling, component life, and the notion of usable strength are discussed.
Transl. by M.G.

N90-18405# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
UNSTEADY AERODYNAMIC PHENOMENA IN TURBOMACHINES
Feb. 1990 325 p In ENGLISH and FRENCH Meeting held in Luxembourg, 28-30 Aug. 1989
(AGARD-CP-468; ISBN-92-835-0543-3; AD-A219741) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Specialists' Meeting was arranged in the following sessions: Flutter or oscillating cascades; wakes or complete stage; transonic and supersonic unsteady phenomena; and experimental studies and instrumentation problems. While around isolated airfoils many results on unsteady aerodynamic phenomena are available; reliable experimental data for unsteady turbomachinery flows were still missing. Therefore a forum was offered to experts to discuss the degree of advancements in this field. It was found that computational fluid dynamics with large numerical codes will be more and more developed and offer a useful tool for designers to improve their products. The experimental work for code verification is lagging somewhat behind. For individual titles, see N90-18406 through N90-18429.

N90-18406# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
A COMPARISON OF FLUTTER CALCULATIONS BASED ON EIGENVALUE AND ENERGY METHOD
A. KLOSE and K. HEINIG In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 9 p (SEE N90-18405 11-07) Feb. 1990
(AGARD-CP-468) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The effect of unsteady aerodynamic loads on the natural modes and frequencies of unshrouded blades of axial flow turbomachinery is investigated. It is shown that significant shifts in eigenfrequencies and aerodynamic coupling between different modes do no occur for blades with a large mass ratio. Even for compressor and turbine bladings of recent design, it is generally possible to neglect the effect of unsteady aerodynamic forces on the vibration characteristics. Therefore, the energy method is applicable for the theoretical flutter investigation of these machines. However, for future light-weight designs, e.g., hollow fan blades or blades made of fiber-reinforced plastics, the effects of unsteady airloads on the vibration characteristics will be larger. In these cases, the eigenvalue method will have to be employed for flutter prediction as well as for the calculation of eigen frequencies and natural modes. Author

N90-18407# Technische Hochschule, Aachen (Germany, F.R.). Inst. fuer Strahlantriebe und Turboarbeitsmaschinen.
NUMERICAL INVESTIGATION OF UNSTEADY FLOW IN OSCILLATING TURBINE AND COMPRESSOR CASCADES
H. P. KAU and H. E. GALLUS In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 11 p (SEE N90-18405 11-07) Feb. 1990
(AGARD-CP-468) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A method of computing the unsteady two dimension- l, inviscid subsonic flow through an oscillating compressor and turbine cascades is presented. The nonlinear Euler equations in conservative law form are solved taking into account the time dependent geometry. For interior points MacCormack's explicit predictor-corrector scheme is used. Boundary conditions are formulated by characteristics methods A comparison of computational results and experimental data is given. A study is performed showing the influence of important aerodynamic and geometric parameters on the time-dependent forces and moments. Author

N90-18408# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
UNSTEADY VISCOUS CALCULATION METHOD FOR CASCADES WITH LEADING EDGE INDUCED SEPARATION
M. GAZAIX, P. GIRODROUX-LAVIGNE, and J. C. LEBALLEUR In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 13 p (SEE N90-18405 11-07) Feb. 1990 In FRENCH; ENGLISH summary Sponsored by SNECMA, France
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The recent progress in viscous-inviscid interaction methods for computation of unsteady separated flows over airfoils, in forced oscillations, as well as, in the buffet regime, makes it possible to develop a numerical method for computations of unsteady flows over airfoils and cascades where the flow separation or stall is induced by sharp leading-edges. The aptitude of the method to describe the leading-edge separation in unsteady flow gives some hope for the prediction of subsonic flutter in cascades. The method solves unsteady thin-layer integral viscous equations, in defect-formulation, including two transport equations for turbulence. The equations are closed by turbulent mean velocity profiles which are modeled and discretized along the normal. The viscous method is strongly coupled time-consistently, by the so-called semi-implicit numerical technique, with a pseudo-inviscid solver based on potential small perturbation approximations. The numerical technique is able to enforce the separation at a sharp leading-edge. A viscous calculation method for airfoils is first shown to predict the leading-edge separation over a sharp flat plate at incidence, and over isolated compressor blades. Steady and unsteady computations are presented, and compared with experimental results. A numerical method for internal flows, including conditions of periodicity in space for steady flows, and in space-time for unsteady flows, is secondly obtained to compute separated flows in a cascade configuration. Steady and preliminary unsteady results are shown. Author

N90-18409# Stuttgart Univ. (Germany, F.R.). Inst. fuer Aerodynamik und Gasdynamik.
CALCULATION OF THE UNSTEADY TWO-DIMENSIONAL, INVISCID, COMPRESSIBLE FLOW AROUND A STRONGLY CAMBERED OSCILLATING SINGLE BLADE
K. M. FOERSTER In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 8 p (SEE N90-18405 11-07) Feb. 1990
(AGARD-CP-468) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Some numerical experiments done with a computational method which was developed recently are described. Its main features are an extension of the computational domain to infinity and a moving grid fixed to the body in question. The first part describes this method in some detail. The second part presents some results about the aerodynamic characteristics of an oscillating blade with respect to the reduced frequency, to the free stream Mach number and to the oscillation amplitude, including an investigation of the higher harmonics introduced by the nonlinearity of the problem. Author

N90-18410# Ecole Polytechnique Federale de Lausanne (Switzerland).
AERODYNAMIC SUPERPOSITION PRINCIPLE IN VIBRATING TURBINE CASCADES
A. BOELCS, T. H. FRANSSON, and D. SCHLAEFLI In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 20 p (SEE N90-18405 11-07) Feb. 1990 Sponsored by Asea Brown Boveri, Swiss Federal Inst. of Tech. and the Swiss Commission for Scientific Research
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In unsteady aerodynamics the superposition principle states that the unsteady aerodynamic perturbatins generated in a vibrating cascade are the same as the sum of the perturbations generated by vibrating single blades. This principle was subjected to controversy in the past; today it was verified experimentally for torsional vibration modes in linear compressor cascades in subsonic and incompressible flow. Experiments on turbine cascades performed in an annular nonrotating test facility in order to validate

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the above mentioned superposition principle are described. Using an annular test facility eliminated the problems with lateral boundaries encountered in linear cascades: the annular cascade flow is truly periodic both for steady and unsteady flow. In the following, experiments are presented: that performed with three different cascades, vibrating in a translational mode, simulating a bending vibration; that cover supersonic, transonic, and subsonic flow; and that cover the entire interblade phase angle range possible with 20 blades. The blade sections of the cascades are typical for the last stages of gas- and steam-turbines. The results obtained show that, within the limitations of experimental accuracy, the superposition principle is valid, i.e., from experiments with single vibrating blades the same conclusions can be drawn as from experiments with the whole cascade vibrating at constant amplitudes and interblade phase angles. Author

N90-18411# Pennsylvania State Univ., University Park. Applied Research Lab.
DESIGN GUIDANCE TO MINIMIZE UNSTEADY FORCES IN TURBOMACHINES
R. E. HENDERSON and J. H. HORLOCK (Open Univ., Milton, England) In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 12 p (SEE N90-18405 11-07) Feb. 1990
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AGARD/Scientific Publications Executive
A method is discussed for the development of design charts which provide guidance in the selection of a stage design loading coefficient and flow coefficient which minimizes the generation of unsteady forces in a blade row due to its interaction with the wakes of an unstream blade row. Two configurations are discussed, the forces on a rotor operating in the wakes of an inlet stator or guide vane and the forces on a stator downstream of a rotor. An example demonstrating the generation of a design chart for the first configuration is presented. Author

N90-18412# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
AERODYNAMIC STUDY ON FORCED VIBRATIONS ON STATOR ROWS OF AXIAL COMPRESSORS
H. JOUBERT and V. RONCHETTI In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 11 p (SEE N90-18405 11-07) Feb. 1990 In FRENCH; ENGLISH summary
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Stator vane rows of axial compressors are dependent on fluctuations induced by the wakes of the previous upstream blades row. The unsteady flow resulting from this rotor-stator interaction creates aerodynamic exitations which may initiate vibrating fatigue stress in the vanes and disable the engine. In order to take into account these phenomena, a numerical model based on two dimensional Euler equations was studied. The upstream condition fluctuations come from correlations established from wake experimental testing. The unsteady pressures calculated from the model are afterwards introduced in a mechanical model which estimate the dynamic stress inside the vane-structure. The variation of aerodynamic values such as pressure loss in the blade and geometric one such as rotor-stator spacing or fluctuation of the number of the vanes or stator were studied; therefore, as soon as the aeromechanic design charts of the compressor are designed, some sizing choice could be made to minimize the stress on the blade assembly. Author

N90-18413# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
UNSTEADY BLADE LOADS DUE TO WAKE INFLUENCE
S. SERVATY and H. E. GALLUS (Technische Hochschule, Aachen, Germany, F.R.) in AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 12 p (SEE N90-18405 11-07) Feb. 1990
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An algorithm for calculating unsteady blade forces and moments due to incoming wakes is presented. The mathematical model describes the unsteady two-dimensional flow through compressor and turbine cascades. Only inviscid transport of the wake is considered. The nonlinear Euler equations in conservative law form

are solved by a combined method. MacCormack's explicit predictor-corrector scheme is used at interior points. Time-dependent boundary conditions are formulated by means of a characteristics method. Fundamental studies and several test cases are presented to check the algorithm. Comparisons with experimental results are discussed as well. Author

N90-18414# Schlumberger Cambridge Research (England).
UNSTEADY AERODYNAMIC PHENOMENA IN A SIMULATED WAKE AND SHOCK WAVE PASSING EXPERIMENT
A. B. JOHNSON, M. J. RIGBY, and M. L. G. OLDFIELD (Oxford Univ., England) In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 13 p (SEE N90-18405 11-07) Feb. 1990
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The propagation of nozzle guide vane trailing edge shock waves and wakes through a turbine rotor passage, using experimental data from a transient cascade tunnel with a rotating bar shock and wake generator are studied. Both unsteady and mean blade surface pressure measurements, together with Schlieren flow visualization were used to unravel the complex sequence of refraction, reflection, and re-reflection of the moving NGV shock waves, together with the effects they have on both the unsteady and time averaged blade surface pressure. The effects of the wakes are similarly described. As well as contributing to the fundamental understanding of the inherently unsteady turbine aerodynamics, the phenomena is shown which must be predicted by any successful unsteady computational fluid dynamic prediction of the flow. Author

N90-18415*# United Technologies Research Center, East Hartford, CT. Computational and Theoretical Fluid Dynamics.
GUST RESPONSE ANALYSIS FOR CASCADES OPERATING IN NONUNIFORM MEAN FLOWS
KENNETH C. HALL and JOSEPH M. VERDON In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 13 p (SEE N90-18405 11-07) Feb. 1990
(Contract NAS3-25425)
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The linearized unsteady aerodynamic response of a cascade of airfoils subjected to entropic, vortical, and acoustic gusts is analyzed. Field equations for the first-order unsteady perturbation flow are obtained by linearizing the full time-dependent mass, momentum, and energy conservation equations about a nonlinear, isentropic, and irrotational mean or steady flow. A splitting technique is then used to decompose the unsteady velocity field into irrotational and rotational parts leading to field equations for the unsteady entropy, rotational velocity, and irrotational velocity fluctuations that are coupled only sequentially. The entropic and rotational velocity fluctuations can be described in terms of the mean-flow drift and stream functions which can be computed numerically. The irrotational unsteady velocity is described by an inhomogeneous linearized potential equation which contains a source term that depends on the rotational velocity field. This equation is solved via a finite difference technique. Results are presented to indicate the status of the numerical solution procedure and to demonstrate the impact of blade geometry and mean blade loading on the aerodynamic response of cascades to vortical gust excitations. The analysis described leads to very efficient predictions of cascade unsteady aerodynamic phenomena making it useful for turbomachinery aeroelastic and aeroacoustic design applications. Author

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N90-18416*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
NUMERICAL PREDICTION OF AXIAL TURBINE STAGE AERODYNAMICS
H. V. MCCONNAUGHEY and L. W. GRIFFIN *In* AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 15 p (SEE N90-18405 11-07) Feb. 1990
(AGARD-CP-468) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive CSCL 21/5

A preliminary assessment is made of two NASA-developed unsteady turbine stage computer codes. The methodology and previous partial validation of the codes are briefly outlined. Application of these codes to a Space Shuttle main engine turbine for two sets of operating conditions is then described. Steady and unsteady, two and three-dimensional results are presented, compared, and discussed. These results include time-mean and instantaneous airfoil pressure distributions and pressure fluctuations, streamlines on the airfoil surfaces and endwalls, and relative total pressure contours at different axial locations in the rotor passage. Although not available at the time of this writing, experimental data for one of the operating conditions simulated is forthcoming and will be used to assess the accuracy of the unsteady, as well as, the steady predictions presented. Issues related to code usage and resource requirements of the two codes are also discussed. Author

N90-18417# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NUMERICAL SIMULATION OF THREE-DIMENSIONAL UNSTEADY FLOWS IN TURBOMACHINES
ANTOINE FOURMAUX, GILLES BILLONNET, ALAIN LEMEUR, and ALAIN LESAIN *In* AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 12 p (SEE N90-18405 11-07) Feb. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-468) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from
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For the aerodynamic study of turbomachinery, the numerical flow-simulation takes a larger and larger place. These viscous and compressible fluid flows are three-dimensional and unsteady; so they are governed by the full Navier-Stokes equations. Nevertheless, the use of numerical methods to solve these equations is limited at the present time, and only applications of the Euler methods are presented. After a short description of the physical phenomena and of the numerical method used, the conditions on the calculation domain boundaries are described. The simplifying assumptions which allow the complete stage computation, are emphasized. The examples presented concern unsteady flow simulations in a turbine stage and in a supersonic nozzle. Author

N90-18418# Rolls-Royce Ltd., Derby (England).
DEVELOPMENT OF A MASS AVERAGING TEMPERATURE PROBE
S. C. COOK and R. L. ELDER (Cranfield Inst. of Tech., Bedford, England) *In* AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 14 p (SEE N90-18405 11-07) Feb. 1990 Sponsored by Ministry of Defence, England
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In research and development testing of axial flow fan and compressor rigs, the overall performance can normally be determined to a satisfactory accuracy using conventional methods. It is known, however, that conventional slow response instrumentation does not respond correctly to the highly unsteady flows encountered between blade rows in high speed turbomachines. Consequently measurements made in these areas, in an attempt to split the loss of the machine, typically lead to gross errors in stage, or blade element, performance assessments A slow response temperature sensor, the Reverse-Kiel probe, was created by employing a judicious shield design in an attempt to allow the probe to indicate the correct mass-weighted temperature of such unsteady turbomachinery flows. The mass-weighted Reverse-Kiel temperature probe was developed using some simple arguments supported by flow visualization and computational modeling. The predicted best probe designs were evaluated and

confirmed on the purposed blade-wake rig. The optimum probe was built as a standard rig probe and now is undergoing preliminary test studies. Author

N90-18419# Massachusetts Inst. of Tech., Cambridge. Gas Turbine Lab.
BLADE ROW INTERACTION EFFECTS ON COMPRESSOR MEASUREMENTS
A. H. EPSTEIN, M. B. GILES, T. SHANG, and A. K. SEHRA (Textron Lycoming, Stratford, CT.) *In* AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 11 p (SEE N90-18405 11-07) Feb. 1990
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The influence of a downstream stator row on the measurement of compressor rotor performance was examined using a computational fluid dynamic code backed by laser anemometry data on a transonic fan stage. The upstream potential influence of the stator causes unsteady circulation about the rotor blades which is a function of the rotor circumferential position. This, in turn, results in a nonuniform circumferential pattern of time averaged temperature and pressure in the stationary frame. An analytical theory relating the temperature and pressure variations to circulation perturbation is presented and shown to give good agreement with the numerical calculations. The results of a parametric study show that the magnitude of this effect is a strong function of rotor-stator blade row spacing and relative blade counts. The effects range from negligible for large spacings typical of high bypass ratio fans to several percent of the stage pressure and temperature rise for closely spaced blade rows typical of high compressors. Because the temperature and pressure perturbations are in spatial phase, the net effect on measured rotor efficiency is negligible so long as the pressure and temperature measurements are made in the same location relative to the stators. If they are not, errors of + or - 1.5 percent can result. The effects of axial position and stator loading are shown to be relatively small. Author

N90-18420# Catania Univ. (Italy). Istituto di Macchine.
HIGH-RESOLUTION EULER COMPUTATIONS OF UNSTEADY TRANSONIC FLOWS IN CASCADES
F. BASSI, C. OSNAGHI, and M. SAVINI (Consiglio Nazionale delle Ricerche, Peschiera Borromeo, Italy) *In* AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 12 p (SEE N90-18405 11-07) Feb. 1990
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A two-dimensional finite volume total variation diminishing (TVD) Euler solver, suited to handle time-dependent transonic flow fields in turbomachinery components, is presented and used together with a method of characteristics (using a shock fitting technique) and with an explicit central difference finite volume code in order to investigate unsteady flow fields. Special care is given to the accurate treatment of boundary conditions, both of solid-wall and far-field type. The method is used to compute two unsteady flow problems which have features of transonic internal flows of practical importance in the analysis of turbomachinery components. The problems are the unsteady flow in a transonic nozzle with oscillating back pressure and the transonic flow in a rotor blade row with translating disturbances at the inflow boundary simulating the wakes shed by a preceding stator blade row. In the first problem the influence of oscillation frequency upon the flow field is investigated with the three methods so as to obtain some indications of the relative accuracies of the schemes and a better understanding of the physical phenomena occurring. Author

N90-18421# Wien Univ. (Austria). Inst. for Stroemungslehre und Waermeuebertragung.

ASYMPTOTIC ANALYSIS OF TRANSONIC FLOW THROUGH OSCILLATING CASCADES

FRANZ KOLLER and ALFRED KLUWICK   In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 10 p (SEE N90-18405 11-07)   Feb. 1990

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The plane flow of a perfect gas through an oscillating cascade at a Mach number close to one is analyzed using matched asymptotic expansions. In the case of steady flow the field quantities in the regions between airfoils are governed by the equations for one-dimensional flow in a first approximation if thickness, camber, and angle of incidence of the blades are small. Moreover, for a particular range of these parameters the velocity disturbances satisfy linear equations ahead of and behind the cascade. The same property is shown to hold in the case of unsteady flow provided the reduced frequency and the amplitudes of the oscillations are small compared to unity. Furthermore, the effects of the sizes of the various parameters on the flow field are discussed. Surface pressures are calculated for cascades of flat plate and double circular arc airfoils.   Author

N90-18422# Technische Hochschule, Aachen (Germany, F.R.). Inst. fuer Strahlantriebe und Turboarbeitsmaschinen.

EXPERIMENTS ON THE UNSTEADY FLOW IN A SUPERSONIC COMPRESSOR STAGE

W. ELMENDORF, G. K. KAUKE, and K. D. BROICHHAUSEN (Motoren-und Turbinen-Union Muenchen G.m.b.H., Germany, F.R.)   In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 13 p (SEE N90-18405 11-07)   Feb. 1990

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The intensity of unsteadiness in compressors strongly depends on the flow velocity and the overall pressure ratio. Thus investigations of the unsteady effects in the case of supersonic flow are of great importance with regard to performance and reliability. For that purpose the unsteady flow in a supersonic compressor stage was studied in a series of experiments. A review on the specially developed measuring techniques including flow visualization and the design of miniaturized semiconductor probes is given. The main feature of unsteady supersonic flow in the compressor are discussed by means of characteristic experimental results.   Author

N90-18423# Cambridge Univ. (England). Dept. of Engineering.

MODELLING UNSTEADY TRANSITION AND ITS EFFECTS ON PROFILE LOSS

H. P. HODSON   In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 15 p (SEE N90-18405 11-07)   Feb. 1990

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The effects of wake interactions on the transition processes of turbomachinery blade boundary layers are considered. A simple model of unsteady transition is proposed which is then used to identify a relationship between a new reduced frequency parameter and the profile loss of a blade row which is subjected to unsteady inflow. The value of this parameter is also used to identify the nature of the boundary layer development on the blade surface. The influence of other parameters on the transition process is also discussed. The model is then extended to deal with the more general case. The validity of the model is demonstrated by a comparison with a correlation of the effects of wake-generated unsteadiness on profile loss which was originally proposed by Speidel. The effects of unsteady inflow on four idealized turbine blades are considered.   Author

N90-18425# Technische Hochschule, Aachen (Germany, F.R.). Inst. fuer Strahlantriebe und Turboarbeitsmaschinen.

EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF ROTOR WAKES ON THE DEVELOPMENT OF THE PROFILE BOUNDARY LAYER AND THE PERFORMANCE OF AN ANNULAR COMPRESSOR CASCADE

H. D. SCHULZ and H. E. GALLUS   In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 15 p (SEE N90-18405 11-07)   Feb. 1990

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The development of the profile boundary layers, particularly the loci of transition and separation, largely depend on the turbulence level of the free-stream and the wake flow effects. For comparison, a detailed survey of the profile boundary layers in an annular compressor cascade was carried out first at a steady, uniform incoming flow and secondly with a rotor upstream. The rotor incorporates cylindrical spokes causing periodic wakes and thus a higher overall turbulence level of the flow. Its impact on the profile boundary layer history and the performance of the compressor cascade will be discussed.   Author

N90-18426# Oxford Univ. (England). Dept. of Engineering Science.

METHODS FOR MAKING UNSTEADY AERODYNAMIC PRESSURE MEASUREMENTS IN A ROTATING TURBINE STAGE

R. W. AINSWORTH, J. L. ALLEN, and A. J. DIETZ   In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 14 p (SEE N90-18405 11-07)   Feb. 1990

(AGARD-CP-468)   Copyright   Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A new method for obtaining detailed unsteady pressure measurements in a rotating turbine stage is described. The technique is based on the use of miniature semiconductor pressure sensors attached directly to the surface where the measurement is required, permitting simultaneously a high surface density of instrumentation together with a high frequency response. In reviewing typical semiconductor behavior, attention is drawn to some of the traditional constraints encountered with these devices. In describing the development of the technology employed here, the methods used to circumvent these traditional constraints are outlined.   Author

N90-18428# Wright Research Development Center, Wright-Patterson AFB, OH. Turbine Engine Div.

COMPRESSOR PERFORMANCE TESTS IN THE COMPRESSOR RESEARCH FACILITY

F. R. OSTDIEK, W. W. COPENHAVER, and D. C. RABE   In AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 16 p (SEE N90-18405 11-07)   Feb. 1990

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An advanced compressor test facility, the Compressor Research Facility (CRF) was established. The CRF is designed for exploration of steady-state and transient behavior of full-scale, multistage gas turbine engine fans, and compressors. Since construction and check-out of the facility, the CRF test team has completed its first five years of testing with a variety of test articles. Customers besides the Air Force have included other Government agencies and industry. Turbine engine technology is changing rapidly with new mission demands on the engine resulting in new aerodynamic, stability, and performance demands on each of its components. The role of the CRF in meeting the challenges inherent in such a rapidly changing field is described. The facility characteristics are described along with a description of the changes, modifications, and enhancements made to the facility in its short history. Several examples of tests performed in the CRF (both steady-state and transient) are used to demonstrate the impact of the CRF results on engine development. Finally, the plans for further facility modifications and enhancement are given. This affords a preview of the impact which this and other test facilities will have on turbine engine technology.   Author

N90-18429# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mechanical Engineering.
STALL AND RECOVERY IN MULTISTAGE AXIAL FLOW COMPRESSORS
WALTER F. OBRIEN and KEITH M. BOYER (Wright Research Development Center, Wright-Patterson AFB, OH.) *In* AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 11 p (SEE N90-18405 11-07) Feb. 1990 Sponsored by AFOSR, Washington, DC
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At low flows relative to the design point, multistage axial flow compressors may enter a globally-stable operational state involving rotating stall within the blade passages. For continued operation in a turbine engine, recovery of the compressor to normal operation is required. Operation in rotating stall is generally characterized by recovery hysteresis; that is, to produce recovery, compressor flow must be allowed to increase substantially beyond the initial flow level observed with rotating stall. In turbine engine applications, it is desirable to reduce compressor recovery hysteresis to a minimum. Stage flow behavior and stage matching at low flows are shown to have a major influence on recovery behavior. Conclusions are supported through the use of an analytical model recently validated with experimental data from tests of a multistage compressor in the Compressor Research Facility at Wright-Patterson Air Force Base. Author

N90-19232# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
THE UNIFORM ENGINE TEST PROGRAMME
PETER F. ASHWOOD and JAMES J. MITCHELL, ed. Feb. 1990 147 p
(AGARD-AR-248; ISBN-92-835-0501-8; AD-A218764) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The results of the Propulsion and Energetics Panel Working Group 15 are summarized. The Group was in operation 1980 to 1987 and performed test runs of two J57 turbojet engines at eight different facilities for ground-level and altitude tests, in five different nations. At two facilities the tests were repeated in order to review a possible deterioration of the engines. The test rig accompanied the engines to the test facilities. The tests were performed observing a carefully composed General Test Plan, being the same for all facilities. Each facility used its own data asquisition and processing system. Author

N90-20985# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
SUBSONIC AND TRANSONIC BLADE DESIGN BY MEANS OF ANALYSIS CODES
R. A. VANDEBRAEMBUSSCHE, O. LEONARD, and L. NEKMOUCHE *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 11 p (SEE N90-20976 14-05) Mar. 1990
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An iterative procedure for cascade blade design, using a direct flow solver and a blade geometry modification algorithm is presented. The procedure starts with the analysis of a given cascade geometry using an existing flow solver. The difference between the calculated velocity distribution and the required one is used as an input for the modification algorithm. This procedure results in the definition of a new blade shape for which the calculated velocity distribution is closer to the desired one. Examples for both subsonic and transonic flow are presented and show a rapid convergence to the geometry required for the desired velocity distribution. The main advantage of the proposed method is that existing analysis codes can be used, for the design and for the off-design analysis. Some restrictions which have to be imposed on the required velocity distribution are also discussed. Author

N90-20988# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Direction de l'Aerodynamique.
AN INVERSE METHOD FOR THE DESIGN OF TURBOMACHINE BLADES [UNE METHODE INVERSE POUR LA DETERMINATION D'AUBES DE TURBOMACHINES]
OLIVIER-PIERRE JACQUOTTE *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 16 p (SEE N90-20976 14-05) Mar. 1990 In FRENCH Sponsored by SNECMA
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An inverse method for the determination of turbomachinery cascade profiles, which can be applied to transonic flow, is described. The method is related to quasi-three-dimensional flow around the blade cascade and is based on the solution of the inverse form of the potential scalar equation associated with the absolute speed in reference to the relative bounds of the blade. The correct mathematical definition of the inverse formula for compressible cascade is examined. The desired profile is obtained after a eries of iterations resulting in parameter adjustments permitted by the convergence. The finite element method is used as the solution technique. The most immediate concern is the preliminary validation of the method and the possibility of restoration of a known profile starting from a gross initialization is shown. Finally, some test cases are shown. Transl. by E.J.R.

N90-20989# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.
APPLICATION OF AN INVERSE METHOD TO THE DESIGN OF A RADIAL INFLOW TURBINE
JOAO EDUARDO BORGES *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 16 p (SEE N90-20976 14-05) Mar. 1990 Sponsored in part by Holset Engineering Co., England; Churchill Coll., Cambridge, England; and Junta Nacional de Investigacao Cientifica e Tecnologica, Portugal
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A truly three-dimensional inverse method is described and applied to the design of the rotor of a radial inflow turbine with a specific speed equal to 0.6. The described indirect method uses a mean swirl (i.e. radius times mean tangential velocity) specification and applies to inviscid and incompressible fluid. In addition, it is assumed that the inlet flow is uniform and that the blades are infinitely thin. The action of the blades is modelled by surface vorticity, using the Clebsch formulation for the calculation of the velocity field. The blade shape is evaluated by requiring it to be aligned with the local velocity vectors throughout its entire length. Since the vorticity depends on the blade shape, the problem must be solved iteratively. As the mean swirl specification is not a familiar input design, its physical significance is discussed and some advice is given on the best way of choosing it. Finally, the results of some experimental tests are briefly discussed. In these tests the performance of a rotor designed using the present indirect method was compared with that achieved by an impeller designed using conventional techniques. It is shown that the rotor designed using the inverse method is more efficient than the conventional impeller. Author

N90-20990# Politecnico di Torino (Italy).
NUMERICAL METHOD FOR DESIGNING 3D TURBOMACHINERY BLADE ROWS
L. ZANNETTI, F. LAROCCA (Fiat Aviazione S.p.A., Turin, Italy), and R MARSILIO *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 9 p (SEE N90-20976 14-05) Mar. 1990
(AGARD-CP-463) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The aim is to present a newly improved method to solve inverse problems for inviscid, compressible, rotational flows in 3-D ducts or 3-D rows of blades. A finite-difference time-dependent computation is performed in a channel whose walls are deformable and that adjust themselves to the design data. In the present 3-D formulation the ideas outlined are followed, a mathematical model based on the contravariant components of the flow velocity and a second-order accurated finite-difference scheme are used. A new

procedure is used at the boundaries, which is simpler and more rigorous than the previous one. Author

N90-21009# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
SECONDARY FLOWS IN TURBOMACHINES
Feb. 1990 342 p In ENGLISH and FRENCH Meeting held in Luxembourg, 30 Aug. - 1 Sep. 1989
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The Specialists' Meeting was arranged in the following sessions: Basic Flow Phenomena; Experimental Results; Three-Dimensional Computation and Comparison with Experiments; Tip Clearance Flows; and Secondary Flow Effects on Heat Transfer. The Technical Evaluation Report is included at the beginning of the proceedings. Questions and answers of the discussions follow each report. A forum was offered for experts to discuss computational and experimental methods and results of secondary flow in cascades, compressors, and turbines. Computational fluid dynamics was found to be an adequate tool to represent qualitative phenomena, but on the accuracy of predicting losses and exit angles there was some disagreement. Many papers dealt with experimental investigations which are obviously essential for evaluating secondary flow models. For individual titles, see N90-21010 through N90-21033.

N90-21010# Vrije Univ., Amsterdam (Netherlands). Dept. of Fluid Mechanics.
SECONDARY FLOWS AND RADIAL MIXING PREDICTIONS IN AXIAL COMPRESSORS
J. DERUYCK, CH. HIRSCH, and P. SEGAERT In AGARD, Secondary Flows in Turbomachines 19 p (SEE N90-21009 14-07) Feb. 1990 Sponsored in part by AFOSR, Bolling AFB, Washington, DC and IWONL, Brussels, Belgium
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A radial mixing computation method is presented in the framework of an integrated quasi-3D approximation method for turbomachinery flow computations. The radial mixing computation is performed on a transverse surface S3, the only type of stream surface hitherto not considered in the quasi-3D computation. Both convective and diffusive mixing mechanisms are taken into account: the convective mixing due to secondary flows is computed explicitly, while the diffusive mixing due to the random effects of turbulence is modeled by empirical coefficients. The flow field on the S3-surface is reconstructed from the knowledge of axial vorticity contributions for different flow regions, which are added to constitute the right-hand side of a quasi-harmonic Poisson-type stream function equation. These axial vorticity components are obtained through vorticity equations for the inviscid flow region, combined with integral methods for the 3D end-wall boundary layers, 3D profile boundary layers, and 3D asymmetric wakes. The validity of the secondary flow computation is assessed through comparisons between computational results and experimental data. The method is applied to predict the redistribution of radial temperature profiles for three axial turbomachines: a linear cascade and two single-stage compressor rotors. Author

N90-21011# United Technologies Research Center, East Hartford, CT.
THE EFFECTS OF COMPRESSOR ENDWALL FLOW ON AIRFOIL INCIDENCE AND DEVIATION
ROBERT P. DRING and H. DAVID JOSLYN In AGARD, Secondary Flows in Turbomachines 9 p (SEE N90-21009 14-07) Feb. 1990
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A previous examination of through flow theory in compressors has demonstrated that while there are many ways to define the average flow angle at a particular span location downstream of an airfoil, only one definition is consistent with the formulation of through flow theory. It was also demonstrated that the flow in the endwall regions is especially sensitive to this question due to the strong secondary flows and the hub corner separations that commonly occur. The question of how these observations may be

extended to the airfoil-to-airfoil flow analysis is examined. It is demonstrated that the question of the correct average can have a strong impact on both airfoil incidence and deviation. Differences of up to 13 degrees are demonstrated. It is also suggested that one specific angle definition results in better predictions of airfoil pressure distributions. Author

N90-21012# Middle East Technical Univ., Ankara (Turkey). Dept. of Mechanical Engineering.
A STUDY ON SECONDARY FLOW AND SPANWISE MIXING IN AXIAL FLOW COMPRESSORS
MURAT ERKILET and AHMET S. UCER In AGARD, Secondary Flows in Turbomachines 10 p (SEE N90-21009 14-07) Feb. 1990
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Axisymmetric throughflow equations are reformulated in order to introduce the effect of spanwise mixing in axial flow compressors. The spanwise mixing model used in this investigation assumes that turbulent diffusion is the dominant physical mechanism for the onset of spanwise mixing rather than the deterministic nature of secondary flow model. Two-dimensional loss and deviation correlations available in the open literature are used together with the 3-D, secondary flow loss models for middle stages. End-wall boundary layer blockage is either introduced from experimental data if available or calculated using simple models. Finite element method is used for the solution of the equation of motion. Author

N90-21014# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
EXPERIMENTAL AND NUMERICAL STUDY ON BASIC PHENOMENA OF SECONDARY FLOWS IN TURBINES
R. NIEHUIS, P. LUECKING, and B. STUBERT In AGARD, Secondary Flows in Turbomachines 17 p (SEE N90-21009 14-07) Feb. 1990 Sponsored by the Germany Ministry for Research and Technology
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The recent understanding and the basic principles of secondary flow development in turbines, such as the formation of a horseshoe vortex and a passage vortex, are illustrated. Results are obtained for an experimental investigation of the three-dimensional flow within an annular cascade rig of an inlet guide vane of a low pressure turbine. Flow calculations with a three dimensional Euler and a partially parabolized Navier-Stokes code were performed, and the numerical results are discussed and compared with the experiment. Additionally, the computer codes were applied to calculate the three dimensional flow within two different model configurations designed to expose the influence and the contribution of different secondary flow phenomena in the end wall region. Author

N90-21015# Brescia Univ. (Italy). Dept. di Meccanica.
SECONDARY FLOWS AND REYNOLDS STRESS DISTRIBUTIONS DOWNSTREAM OF A TURBINE CASCADE AT DIFFERENT EXPANSION RATIOS
ANTONIO PERDICHIZZI, MARINA UBALDI, and PIETRO ZUNINO (Genoa Univ., Italy) In AGARD, Secondary Flows in Turbomachines 13 p (SEE N90-21009 14-07)
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The results are presented for an experimental investigation on secondary flows and turbulence in a plane located 30 percent of an axial chord downstream of a turbine cascade. Mean velocity field, energy loss, and Reynolds stress distributions were measured with pressure and hot-wire probes at different expansion ratios for three isentropic outlet Mach numbers $M(sub 2is) = 0.3, 0.5$, and 0.7. High levels of turbulence kinetic energy are found in the passage-shed vortex interaction region and in the corner vortex, while lower values are present in the wake. The turbulent shear stress distributions, analyzed in detail, are consistent with the mean strain field. As the Mach number increases, the turbulence kinetic energy level is significantly reduced. The bar UV and bar vw shear stresses show a similar trend, while the bar uw component remains

the same magnitude, revealing different contributions to the dissipation rate. Author

N90-21016# Durham Univ. (England). School of Engineering and Applied Science.
AN INVESTIGATION OF SECONDARY FLOWS IN NOZZLE GUIDE VANES
R. G. DOMINY and S. C. HARDING (Rolls-Royce Ltd., Bristol, England) *In* AGARD, Secondary Flows in Turbomachines 15 p (SEE N90-21009 14-07) Feb. 1990 Sponsored by the British Science and Engineering Research Council
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Much of the energy loss that occurs in turbine nozzles is associated with the strongly three dimensional secondary flows that result from the interaction between the surface boundary layers and the nozzle row with its associated pressure field. Three alternative nozzles, each performing the same duty, with different degrees of three dimensionality in their designs to control secondary flow are studied. The chosen nozzle guide vanes are fully representative of the current generation of high hub-tip ratio aero engine nozzles in which the proportion of the overall loss that is attributable to secondary flows is high. A computational analysis of all three nozzles is presented including predictions from three alternative viscous, three dimensional methods. These detailed measurements and predictions demonstrate the significant influence of the vane geometries on the magnitude and the distribution of the secondary losses. Author

N90-21017# Royal Aerospace Establishment, Farnborough (England). Propulsion Dept.
SECONDARY FLOW PREDICTIONS FOR A TRANSONIC NOZZLE GUIDE VANE
G. C. HORTON *In* AGARD, Secondary Flows in Turbomachines 12 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
To improve turbine efficiency it is necessary to design the blading to control the flow, including the secondary flow, and hence reduce the losses. A method is therefore required to predict the three-dimensional flow, with losses, within turbine geometries. Three-dimensional viscous flow programs offer the capability of doing this. Such a program (as developed by Dawes) is available at the Royal Aerospace Establishment, Pyestock. It was used to analyze the flow through a transonic turbine nozzle guide vane which was tested in cascade at Pyestock. The predictions are compared with surface pressure and downstream traverse results to assess the ability of the program to predict secondary flows and losses in a highly loaded nozzle guide vane operating at representative engine conditions. Author

N90-21018# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.
SECONDARY FLOW IN A TURBINE GUIDE VANE WITH LOW ASPECT RATIO
D. WEGENER, J. QUEST, and W. HOFFMANN *In* AGARD, Secondary Flows in Turbomachines 9 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The flow field of an annular turbine cascade with low aspect ratio (0.6) is investigated by means of experiments and numerical calculations. An advanced computer code was applied to solve the three dimensional Reynolds averaged Navier-Stokes equations. Detailed measurements with 5-hole probes and an advanced Laser-Two-Focus velocimeter (L2F) were carried out to evaluate the numerical solution of the flow field. Flow visualization on the endwalls and on the blade surfaces complement the experimental data and help to understand the secondary flow phenomena. The results show that this 3D-NS calculation is an efficient tool to predict complex secondary flow phenomena. Author

N90-21019# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. fuer Experimentelle Stroemungsmechanik.
MEASUREMENT OF THE FLOW FIELD IN THE BLADE PASSAGE AND SIDE-WALL REGION OF A PLANE TURBINE CASCADE
E. DETEMPLE-LAAKE *In* AGARD, Secondary Flows in Turbomachines 13 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The transonic flow through a plane cascade consisting of profiles designed for a highly loaded gas turbine rotor of a high pressure stage is investigated. The experiments presented are part of an entire test program performed in a special wind tunnel at the DLR. The measurements of the side-wall pressure distribution in a blade passage are described. The parameters varied are the inlet flow angle and the downstream isentropic Mach number. Based on the results of Schlieren photographs of the flow field and suface oil flow patterns on the blades and the side-wall, the experimental results are interpreted. Author

N90-21020# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.
CENTRIFUGAL IMPELLER GEOMETRY AND ITS INFLUENCE ON SECONDARY FLOWS
H. KRAIN and W. HOFFMANN *In* AGARD, Secondary Flows in Turbomachines 17 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Detailed experimental and theoretical flow field studies are carried out for two 30 degree, high pressure ratio impellers having the same blade geometry but different shroud contours. An advanced Laser-Two-Focus Velocimeter is used to obtain experimental data. The theoretical investigations are performed with a 3D-viscous code that was coupled with a postprocessor primarily suitable for turbomachinery flow field studies. Comparisons between measured and calculated data are carried out and the influence of the flow channel variation on the through flow velocity patterns and secondary flow structures are discussed. Author

N90-21021# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
CALCULATION OF THE THREE DIMENSIONAL TURBULENT FLOW IN A LINEAR TURBINE BLADE [CALCUL DE L'ECOULEMENT TRIDIMENSIONNEL TURBULENT DANS UN AUBAGE RECTILIGNE DE TURBINE]
L. CAMBIER and B. ESCANDE *In* AGARD, Secondary Flows in Turbomachines 15 p (SEE N90-21009 14-07) Feb. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The numerical simulation of a three-dimensional turbulent flow in a linear turbine cascade, is examined by solution of the Reynolds-averaged compressible Navier-Stokes equations with an algebraic turbulence model. The numerical method is characterized by an explicit centered finite difference scheme, associated with a multigrid convergence acceleration. The splitting of the computational domain in an O-type subdomain around the blade and two H-type subdomains upstream and downstream allows an accurate description of the round leading edges and trailing edges, while setting the upstream and downstream boundaries of the domain sufficiently far from the blade. The results obtained in a mesh containing more than 300,000 points (in a domain bounded by a symmetry plane) show complex phenomena of secondary flows, qualitatively similar to the phenomena observed in an experiment carried out at a lower flow velocity. Author

N90-21022# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
CALCULATION OF THE SECONDARY FLOW IN AN AXIAL TURBINE [CALCUL DES ECOULEMENTS SECONDAIRES DANS UNE TURBINE AXIALE]
J. BERNARD and F. FALCHETTI *In* AGARD, Secondary Flows in Turbomachines 12 p (SEE N90-21009 14-07) Feb. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Satisfactory prediction of secondary flow effects can be considered a major objective in the design and analysis of turbine blades. A method, initially developed for the computation of secondary flows in multi-stage compressors, is briefly presented together with results obtained on a turbine nozzle cascade and on a low pressure turbine stage. Satisfactory results are obtained for the secondary vorticity as well as for the local variations in the velocity triangles. However, secondary losses and blockage are not well predicted due to the integral character of the wall boundary layer calculation used in the model. However, use of the method together with current correlations can yield interesting results especially as far as successive blade row adaptation is concerned. For detailed predictions of blade row performance, in particular secondary flow effects, the turbine designer must implement more complex methods developed for the resolution of the three-dimensional Navier-Stokes equations. Author

N90-21023# General Electric Co., Schenectady, NY. Corporate Research and Development.
GENERATION AND DECAY OF SECONDARY FLOWS AND THEIR IMPACT ON AERODYNAMIC PERFORMANCE OF MODERN TURBOMACHINERY COMPONENTS
C. HAH *In* AGARD, Secondary Flows in Turbomachines 13 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A three-dimensional viscous flow code is used to distinguish aerodynamic performance of different designs of turbomachinery components. Two designs of a high-pressure-ratio turbine nozzle and a centrifugal compressor impeller are numerically studied to investigate detailed flow development and overall aerodynamic performance. It is indicated that the current viscous code can differentiate aerodynamic performance of various designs of turbomachinery components. Author

N90-21024# National Technical Univ., Athens (Greece). Lab. of Thermal Turbomachines.
SECONDARY FLOW CALCULATIONS FOR AXIAL AND RADIAL COMPRESSORS
D. DOUVIKAS, J. KALDELLIS, and K. D. PAPAILIOU *In* AGARD, Secondary Flows in Turbomachines 17 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A secondary flow calculation method is presented, the development of which was recently completed in the Thermal Turbomachinery Laboratory of the National Technical University of Athens. This method makes use of the meridional vorticity transport equation, the momentum integral equation, and the mean kinetic energy integral equation. Emphasis is placed upon the use of a coherent two-zone model and care is taken to describe adequately the flow inside an unbounded (external), semi-bounded (annulus), and fully-bounded (bladed) space. The hub and tip secondary flow development is calculated simultaneously, so that, the use of an approximate model for the interaction between the viscous shear layer and the external flow, permits this last flow field to be adapted to the growth of the wall shear layers during the computational procedure. Not only the meridional but also the peripheral blockage is taken into account during this procedure. An additional approximate viscous-inviscid interaction model is used, when shocks are present in the passage. An attempt is made to place the method in historical perspective. Then, after its brief discription, comparisons with experimental results are presented along with the appropriate discussion in order to evaluate the capabilities of the method. Author

N90-21025*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE NUMERICAL SIMULATION OF MULTISTAGE TURBOMACHINERY FLOWS
J. J. ADAMCZYK, T. A. BEACH, M. L. CELESTINA, R. A. MULAC, and W. M. TO (Sverdrup Technology, Inc., Cleveland, OH.) *In* AGARD, Secondary Flows in Turbomachines 13 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 21/5

The need to account for momentum and energy transport by the unsteady deterministic flow field in modeling the time-averaged flow state within a blade row passage embedded in a multistage compressor is assessed. It was found that, within the endwall regions, large-scale three-dimensional unsteady structures existed which caused significant transport of momentum and energy across the time-averaged stream surface of a stator flow field. These experiments confirmed that the tranport process is dominated by turbulent diffusion in the midspan region. A model was then proposed for simulating this transport process, and a limited study was undertaken to assess its validity. Author

N90-21026# Connecticut Univ., Storrs. Dept. of Mechanical Engineering.
RESEARCH ON CASCADE SECONDARY AND TIP-LEAKAGE FLOWS: PERIODICITY AND SURFACE FLOW VISUALIZATION
L. S. LANGSTON *In* AGARD, Secondary Flows in Turbomachines 15 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Large scale planar cascade experimental studies were used for some years now to sort out and measure three-dimensional flows in axial flow turbines. In particular, these planar cascades were and are used for secondary flow studies and more recently for tip clearance studies. Cascade periodicity and the use of surface flow visualization in planar turbine cascades, in these studies are the topics of focus. Since results from these cascade experimental studies are based on a planar casade that usually has few airfoils, the topic of how periodicity is achieved in a finite cascade is an important one. One method of achieving periodicity in a 4-airfoil cascade is discussed. The use of surface flow visualization in these cascade studies has benn prominent. A commetary is given on three techniques that were used, and on the interpretation of the results from each technique. Author

N90-21027# Carleton Univ., Ottawa (Ontario). Dept. of Mechanical and Aerospace Engineering.
LOSSES IN THE TIP-LEAKAGE FLOW OF A PLANAR CASCADE OF TURBINE BLADES
M. I. YARAS and S. A. SJOLANDER *In* AGARD, Secondary Flows in Turbomachines 13 p (SEE N90-21009 14-07) Feb. 1990 Sponsored in part by Pratt and Whitney Canada, Inc.
(Contract NSERC-A1671)
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The total pressure losses in the tip-leakage flow of a planar cascade of turbine blades are examined. The objective is to clarify the loss mechanisms which affect the tip gap flow as well as to provide additional data on tip-leakage losses for use in correlations. Clearances of 1.5 to 5.5 percent of the blade chord are considered. The flow was measured also for zero clearance to identify the conventional secondary flow component of the loss. The data presented clarify the role played in the evolution of the tip-leakage losses by: the viscous stresses and separation bubbles inside the tip gap; the sudden expansion as the flow emerges from the gap; and the mixing out process as the tip-leakage vortex develops downstream of the trailing edge. The direct loss within the clearance gap is found to be relatively unimportant for the full range of clearances. The measurements are compared with commonly-used correlations for the tip-leakage losses. Author

N90-21028# Technische Hochschule, Aachen (Germany, F.R.). Inst. fuer Strahlantriebe und Turboarbeitsmaschinen.
COMPUTATIONAL PREDICTION AND MEASUREMENT OF THE FLOW IN AXIAL TURBINE CASCADES AND STAGES
H. E. GALLUS, K. WESKAMP, and J. ZESCHKY *In* AGARD, Secondary Flows in Turbomachines 10 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A partially-parabolic program was developed to calculate the three-dimensional, viscous flow through subsonic axial turbine guide vanes and rotor blades. To provide test cases for the calculations, a detailed experimental study of the flow in an axial turbine stage as well as in an axial-flow turbine cascade was performed. The obtained results and the comparison of the theoretical and experimental data are discussed. Author

N90-21029# Technische Hochschule, Aachen (Germany, F.R.). Inst. for Jet Propulsion and Turbomachinery.
ANALYSIS OF THE ROTOR TIP LEAKAGE FLOW WITH TIP COOLING AIR EJECTION
W. KOSCHEL, H. SCHMIDT, and A. VORNBERGER *In* AGARD, Secondary Flows in Turbomachines 14 p (SEE N90-21009 14-07) Feb. 1990 Sponsored by Deutsche Forschungsgemeinschaft
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A numerical simulation of turbine rotor tip leakage flow was carried out taking into account tip coolant flow injection. The numerical scheme is based on a finite element method for the integration of the Navier-Stokes equations in the conservative form using an explicit two-step Taylor-Galerkin algorithm. The application of unstructured grids together with local refinement strategies allows a detailed resolution of viscous flow phenomena in the clearance gap. The analysis is performed for an HP turbine blade with a tip groove without and with tip coolant flow injection. The effect of varying clearance height and of wall motion is also considered. Results on 2D-flow computations are presented and discussed in regard to viscous flow effects and to the relative mass flow discharge in the tip clearance for the different investigated configurations. Author

N90-21033# National Research Council of Canada, Ottawa (Ontario). Gas Dynamics Lab.
THE EFFECT OF SECONDARY FLOW ON THE REDISTRIBUTION OF THE TOTAL TEMPERATURE FIELD DOWNSTREAM OF A STATIONARY TURBINE CASCADE
W. E. CARSCALLEN and P. H. OOSTHUIZEN (Queens Univ., Kingston, Ontario) *In* AGARD, Secondary Flows in Turbomachines 18 p (SEE N90-21009 14-07) Feb. 1990
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Early testing at the National Research Council of Canada's (NRCC) Highly Loaded Turbine Test Rig revealed that the total temperature downstream of a turbine nozzle was redistributed relative to the nozzle inlet total temperature distribution and furthermore there was an apparent change in area averaged total temperature across the stator row. In order to examine these observations a transonic planar cascade of the exhauster type was constructed at NRCC. Tests were carried out at pressure ratios giving nozzle isentropic exit Mach numbers ranging from low subsonic to low supersonic. Wedge probes were used to measure total pressure, total temperature, and flow angles downstream of the nozzle blade. Test results indicated that the exit total temperature distributions are highly redistributed and possible reasons for this phenomena are discussed. Results on area averaged aerodynamic losses are also given and their relation to the change in total temperature across the nozzle blades are discussed. Author

N90-21981# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
MESH GENERATION FOR FLOW COMPUTATION IN TURBOMACHINE
M. GOUTINES, G. KARADIMAS, and C. HAH (General Electric Co., Schenectady, NY.) *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 13 p (SEE N90-21975 15-34) Mar. 1990
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Building grids for flow computation in turbomachine applications is examined. H,I,C, and O types are discussed for 2D or 3D, inviscid or viscous flow cases. The given examples concern 3D Euler application on a fan with part-span damper and splitter, 2D Navier-Stokes on turbine and compressor transonic cascades, and 3D Navier-Stokes on a transonic fan. Author

N90-27704# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AGARD/SMP REVIEW DAMAGE TOLERANCE FOR ENGINE STRUCTURES. 3: COMPONENT BEHAVIOUR AND LIFE MANAGEMENT
Jun. 1990 71 p In ENGLISH and FRENCH Meeting held in Ottawa, Ontario, 23-28 Apr. 1989 Original contains color illustrations
(AGARD-R-770; ISBN-92-835-0545-X; AD-A229327) Copyright Avail: NTIS HC A04/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Current approaches to the prediction of component behavior and the establishment of suitable inspection schedules were surveyed. The role of testing and life management planning in these approaches was examined. Future technology requirements and the need for a common AGARD approach were discussed. For individual titles, see N90-27705 through N90-27710.

N90-27705# Rolls-Royce Ltd., Derby (England). Materials and Mechanical Technology.
AGARD DAMAGE TOLERANCE CONCEPTS FOR ENGINE STRUCTURES WORKSHOP 3, COMPONENT BEHAVIOUR AND LIFE MANAGEMENT
R. H. JEAL *In* AGARD, AGARD/SMP Review Damage Tolerance for Engine Structures. 3: Component Behaviour and Life Management 9 p (SEE N90-27704 22-07) Jun. 1990 Original contains color illustrations
(AGARD-R-770) Copyright Avail: NTIS HC A04/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
This workshop covered the critical technologies that relate the science of materials and defect behavior, and the knowledge of component quality, to the reality of component performance in the engine. The initial predictions of life and integrity, even using todays complex models and super computing methodology, is relatively cheap. The validation of these models by component testing and engine accelerated mission testing is expensive. The inevitable move to less validation testing must be balanced by appropriate in service planning and monitoring. This workshop should allow balance of these to be assessed at todays level of capability. Author

N90-27706# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France). Div. Mecanique.
CALCULATION OF SERVICE LIFE OF TURBOMACHINE COMPONENTS [CALCU DE DUREE DE VIE DES COMPOSANTS DE TURBOMACHINES]
JEAN PIERRE MASCARELL *In* AGARD, AGARD/SMP Review Damage Tolerance for Engine Structures. 3: Component Behaviour and Life Management 11 p (SEE N90-27704 22-07) Jun. 1990 In FRENCH
(AGARD-R-770) Copyright Avail: NTIS HC A04/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Today, it is realized that turbomachines are necessary high performance equipment. Taking into account temperature effects, loads, and the configuration of the most used parts of the engine, methods for predicting service life are presented which use damage analysis of materials caused by temperature. The results are used

from temporal evolution of the behavior and damage, which comes from multiaxial thermomechanical forces and cyclic load test or the components of the structure. Some applications are proposed for various concepts of service life by crack initiation or crack propagation.
Author

N90-27707# Rolls-Royce Ltd., Derby (England). Materials and Mechanical Technology Dept.
THE ROLE OF COMPONENT TESTING
G. ASQUITH In AGARD, AGARD/SMP Review Damage Tolerance for Engine Structures. 3: Component Behaviour and Life Management 19 p (SEE N90-27704 22-07) Jun. 1990 Previously announced as N90-12608
(AGARD-R-770) Copyright Avail: NTIS HC A04/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
The importance of component testing in ensuring that design and life goals of engines are met is addressed. The integration of component testing and materials data generation into a material data bank is described. The techniques of stress and fracture mechanics analysis, crack monitoring, metallography and probabilistic approaches are used in establishing this data bank. The use of data on the material behavior of components in the development of new and improved materials is stressed. The above are discussed under the headings of: types of test; relationships of test conditions to engine cycles; testing facilities; test monitoring techniques; test analysis; scatter effects; use of results in component behavior analysis; and future use of component testing.
Author

N90-27708# Hawker Siddeley Canada Ltd., Toronto (Ontario). Orenda Div.
THE ROLE OF INFLIGHT ENGINE CONDITION MONITORING ON LIFE CYCLE MANAGEMENT OF CF-18/F404 ENGINE COMPONENTS
D. SPRAGG, U. GANGULI, R. THAMBURAJ, H. HILLEL, and R. W. CUE (Department of National Defence, Ottawa, Ontario) In AGARD, AGARD/SMP Review Damage Tolerance for Engine Structures. 3: Component Behaviour and Life Management 13 p (SEE N90-27704 22-07) Jun. 1990
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Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
The Canadian Forces have developed an Engine Parts Life Tracking System (EPLTS) to facilitate effective On Condition Maintenance (OCM) of the CF-18/F404 engine. The system tracks 64 parts and modules on the basis of 8 Life Used Index values (LUIs) defined by the engine manufacturer. The LUI values are obtained by the Inflight Engine Condition Monitoring System (IECMS) in the mission computer onboard the CF-18 aircraft. The EPLTS database is updated daily to provide an up to date status of all engines in the fleet. The organization of EPLTS is described and the parameters being monitored are detailed. Various EPLTS capabilities, with respect to critical part life management and analysis, are then reviewed.
Author

N90-27709# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec). Structures and Dynamics.
LIFE MANAGEMENT PLANNING
K. REZAI and R. N. TADROS In AGARD, AGARD/SMP Review Damage Tolerance for Engine Structures. 3: Component Behaviour and Life Management 6 p (SEE N90-27704 22-07) Jun. 1990
(AGARD-R-770) Copyright Avail: NTIS HC A04/MF A01;
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Structural integrity and safe operation of gas turbine engines for commercial aircraft was gained through the application of a life management procedure, which combines state of the art technology from various disciplines of engineering. The core of the process is substantiation of components and their materials for low cycle fatigue/mission life and it is essentially based on Safe Life Approach (SLA) design. Fracture mechanics analyses are also applied in some cases for proper understanding of the behavior of materials susceptible to fatigue crack growth. The life management procedure is discussed. Basic lifing process on the basis of SLA and application of fracture mechanics are also presented.
Author

N90-27710# Royal Aircraft Establishment, Farnborough (England). Propulsion Dept.
COMPONENT BEHAVIOUR AND LIFE MANAGEMENT: THE NEED FOR COMMON AGARD APPROACHES AND ACTIONS
C. R. GOSTELOW In AGARD, AGARD/SMP Review Damage Tolerance for Engine Structures. 3: Component Behaviour and Life Management 4 p (SEE N90-27704 22-07) Jun. 1990
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Component behavior and life management are central to Damage Tolerant Design and Engine Certification. With an 'international product' such as the gas turbine engine there is a need for labs in the various countries to be able to believe each others data, results, and fly modern engines using new lifing methods, materials, and manufacturing processes with confidence and in safety. In particular: all AGARD Countries are customers and users of gas turbine engines, military and civil, bought from a number of sources. There is a need to establish a common position if components lifed by DTD are to be introduced and managed in a safe and cost effective manner, and the various Lifing Authorities convinced that the lifing methodologies are safe. There are a number of material related areas that would benefit from collaborative activity: Materials (small cracks, mission cycling, surface condition, and statistics); Stress Analysis (algorithms, and forging modeling); and damage rules.
Author

N90-27711# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
COMPARATIVE ENGINE PERFORMANCE MEASUREMENTS
May 1990 289 p Lecture series held in Torino, Italy, 14-15 May 1990; in London, England, 17-18 May 1990; in Montreal, Quebec, 4-5 Jun. 1990; and in Monterey, CA, 7-8 Jun. 1990
(AGARD-LS-169; ISBN-92-835-0565-4; AD-A224601) Copyright Avail: NTIS HC A13/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The AGARD Propulsion and Energetics Panel has sponsored an international, interfacility comparison program for turbine test facilities over the past nine years. The effort was driven by the critical nature of engine test measurements and their influence on aircraft performance predictions, as well as the need for a sound understanding of test-related factors which may influence measurements. The basic idea was that a nominated engine would be tested in several facilities, both ground-level and altitude, the results then compared, and explanations sought for any observed differences. The information obtained from this comprehensive program is presented. Emphasis is given to the definition and explanation of differences in test facility measurements and to the lesson learned from this experiment. For individual titles, see N90-27712 through N90-27721.

N90-27712# Sverdrup Technology, Inc., Arnold AFS, TN.
DESIGN OF THE UETP EXPERIMENT
ROBERT E. SMITH, JR. In AGARD, Comparative Engine Performance Measurements 10 p (SEE N90-27711 22-07) May 1990
(AGARD-LS-169) Copyright Avail: NTIS HC A13/MF A02;
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An experiment was successfully designed to meet the objectives of the Uniform Engine Test Program (UETP) as defined by the Propulsion and Energetics Panel (PEP) of AGARD. The experiment was based on the use of two specially modified J57-PW-19W turbine engines. The experiment was compatible with the capability and availability of eight different engine test facilities located within five NATO countries. Four of these test facilities are ground-level engine test facilities, and four are altitude engine test facilities. The experiment as designed was consistent with the test resources available at each test site. The design of the experiment included the specification of the test article, the matrix of variables, the experimental measurements, and the formats of the test reports. In addition, the design of the experiment included the definition of three methodologies, i.e., test, data processing, and measurement uncertainty, to the minimum extent necessary to meet the objectives of the UETP, and to maximize the level of confidence in the comparative engine performance measurements from each facility. This approach was consistent with a basic

requirement of the UETP, which was to utilize local facility practices to the maximum extent possible. The experiment as designed was defined in a General Test Plan which was coordinated with and approved by all participants in the Uniform Engine Test Program. The General Test Plan was published and made available to all program participants. A literature search did not identify any existing publications which defined experiments of the scope required for the UETP. The successful design of the UETP experiment was a major technical and management accomplishment and was a key contributor to the success of the UETP. The General Test Plan should serve as a baseline for the design of future experiments having the scope and complexity of the AGARD Uniform Engine Test Program.   Author

N90-27713#   Royal Aerospace Establishment, Farnborough (England). Dept. of Propulsion.
THE BASIS FOR FACILITY COMPARISON
A. R. OSBORN   *In* AGARD, Comparative Engine Performance Measurements 28 p (SEE N90-27711 22-07)   May 1990
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  One of the main objectives of the Uniform Engine Test Program (UETP) was an engine facility comparison to identify the bias measurement performance differences between the sites. The methods used to present these comparisons are identified and the alternative presentations considered in the Working Group 15 discussions, but not published elsewhere. In addition, many other factors affecting engine performance determination are discussed and the planned methodology adopted by the UETP to determine these elemental differences. Finally, some examples of UETP engine performance measurement anomalies are highlighted and an attempt made to identify the reason for them with a recommendation on how they should be treated.   Author

N90-27714#   National Research Council of Canada, Ottawa (Ontario). Engine Lab.
INVESTIGATION OF FACTORS AFFECTING DATA COMPARISON
D. M. RUDNITSKI   *In* AGARD, Comparative Engine Performance Measurements 18 p (SEE N90-27711 22-07)   May 1990
(AGARD-LS-169)   Copyright   Avail: NTIS HC A13/MF A02;
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  In evaluating engine performance in test facilities, ground-level test beds or altitude tanks, facility influences on performance measurements must be quantified. Of the three main engine parameters, only fuel flow measurement is facility type independent, whereas thrust and airflow calculation procedures tend to be facility type specific. Data consistency checks for thrust and airflow using the method of flow coefficient, was demonstrated to be quite a useful tool for inter-facility comparisons, whereas for fuel flow, sensor redundancy is most common. The possibility of engine deterioration occurring during an extended test program required close monitoring of basic engine parameters using facility independent sensors. Although some long-term changes in engine behavior did occur, the magnitude of these shifts did not warrant data correction.   Author

N90-27715#   Sverdrup Technology, Inc., Arnold AFS, TN.
COMPARISON OF ALTITUDE TEST CELL RESULTS
ROBERT E. SMITH, JR.   *In* AGARD, Comparative Engine Performance Measurements 12 p (SEE N90-27711 22-07)   May 1990
(AGARD-LS-169)   Copyright   Avail: NTIS HC A13/MF A02;
Non-NATO Nationals requests available only from
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  The steady-state performance of the J57-PW-19W engine as measured in four altitude test facilities located at NASA (Lewis), AEDC, RAE(P), and CEPr was compared and analyzed at each of ten simulated flight conditions. All of the performance comparisons were based on six pairs of fundamentally related parameters, which included combinations of engine rotor speeds, temperature ratio, pressure ratio, airflow, fuel flow, net thrust, and specific fuel consumption. Two different methods were used to make the facility comparisons. First, the facility performance was compared using all engine data over the full range of test conditions and power settings tested. The comparison between the four altitude facilities

was based on the fraction of test data which are within a 2-percent band i.e., + or - 1 percent of the mean performance curves at each of the ten environmental test conditions. Second, facility performance was compared using the overall percentage spread of the characteristic curves fit to the six pairs of key engine performance parameters for all of the simulated flight conditions at one engine power setting. Facility comparisons based on the first method showed approximately 90 percent or more of all the data was within a 2-percent bandwidth for four of the six parameter sets, i.e., engine speed ratio, engine temperature ratio, airflow, and specific fuel consumption. Only about 65 percent of the fuel flow and net thrust data was within the 2-percent band. The fuel flow and thrust data from Centre d'Essais des Propulseurs (CEPr) were significantly different from the other three test facilities and combined confirmed anomalies. Omitting the CEPr data for these two parameters increased the fraction of data points within the 2-percent band to 85 percent for fuel flow and 92 percent for net thrust. The ranges of overall engine performance spreads based on the second method are presented for three of the key pairs of engine performance parameters. The differences were evaluated at approximately the mid-thrust level of the engine power range at each of the test conditions.   Author

N90-27716#   National Research Council of Canada, Ottawa (Ontario). Engine Lab.
COMPARISON OF GROUND-LEVEL TEST CELLS AND GROUND-LEVEL TO ALTITUDE TEST CELLS
D. M. RUDNITSKI   *In* AGARD, Comparative Engine Performance Measurements 13 p (SEE N90-27711 22-07)   May 1990
(AGARD-LS-169)   Copyright   Avail: NTIS HC A13/MF A02;
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AGARD/Scientific Publications Executive
  The Uniform Engine Test Program was set up to examine gas turbine test procedures, instrumentation techniques and data reduction methods employed by engine test facilities in several AGARD countries. Two major classes of facilities participated, altitude and ground-level test beds. Two engines were to be operated in the test facilities, but as the program evolved, only one engine was tested in all the altitude facilities, and the other in the ground-level beds, with some overlap between. Thus the performance assessment had to be laid out with three specific objectives: altitude with altitude; ground-level with ground-level; and ground-level with altitude. This lecture will deal with ground-level with ground-level and ground-level with altitude. Steady-state performance of a J57-P-19 turbojet engine was evaluated in four ground-level test beds, three of them enclosed: NRCC, CEPr, and TUAF, and an open-air test bed at NAPC. Detailed inter-facility comparisons were made on the three basic engine parameters, airflow, net thrust, and specific fuel consumption, and reasons sought for any differences. The ground-level with altitude objective was to compare data taken in an altitude facility to those obtained in a ground-level test bed. As not all facilities tested both engines in the round-robin, engine SN 607594 was used for altitude to altitude and altitude to ground-level, and engine 615037 for ground-level bed comparison. AEDC was the only altitude facility capable of operation at sea-level-static conditions for both engines, which provided a direct comparison of the validity of the normalizing equations. CEPr tested one engine in both a ground-level bed and in their altitude facility. Significant data scatter and biases in the CEPr data made meaningful comparisons of dubious value, reducing the size of the database.
                                                      Author

N90-27717#   National Aerospace Lab., Amsterdam (Netherlands).
MEASUREMENT UNCERTAINTY IN GAS TURBINE PERFORMANCE DETERMINATION
J. P. K. VLEGHERT   *In* AGARD, Comparative Engine Performance Measurements 7 p (SEE N90-27711 22-07)   May 1990
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  A pre-test estimate of data uncertainty shows up weak links in the data chain and serves as a yardstick to judge whether observed differences in measured data are significant. On the other hand post-test analysis is essential to identify data validity problems. The uncertainty estimates are based on the Abernethy concept, which splits total uncertainty in precision and bias. With the help

of an error audit four types of elemental errors are estimated for each of five basic physical parameters. This error is then propagated to the engine performance parameters, and from there to the target values on which the comparison is based. Values for predicted errors are compared between the participating facilities and reasons for discrepancies are discussed.　　Author

N90-27718# Sverdrup Technology, Inc., Arnold AFS, TN.
EXPERIENCE IN DEVELOPING AN IMPROVED DESIGN OF EXPERIMENT (LESSONS LEARNED)
ROBERT E. SMITH, JR.　In AGARD, Comparative Engine Performance Measurements 5 p (SEE N90-27711 22-07)　May 1990
(AGARD-LS-169)　Copyright　Avail: NTIS HC A13/MF A02;
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　　The design of the experiment for the AGARD PEP Uniform Engine Test Program (UETP) was a highly successful effort. The plan and organization for this program included contemporary recording of lessons learned regarding improvements to the design of the UETP experiment. Nine major lessons learned were identified which provide the opportunity for improvements in the design of experiments for future programs having a scope and complexity similar to the UETP. These lessons learned were spread across the seven key technical elements of the experiments as follows: test article - validated engine math model; matrix of variables - engine performance tracking; experimental measurements - referee tailpipe measurements, engine inlet turbulence; test method - compressor inlet flow distortion engine thermal stabilization; test data processing - lapse characteristics for engine performance; measurement uncertainty - defined measurement process; and reporting - data comparison strategies. In addition, one lesson learned related to the management of major, round-robin programs.　　Author

N90-27719# Royal Aerospace Establishment, Farnborough (England). Dept. of Propulsion.
EXPERIENCE IN DEVELOPING AN IMPROVED ALTITUDE TEST CAPABILITY
A. R. OSBORN　In AGARD, Comparative Engine Performance Measurements 16 p (SEE N90-27711 22-07)　May 1990
(AGARD-LS-169)　Copyright　Avail: NTIS HC A13/MF A02;
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　　Each test site benefitted in different ways from participating in the Uniform Engine Test Program (UETP), not least from observing how other test sites approached the testing, through participating in the Working Group discussions on procedures and methods of analysis. A review of the lessons learned by the participants during the altitude testing of the UETP was carried out and a strategy proposed for an improved altitude test capability. Many of the good practices proposed for a better test capability are based on experience found to be successful at RAE, Pyestock, in the UK.
　　Author

N90-27720# National Research Council of Canada, Ottawa (Ontario). Engine Lab.
EXPERIENCE IN DEVELOPING AN IMPROVED GROUND-LEVEL TEST CAPABILITY
D. M. RUDNITSKI　In AGARD, Comparative Engine Performance Measurements 10 p (SEE N90-27711 22-07)　May 1990
(AGARD-LS-169)　Copyright　Avail: NTIS HC A13/MF A02;
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　　Enclosed ground-level cell engine testing requires a thorough understanding of engine and test cell aerodynamic interaction to ensure accurate and repeatable engine performance evaluation. The key elements of cell design have been identified and design considerations outlined. Some examples of practices employed at NRCC have been listed, a number of them directly reflecting experience gained from the Uniform Engine Test Program (UETP).　　Author

N90-27721# Sverdrup Technology, Inc., Arnold AFS, TN.
GENERAL TEST PLAN
ROBERT E. SMITH, JR.　In AGARD, Comparative Engine Performance Measurements 139 p (SEE N90-27711 22-07)　May 1990　Revised
(AGARD-LS-169)　Copyright　Avail: NTIS HC A13/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
　　The overall purpose of the AGARD-Uniform Engine Test Program (UETP) is to bring an understanding of turbine ground test data for participating AGARD countries to a common denominator, and to improve test techniques, instrumentation and test equipment for turbine engine testing. The improved understanding and methods are to be achieved through a comparative engine test program. Two J57P-19W nonafterburning turbojet engines are to be made available from the U.S. Air Force. The plug type nozzle of the J57 will be replaced with a cylindrical tailpipe and a reference convergent nozzle. The intent of replacing the exhaust nozzle is to simplify the installation of nozzle instrumentation and the calculation of nozzle performance. Certain fixed instrumentation will be provided to travel with the engine. This reference instrumentation will be used to set test conditions, monitor engine health and engine performance degradation. The basic objectives of the UETP is that each participant use those facility test procedures, instrumentation arrangements and analysis methods that are that are consistent with their normal practices to define three basic engine performance parameters: airflow rate net thrust, and specific fuel consumption. NASA Lewis Research Center will initiate the test program and be responsible for the initial program management. Two newly overhauled engines will be delivered to NASA Lewis Research Center for modification and checkout prior to the initiation of the UETP. The initial and final participant facility tests of the UETP will be conducted at NASA Lewis Research Center. Test data from the final retest at NASA Lewis Research Center will be used to assess engine performance degradation. The purpose of this document, the General Test Plan (GTP), is to specify participant common test hardware, instrumentation, data acquisition, data processing procedures and will serve both as a guideline for the preparation of the participants test plan and as a control document for the identification of the test engine and related test hardware.
　　Author

N90-28069# Rolls-Royce Ltd., Derby (England).
THE ROLE OF NDI IN THE CERTIFICATION OF TURBINE ENGINE COMPONENTS
R. G. TAYLOR, SHARON I. VUKELICH, and THOMAS D. COOPER (Wright Research Development Center, Wright-Patterson AFB, OH.)　In AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 5 p (SEE N90-28068 22-38)　May 1990
(AGARD-CP-462)　Copyright　Avail: NTIS HC A11/MF A02;
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　　During the past few years, the UK and USA have developed different approaches in the use of nondestructive inspection (NDI) in the certification and life estimation of aircraft gas turbine engine components. While both countries have utilized a fracture mechanics philosophy on critical rotating components, the use of NDI has been significantly different. The USA has developed NDI technology to be utilized in a quantitative role where the size of the defect that must be detected to meet the life estimate objectives can demonstrably be achieved to an agreed level of confidence. This approach was defined in the USA in a mil standard under the Engine Structural Integrity Program (ENSIP), and is now a mandatory requirement for all future USAF power plants. In the UK, the approach was to utilize NDI in a process monitoring role having first established, by intense NDI application together with process defect hazard reviews during the process development, that the process is under control. The historical reasons for the different approaches, the current status of these activities are highlighted, and finally, the future developments which may have the effect of minimizing the differences which exist, are addressed.　　Author

N90-28073# Air Force Systems Command, Wright-Patterson AFB, OH.
CRITICAL INSPECTION OF HIGH PERFORMANCE TURBINE ENGINE COMPONENTS: THE RFC CONCEPT
BRUCE A. RASMUSSEN, ERIC L. POHLENZ, JAMES D. HOEFFEL, and DENA G. WILLIAMS (Systems Research Labs., Inc., Dayton, OH.) In AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 7 p (SEE N90-28068 22-38) May 1990
(Contract F33615-81-C-5002)
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The U.S. Air Force has implemented a new maintenance philosophy, known as Retirement for Cause (RFC), to extend the usefulness of gas turbine engine disks and spacers beyond their original design life. Essential to the successful implementation of this philosophy was the development of a generic, totally-automated engine part inspection system that could reliably detect 5 mil flaws and determine a part's accept/reject status using critical flaw size criteria. Initial implementation of the RFC Inspection System on the Pratt and Whitney F100 engine has significantly reduced the U.S. Air Force engine spare parts inventory requirement and has resulted in a large savings in reprocurement costs. Author

N90-29393# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel Working Group 19.
RECOMMENDED PRACTICES FOR MEASUREMENT OF GAS PATH PRESSURES AND TEMPERATURES FOR PERFORMANCE ASSESSMENT OF AIRCRAFT TURBINE ENGINES AND COMPONENTS
H. I. H. SARAVANAMUTTOO 1990 162 p
(AGARD-AR-245; ISBN-92-835-0499-2; AD-A226378) Copyright Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The results of the Propulsion and Energetics Panel Working Group 19 are summarized. It is of interest to engineers concerned with steady state testing of aircraft turbine engines and their components, and provides information on gas path pressure and temperature measurement techniques and instrumentation. Manufacturers and research institutions throughout the world have developed their own practices for measurement techniques and instrumentation. These practices vary significantly, leading to confusion and misunderstanding between researchers, development organizations, contract agencies and customers. The trend towards multi-company and multi-national engine projects increases these difficulties. The goal is to recommend practices, the application of which will generate confidence through a common understanding, which will increase the quality of the data obtained. The recommended practices described address components and instrumentation, and the problems of interpreting the information obtained in terms of spatial and temporal resolution. Measurement uncertainties are discussed in detail. Author

N91-11022# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
TEST CASES FOR COMPUTATION OF INTERNAL FLOWS IN AERO ENGINE COMPONENTS
LEONHARD FOTTNER, ed. (Universitaet der Bundeswehr Muenchen, Neubiberg, Germany, F.R.) Jul. 1990 393 p
(AGARD-AR-275; ISBN-92-835-0573-5; AD-A227855) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An analytical and experimental database intended as support in the development of new and the refinement of existing codes for computing internal flows in aero engine components, specifically in cascades, compressors, turbines and ducts ahead of and between them is presented. All the analytical test cases described are relevant to steady, 2-dimensional, inviscid flow calculations. The experimental test cases are relevant to steady 2-dimensional, quasi- or fully 3-dimensional flow calculations for viscous flows in axial turbomachinery components. These data are believed to represent the highest quality analytical and experimental test cases available today. However, in appraising the large amount of experimental data submitted, the Working Group necessarily had to consider what the requirements for a satisfactory test case are

and what experimental precautions and problems have to be addressed and overcome. It also became apparent where gaps exist in the available test cases and what is required for the future. Author

N91-18080# British Aerospace Aircraft Group, Woodford (England). Airlines Div.
THE POWERPLANT OPTIONS FOR A FUTURE LARGE AIRCRAFT
D. G. SPENCER and R. S. CLOUGH In AGARD, Progress in Military Airlift 13 p (SEE N91-18067 10-03) Dec. 1990 Prepared in cooperation with Rolls-Royce Ltd., Derby, England
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Future large aircraft is a generic term used to describe a future medium sized tactical transport aircraft and derivatives for other roles. Its design will utilize modern technology to provide a replacement for airforces' mixed fleets of Hercules, Transall, and a multitude of other aircraft used in tanking, maritime patrol, and other such roles. Studies conducted so far have shown the powerplant to be the key technology for a new military transport aircraft. Relative to the Hercules and the Transall, large gains in capability, savings in cost, are available with modern powerplants. The influence of powerplant selection is so critical that it is likely to drive the mission capability that can be economically provided. The main design requirements are identified for this type of aircraft. The benefits of modern technology when applied to both airframe and engine in a military transport are discussed. Turboprop, turbofan, and propfan engines are compared, and the benefits and availability of civil engines reviewed. Finally, several different aircraft solutions are presented, covering the range of possible powerplants, and their characteristics compared. Author

N91-23147# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
HYPERSONIC COMBINED CYCLE PROPULSION
Dec. 1990 474 p In ENGLISH and FRENCH Symposium held in Madrid, Spain, 28 May - 1 Jun. 1990
(AGARD-CP-479; ISBN-92-835-0594-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The proceedings of the symposium are presented. The symposium was arranged in the following sessions: (1) Technical review of hypersonic propulsion/mission requirements; (2) Propulsion concepts; (3) Air intake flow; (4) Turbomachinery; (5) Combustion and ram/scramjets; (6) Nozzle flow; and (7) High temperature materials. The present status in the broad subject of contributing to hypersonic combined cycle propulsion is discussed. Considerable progress in design and analysis, using computational fluid dynamics techniques are reported. For individual titles, see N91-23148 through N91-23178.

N91-23148# Sener S.A., Madrid (Spain).
HYPERSONIC PROPULSION: PAST AND PRESENT
C. SANCHEZTARIFA In AGARD, Hypersonic Combined Cycle Propulsion 24 p (SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The change in the concept of hypersonic speed with time is briefly discussed. The evolution of the hypersonic propulsion is restricted to the history of the ramjets. Considering the abundance of literature on the subject, only the most remarkable achievements are reviewed. Less divulged historical events, such as the propulsion of helicopters by ramjets, are discussed in more detail, and special attention is given to the contributions of Spain to supersonic combustion. The present state of the hypersonic propulsion is examined. Some of the most demanding problems facing the propulsion system of the Aerospace Plane and the Hypersonic Cruise Aircraft are reviewed. Author

N91-23149# Office National d'Etudes et de Recherches Aerospatiales, Modane (France).
A STUDY OF SUPERSONIC AND HYPERSONIC RAMJET ENGINES IN FRANCE FROM 1950 TO 1974 (APPLICATION ON COMBINED CYCLE AIRCRAFT ENGINES) [L'ETUDE DU STATOREACTEUR SUPERSONIQUE ET HYPERSONIQUE EN FRANCE DE 1950 A 1974 (APPLICATION AUX MOTEURS COMBINES AEROBIES)]
ROGER MARGUET, PIERRE BERTON, and FRANCIS HIRSINGER *In* AGARD, Hypersonic Combined Cycle Propulsion 16 p (SEE N91-23147 15-07) Dec. 1990 In FRENCH
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France has the potential for theoretical and experimental research on the ramjet engine which would allow its operational programs such as ASMP (Air Surface Medium Range by nuclear stress). The direction of these studies evolved trends for the future, especially in the area of very high speed and the use of combined engines. This is due in large part to significant national action on the ramjet engine during the period of 1951 to 1972, during which a number of flight tests or ground tests has proven the concepts of the conventional ramjet engine and the combined turbo-ramjet, as well as the dual mode hypersonic ramjet, the latter comes from a subsonic combustion after supersonic. These fixed point tests, on a large scale, were done in the ONERA wind tunnel at Modane. At the request of the organizers of the symposium, the status, main work, and results are reviewed which was conducted during this period in France. An analysis is made of the data. It is hoped that it will lead to more research on the hypersonic propulsion ramjet engine. Transl. by E.R.

N91-23151# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.
TRAJECTORY OPTIMIZATION CONSIDERATIONS FOR RAMJET ENGINES
FRANS G. J. KREMER *In* AGARD, Hypersonic Combined Cycle Propulsion 12 p (SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20;
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For supersonic and hypersonic flight conditions with ramjets, trajectory calculations have to be coupled with the engine performances. In space transportation systems ramjet will be used in a relatively wide range of Mach numbers, and therefore not always near the optimum design point. Optimization of several physical parameters along the trajectory will be inevitable. Some of these parameters are discussed along with their importance for an ascent trajectory, having a minimum fuel requirement. Author

N91-23152# Societe Europeenne de Propulsion, Suresnes (France).
COMPARATIVE STUDY OF DIFFERENT SYSTEMS OF COMBINED CYCLE PROPULSION
PHILIPPE RAMETTE, DOMINIQUE SCHERRER, and MICHEL DOUBLIER (Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Suresnes, France) *In* AGARD, Hypersonic Combined Cycle Propulsion 11 p (SEE N91-23147 15-07) Dec. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20;
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Since 1986 the French Space Agency, CNES, is sponsoring some comparative studies of different concepts of combined cycle engines made jointly by SNECMA, SEP, and ONERA. SNECMA and SEP recently joined their efforts in combined cycle propulsion by creating a common Joint Venture named HYPERSPACE. The recent progress of comparative studies of different combined cycle engine systems is presented focusing on the following concepts: (1) the turborocket family including the turbo rocket-ramjet and the turbo expander-ramjet; (2) the turbojet family with the turbofan-ramjet and the turboramjet; (3) the rocket-ramjet; (4) the liquefied air rocket; (4) the cooled air rocket; and (5) the scramjet which is also presently in progress. The comparison of these concepts include their theoretical performance, some design considerations and an approximate evaluation of the technological difficulties with each concept. Author

N91-23153*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HYPERSONIC PROPULSION: STATUS AND CHALLENGE
R. WAYNE GUY *In* AGARD, Hypersonic Combined Cycle Propulsion 19 p (SEE N91-23147 15-07) Dec. 1990
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Scientists in the U.S. are again focusing on the challenge of hypersonic flight with the proposed National Aerospace Plane (NASP). This renewed interest has led to an expansion of research related to high speed airbreathing propulsion, in particular, the supersonic combustion ramjet, or scramjet. The history is briefly traced of scramjet research in the U.S., with emphasis on NASA sponsored efforts, from the Hypersonic Research Engine (HRE) to the current status of today's airframe integrated scramjets. The challenges of scramjet technology development from takeover to orbital speeds are outlined. Existing scramjet test facilities such as NASA Langley's Scramjet Test Complex as well as new high Mach number pulse facilities are discussed. The important partnership role of experimental methods and computational fluid dynamics is emphasized for the successful design of single stage to orbit vehicles. Author

N91-23154# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
AIRBREATHING PROPULSION FOR SPACE TRANSPORT: NEW CONCEPTS, SPECIAL PROBLEMS AND ATTEMPTS AT SOLUTIONS
H. KUENKLER *In* AGARD, Hypersonic Combined Cycle Propulsion 14 p (SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20;
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The design requirements of airbreathing propulsion for space transport application strongly depend on the particular mission demands and differ markedly from those of conventional airbreathing propulsion systems. Especially the low thrust densities and high thermal loads at high Mach numbers demands a systematic approach to design and selection of possible propulsion concepts. Main problems of propulsion system concepts and of their development as well as to present attempts for possible solutions are discussed. Author

N91-23155# Wright Research Development Center, Wright-Patterson AFB, OH. Turbine Engine Div.
TURBOJET POTENTIAL FOR HYPERSONIC FLIGHT
JEFFREY M. STRICKER and DOUGLAS J. ESSMAN *In* AGARD, Hypersonic Combined Cycle Propulsion 11 p (SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20;
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Over the past few years, interest in manned hypersonic flight has increased significantly. The disadvantages of a three mode propulsion system (turbojet/ramjet/scramjet) are the complexity, weight, and costs which accompany it. Inlet and exhaust geometry variations required for proper integration play a major role. The utilization is explored of the turbine engine for aircraft propulsion up to the scramjet transition. Examination of the uninstalled cycle performance is presented as well as an assessment of installed engine operation in a hydrogen fueled aircraft. Both non-afterburning and afterburning turbine engines are compared to turboramjet and air turboramjet (ATR) engines for a Mach 5 long duration cruise mission along with a pure acceleration mission, i.e., the turbomachinery is used to accelerate the vehicle to a Mach number where the scramjet can take over. From this assessment, a baseline engine configuration/cycle is defined for feasibility studies and critical technology identification. A discussion of the feasibility of the perferred concept from an engine component by component standpoint is provided as well as a discussion of technology risk compared to the state of the art. Author

N91-23156# Fiat Aviazione S.p.A., Turin (Italy).
AIRBREATHING PROPULSION FOR TRANSATMOSPHERIC FLIGHT
G. ANDREI, U. BORIO, and M. MAIURANO *In* AGARD, Hypersonic Combined Cycle Propulsion 11 p (SEE N91-23147 15-07) Dec. 1990
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The application of airbreathing propulsion systems to winged launchers is examined. The characteristics of ramjet based, LH2 fueled, powerplants are analyzed. The main ramjet design parameters are highlighted. Options (rockets, turboengines) for the boost phase from takeoff to ramjet mode transition are described, and their potential applicability to Single Stage to Orbit (SSTO) and Two Stage to Orbit (TSTO) launcher is discussed. Author

N91-23157# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
COMPACT HEAT EXCHANGER FOR AN INVERSE COMPONENTS ENGINE [ECHANGEUR COMPACT POUR MONTEUR A COMPOSANTS INVERSES (MCI)]
YVES RIBAUD *In* AGARD, Hypersonic Combined Cycle Propulsion 10 p (SEE N91-23147 15-07) Dec. 1990 In FRENCH; ENGLISH summary
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A presizing study on a counter current heat exchanger fitted for the inverse components engine (ICE) was performed first using analytical calculations and then with a calculation code. The first calculation results show that the heat exchanger integration on the engine axis seems to be possible without a too great penalty on weight and length. The future main research purpose will be directed towards the reduction of the turbine exhaust section. Author

N91-23158# Aerojet TechSystems Co., Sacramento, CA. Aeropropulsion.
DESIGN CONSIDERATIONS FOR COMBINED AIR BREATHING-ROCKET PROPULSION SYSTEMS
DAVID L. KORS *In* AGARD, Hypersonic Combined Cycle Propulsion 13 p (SEE N91-23147 15-07) Dec. 1990 Previously announced in IAA as A91-14442
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Combined air breathing rocket propulsion systems have been studied and carried through proof of principle demonstrations during the last three decades. Currently, a number of countries are studying and in some cases actually starting development of demonstrator vehicles for hypersonic flight which use combinations of air breathing and rocket propulsion. A summary of this activity including the propulsion options being studied is discussed. This type of propulsion is much more revolutionary in nature than most previous propulsion developments and thus results in technology challenges that are even more severe than those faced by either conventional air breathing propulsion or rocket designers. These include: (1) propulsion/vehicle integration; (2) engine stability over a wide operating range; (3) high performance over a wide operating range; (4) system level thermal management; and (5) advanced materials. A discussion of these technical issues including the impact of underachieved development goals on system level performance is also included. Author

N91-23159*# National Aeronautics and Space Administration, Washington, DC.
CRYOGENIC HYDROGEN-INDUCED AIR-LIQUEFACTION TECHNOLOGIES
WILLIAM J. D. ESCHER *In* AGARD, Hypersonic Combined Cycle Propulsion 13 p (SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 21/5

Extensive use of a special advanced airbreathing propulsion archives data base, as well as direct contacts with individuals who were active in the field in previous years, a technical assessment of cryogenic hydrogen induced air liquefaction, as a prospective onboard aerospace vehicle process, was performed and documented in 1986. The resulting assessment report is summarized. Technical findings relating the status of air liquefaction technology are presented both as a singular technical area, and also as that of a cluster of collateral technical areas including: Compact lightweight cryogenic heat exchangers; Heat exchanger atmospheric constituents fouling alleviation; Para/ortho hydrogen shift conversion catalysts; Hydrogen turbine expanders, cryogenic air compressors and liquid air pumps; Hydrogen recycling using slush hydrogen as heat sinks; Liquid hydrogen/liquid air rocket type combustion devices; Air Collection and Enrichment System (ACES); and Technically related engine concepts. Author

N91-23160# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
SUPERSONIC-HYPERSONIC INLET STUDIES FOR AEROSPACEPLANE
C. SANS, P. CHAMPIGNY, P. DUVEAU, and C. GINOVART *In* AGARD, Hypersonic Combined Cycle Propulsion 11 p (SEE N91-23147 15-07) Dec. 1990 In FRENCH; ENGLISH summary
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Recent improvements in technology have allowed the design of rockets to launch satellites. Reusable shuttles were then used to limit launch costs. A new stage is needed for horizontal takeoff and landing aerospace planes. These single or two stage vehicles will need new propulsion systems, able to provide enough thrust in the whole flight corridor. Mixed propulsion systems seem to be well adapted to this need. During atmospheric flight air breathing engines are necessary to improve performances. Thus inlets will have to be installed. The success of this project will depend on the choice of the inlets, for which mass flow ratios is a paramount objective. Pressure recovery seems to be of less importance at high Mach numbers because of structural stresses. Current design methods are examined which are based on: (1) semiempirical predictions, using experimental data bases, shock boundary layer interaction laws, shock and side overflow losses; (2) 2-D and 3-D Euler codes taking into account the internal bleed effects; and (3) Navier-Stokes codes for specific problems. Some examples of inlet design are presented for rocket ramrocket engines. Problems of inlet integration are presented. Author

N91-23163# Rolls-Royce Ltd., Bristol (England). Turbine Technology Dept.
DESIGN CONSIDERATIONS OF A HIGH EXPANSION RATIO HYDROGEN TURBINE
A. T. HOLMES and R. VARVILL *In* AGARD, Hypersonic Combined Cycle Propulsion 8 p(SEE N91-23147 15-07) Dec. 1990
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The high specific heat of hydrogen compared with air leads to turbine stages which have low pressure ratios for comparable levels of specific work. In high speed propulsion systems designed for reusable space launch vehicles, the choice of scantlings is influenced by the need to minimize weight consistent with the achievement of the required efficiency. The effect of unit increase of mass in a component is, typically, to increase the takeoff weight by approximately five units, and efficiencies significantly lower than those of normal aero-gas turbine practice are adopted. A multi-stage turbine design with overall pressure ratio of 7.6 and overall loading delta H/ u squared = 31.4 is described. A parametric study covering a range of mean diameters and number of stages was performed, in which the aim was to establish the trends of efficiency against weight. The final design has ten stages with a common hub diameter. Author

N91-23166# Johns Hopkins Univ., Laurel, MD. Applied Physics Lab.
DESIGN TECHNIQUES FOR DUAL MODE RAM-SCRAMJET COMBUSTORS
F. S. BILLIG, S. CORDA, and P. P. PANDOLFINI *In* AGARD, Hypersonic Combined Cycle Propulsion 20 p (SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A disciplined analytical method that describes the different engine operating modes and internal flow structures in dual mode ram-scramjet combustors is presented. Solutions for physical systems are dependent on empirical data bases from unit process experiments which include shock trains, jet penetration, and mixing. A synopsis of an experimental data base is presented and the method by which it is embodied in the analytical models is discussed. The models are then applied to develop design procedures for combustor-inlet isolators, discrete hole injectors, controlled shear layer mixing, and establishes the efficacy of sudden expansion steps for anchoring shock trains. Author

N91-23167# Rockwell International Corp., Canoga Park, CA. Rocketdyne Div.
USE OF SECONDARY FLOWS FOR RAPID MIXING IN SCRAMJET COMBUSTORS
G. V. R. RAO and A. A. HEIBA *In* AGARD, Hypersoic Combined Cycle Propulsion 7 p (SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

An efficient scramjet combustor requires rapid mixing of parallel supersonic streams of air and injected fuel. The velocity differential between the two streams may not be enough for spreading the mixing layer. To augment the mixing process, secondary flows can be generated by a skewed supersonic nozzle for the fuel. A conical ramp that shields the injector can provide large lateral gradients in the airflow. The Unified Solution Algorithm (USA) code developed by Rockwell International was used to compute inviscid flow fields over typical configurations. The results are presented. The interaction of the pressure and density gradients in the air and fuel streams at the injector exit appears to be the major source of rapid mixing of the stream. Author

N91-23168# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
PERFORMANCE CHARACTERISTICS OF HYPERSONIC DETONATION WAVE RAMJETS
T. M. ATAMANCHUK and J. P. SISLIAN *In* AGARD, Hypersonic Combined Cycle Propulsion 13 p (SEE N91-23147 15-07) Dec. 1990 Previously announced in IAA as A90-42188
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

One method of heat addition to a supersonic flow is by means of shock-induced combustion or in this particular study a detonation wave. In order to assess the performance potential of a propulsion utilizing such a mode of heat addition a first order inviscid computational scheme based on Godunov's method was developed. This computational method was chosen since it allows the tracking of flow-field discontinuities such as shocks and slipstreams, thus making it possible to generate a vehicle geometry operating at design conditions for given freestream conditions. This same code was also used to determine the flow-field generated by a given body geometry at off-design conditions. Pressures acting on these planar and axisymmetric bodies were calculated and used to determine various performance parameters over a range of Mach numbers. Two configurations consisting of multiple shock external and internal inlet compression, followed by an oblique Chapman-Jouguet detonation wave, were considered. Aerodynamic performance of planar multiple external shock inlet compression vehicles acting as lifting-propulsive bodies (integrated engine-airframe configurations) were also investigated. Off-design performance of these geometries was evaluated by varying the heat addition to the flow in order to obtain the desired thrust-to-dray ratio. For most body geometries operating at flight Mach numbers less than the design Mach number, it was found that no value of heat addition would maintain the design thrust-to-drag ratio.

However, for flight Mach numbers greater than the design Mach number it was found that there usually existed at least two values, and in some cases three, of heat addition which would give the design thrust-to-drag ratio. Author

N91-23169*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ANALYTICAL AND EXPERIMENTAL INVESTIGATIONS OF THE OBLIQUE DETONATION WAVE ENGINE CONCEPT
GENE P. MENEES, HENRY G. ADELMAN, and JEAN-LUC CAMBIER (Eloret Corp., Moffett Field, CA.) *In* AGARD, Hypersonic Combined Cycle Propulsion 15 p (SEE N91-23147 15-07) Dec. 1990
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Wave combustors, which include the oblique detonation wave engine (ODWE), are attractive propulsion concepts for hypersonic flight. These engines utilize oblique shock or detonation waves to rapidly mix, ignite, and combust the air-fuel mixture in thin zones in the combustion chamber. Benefits of these combustion systems include shorter and lighter engines which require less cooling and can provide thrust at higher Mach numbers than conventional scramjets. The wave combustor's ability to operate at lower combustor inlet pressures may allow the vehicle to operate at lower dynamic pressures which could lessen the heating loads on the airframe. The research program at NASA-Ames includes analytical studies of the ODWE combustor using Computational Fluid Dynamics (CFD) codes which fully couple finite rate chemistry with fluid dynamics. In addition, experimental proof-of-concept studies are being performed in an arc heated hypersonic wind tunnel. Several fuel injection design were studied analytically and experimentally. In-stream strut fuel injectors were chosen to provide good mixing with minimal stagnation pressure losses. Measurements of flow field properties behind the oblique wave are compared to analytical predictions. Author

N91-23170# Prins Maurits Lab. TNO, Rijswijk (Netherlands).
THEORETICAL AND EXPERIMENTAL PERFORMANCE OF A SOLID FUEL RAMJET COMBUSTION CYCLE FOR HYPERSONIC FLIGHT CONDITIONS
P. J. M. ELANDS, P. A. O. G. KORTING, R. G. VERAAR, and P. DIJKSTRA (Technische Univ., Delft, Netherlands) *In* AGARD, Hypersonic Combined Cycle Propulsion 11 p (SEE N91-23147 15-07) Dec. 1990
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A research program was performed to validate a numerical simulation of the flow and combustion process in the combustion chamber of a solid fuel ramjet with experimental results. Operating conditions were chosen to represent a sustained missile flight at Mach 4 at an altitude of 13 km. Experimental data were obtained by burning cylindrical fuel grains made of polyethylene and hydroxyl terminated polybutadiene in a solid fuel ramjet using a connected pipe facility. For numerical simulation a computer code was developed, describing rotational symmetric steady-state turbulent reacting flows through channels with and without a sudden expansion. Calculations were performed using polyethylene as a fuel. For the validation emphasis was laid on the regression rate. The results show that the computer code predicts the mean regression rate with reasonable accuracy. The value for the effective heat of gasification is found to be very important. The experiments and the calculations performed show the feasibility to apply a solid fuel ramjet for sustained hypersonic flight at these conditions. Author

N91-23172# Oxford Univ. (England). Dept. of Engineering Science.
PITOT SURVEYS OF TWO MODERATELY UNDER-EXPANDED JETS
T. M. CAIN and T. V. JONES *In* AGARD, Hypersonic Combined Cycle Propulsion 15 p (SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

In the free expansion of the exhaust gases of engines flying at altitudes suitable for air-breathing launchers, the turbulent shear

layers interact with the jet shock structure, posing a challenge for CFD. A series of experiments in this flow regime is performed to provide data suitable for code validation. Angular and axial Pitot surveys of heated, high pressure, nitrogen jets exhausted from a Mach 3 conical nozzle into a low pressure tank are presented. The results indicate that there is strong turbulent mixing throughout the flow field downstream of the first Mach disk in addition to a repetitive shock cell structure. Author

N91-23173# Rockwell International Corp., Canoga Park, CA. Rocketdyne Div.
THE EFFECT OF COMBUSTOR FLOW NONUNIFORMITY ON THE PERFORMANCE OF HYPERSONIC NOZZLES
P. GOEL, S. L. BARSON, and S. D. HALLORAN *In* AGARD, Hypersonic Combined Cycle Propulsion 18 p (SEE N91-23147 15-07) Dec. 1990
(Contract F33657-87-C-2214)
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A parametric, 3-D Euler, CFD study was performed on a hypersonic vehicle engine nozzle. The configuration analyzed, though generic, is representative of those being considered for current generation vehicles. A series of flow profiles ranging from completely uniform to highly distorted were developed and introduced at the inflow plane of the nozzle in an effort to understand the associated impact on nozzle performance. Nozzle performance is quantified for each case and a qualitative rationale for the performance impact is developed. Author

N91-23176# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
THE 2-D SUPERSONIC NOZZLE DESIGN
MICHAEL GOEING and JOERG HEYSE *In* AGARD, Hypersonic Combined Cycle Propulsion 10 p (SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A method based on the theory of characteristics is presented for two-dimensional, supersonic nozzle design. Individual nozzle configurations for different applications are obtained by combining the geometric attributes of the symmetric, single expansion ramp, and Prandtl-Meyer type expansion nozzles. Corresponding to the design criteria, such as minimum length and optimum thrust efficiency, relations between desired properties of the flow field and nozzle geometry parameters are found, and a family of length-optimized, two-dimensional, supersonic nozzles is defined. The method can be applied for the design of wind tunnel and steam turbine nozzles as well as for thrust nozzle design of high Mach number aircraft. Author

N91-23177# Air Force Materials Lab., Wright-Patterson AFB, OH. Materials Technology.
MATERIALS FOR HYPERSONIC ENGINES
TERENCE M. F. RONALD *In* AGARD, Hypersonic Combined Cycle Propulsion 4 p(SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The structural materials development program for the National AeroSpace Plane (NASP) is described. It indicates the materials studied, the approaches followed, and the general properties being developed. The major materials include titanium-aluminides, titanium-aluminide metal matrix composites, carbon-carbon composites, ceramic-matrix composites, beryllium alloys, and copper-matrix composites. Author

N91-23178# Societe Europeenne de Propulsion, Saint-Medard-en-Jalles (France).
MATERIALS AND MATERIAL SYSTEMS FOR COMBINED CYCLE ENGINES [MATERIAUX ET SYSTEMES DE MATERIAUX POUR LA PROPULSION COMBINEE]
D. BOURY, A. BEAURAIN, A. LASALMONIE, and Y. HONNORAT (Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex, France) *In* AGARD, Hypersonic Combined Cycle Propulsion 18 p (SEE N91-23147 15-07) Dec. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The different categories of materials which can be considered for the engineering and production of the future hypersonic combined cycle engines are reviewed. The large size of the parts associated with the non-current conditions of temperature and environment makes new problems, the solution of which require programs of very large extent. The non-metallic reinforced materials have a potential place as large as that of the metallic materials on these developments. The assembly of such dissimilar parts goes through specific solution of mechanical assembly and the solving of a great deal of tribological problems. Author

N91-31144# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
LOW TEMPERATURE ENVIRONMENT OPERATIONS OF TURBOENGINES (DESIGN AND USER'S PROBLEMS)
1990 373 p Partly in FRENCH and ENGLISH Presented at the Propulsion and Energetics Panel 76th Symposium, Brussels, Belgium, 8-12 Oct. 1990
(AGARD-CP-480; ISBN92-835-0618-9; AD-A239844) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The papers presented at the Propulsion and Energetic Panel 76th Symposium and the discussions represent a significant contribution to improved cold weather tolerant and anti-icing design and to safer aircraft operation in a low temperature environment. The following subject areas are covered: cold weather operational experience and requirements, system design considerations, fuel effects and lubricants behavior, and icing condition and testing. For individual titles, see N91-31145 through N91-31173.

N91-31145# Army Air Corps, Stockbridge (England). School of Aeronautical Engineering.
LOW TEMPERATURE ENVIRONMENT OPERATION OF TURBO ENGINES: A MILITARY OPERATOR'S EXPERIENCE AND REQUIREMENTS
M. SUMMERTON *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 3 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The United Kingdom's commitment to NATO includes the regular use of Royal Marine and Army helicopters in low temperature conditions. The operation of the Westland LYNX helicopter is addressed with its Rolls Royce GEM engines during winter deployments in Norway where the near-arctic conditions present certain operating and working difficulties. These difficulties are considered both generally, from a human and physical point of view, and then more specifically with regard to the engines themselves. Finally, a few areas for improvements are discussed, with the emphasis on reliability, ease of maintenance, and effective development and testing before entry into service. Author

N91-31146# Canadian Forces Base Cold Lake, Medley (Alberta). Base Aircraft Maintanence Engineering Or,:anization.
LOW TEMPERATURE ENVIRONMENT OPERATIONS OF TURBO ENGINES
CHRISTIAN OUELLETTE *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 3 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The following subject areas are covered: (1) the climate conditions in Canada; (2) a summary of the Operational and Maintenance community of the Canada Armed Forces operational role and commitments: (3) maintenance problems and practices associated with the cold weather environment; (4) the 'Hung Start' problem associated with CF-18. GE-F404 engines; and (5) the status of the infamous J-85-CAN-15 compressor stall problem.
Author

N91-31147# Flugplatz Butzweilerhof, Cologne (Germany, F.R.).
ANALYSIS OF STARTING PROBLEMS IN COLD WEATHER WITH ASTAZOU TYPE TURBINE ENGINES IN HELICOPTERS [ANALYSE DES PROBLEMES DE DEMARRAGE PAR TEMPS FROID AVEC LES TURBOMOTEURS D'HELISOPTERE DE TYPE ASTAZOU]
W. PIETERS *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 6 p (SEE N91-31144 23-07) 1990 In FRENCH; ENGLISH summary
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
During the heavy winter periods in the beginning of the 80th, the Belgian army had considerable starting problems on its helicopters ALOUETTE equipped with ASTAZOU turbo engines. The different detection methods of the phenomena employed by the users, the immediate actions undertaken by the army, and the solutions worked out in collaboration with the constructors as well as their budgetary consequences are discussed. Author

N91-31148# Fokker B.V., Schipol-Oost (Netherlands). Environmental Control and Ice Protection Systems.
VULNERABILITY OF A SMALL POWERPLANT TO WET SNOW CONDITIONS
R. MEIJN *In* AGARD, Low Temperature Environment Operations of Turboengines (Design ano User's Problems) 6 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Several temporary flame-out incidents were experienced in descent through light icing conditions and precipitation during regular scheduled flights. Extensive ground testing of the engine indicated less tolerance to ice ingestion than was demonstrated in engine certification tests. Powerplant ice protection was enhanced by additional anti-icing of the engine flexible seal by bleed air. Factors are discussed influencing unexpected ice formation and associated uncertainties in the qualification process of a small turboprop powerplant. Author

N91-31149# Boeing Canada, Toronto (Ontario).
ICE TOLERANT ENGINE INLET SCREENS FOR CH113/113A SEARCH AND RESCUE HELICOPTERS
P. B. JONES and W. A. LUCIER *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 11 p (SEE N91-31144 23-07) 1990 Sponsored in part by National Research Council of Canada
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The Canadian Forces CH113/113a Search and Rescue Helicopters occasionally encounter unavoidable icing conditions in their operating environment, The original engine inlet safeguards were not designed form nor capable of sustained operations in icing environments, necessitating removal of the inlet screens in these conditions. This arrangement resulted in unacceptable risk of foreign object damage to the engine, and compromised operational safety. Ice tolerant inlet screens were developed as a remedy for this problem. The flat faced, inverted cone screens

with a bypass opening accommodate progressive ice congestion during the various operational modes with minimum engine performance degradation. Author

N91-31150# Sundstrand Turbomach, San Diego, CA.
COLD STARTING SMALL GAS TURBINES: AN OVERVIEW
C. RODGERS *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 22 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The requirements to operate aircraft gas turbines over a large range of environmental conditions prove particularly demanding to the systems designer, especially when rapid starting of a cold engine is stipulated at sub-zero ambient temperature. As a consequence the occurrence of cold climatic extremes are discussed and a trend is observed toward designing aircraft for specific areas and deployment, rather than worldwide usage. Cold engine cranking torque characteristics are basically controlled by the lubricant viscous drag in the mechanical drive train and accessories. This viscous drag is dependent upon the magnitude of the applied start torque. Experience with start system for small gas turbine Auxiliary Power Units (APU's) showed that the total weight required for successful starting at -54 C can approach the weight of the APU powerhead itself. As a consequence, most cold start requirements are relaxed to -40 C or higher. Methods for reducing APU viscous drag and start energy requirements that deserve future study are the all electric gearbox-less APU, and the possibility of a self-start combustor concept. Author

N91-31151# Hans-Sachs-Str., Groebenzell (Germany, F.R.).
COLD START OPTIMIZATION ON A MILITARY JET ENGINE
H. GRUBER *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 5 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Cold-starting testing at temperatures of approximately -40 C was performed on 2 RB 199 engines at a West Germany altitude test facility. The engines were of the same build standard with exception of the seal configuration (labyrinth or brush), and running times. One part of the test was performed with F34 fuel, the other with F40. The facilities, test methods, and test results are presented. Author

N91-31152# Pratt and Whitney Aircraft of Canada Ltd., Mississauga (Ontario).
COLD WEATHER IGNITION CHARACTERISTICS OF ADVANCED SMALL GAS TURBINE COMBUSTION SYSTEMS
I. CRITCHLEY, P. SAMPATH, and F. SHUM *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 7 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Low temperature and high altitude starting requirements of present day small aero-gas turbine engines are discussed from the viewpoint of their influence on the design of the combustors and ignition systems. Use of electric starters, common in small engines, creates particular challenges to starting especially under cold soak sea level and altitude startup conditions. The main factors in combustion system design affecting starting performance are discussed, including combustor sizing, fuel placement, fuel atomization, fuel scheduling, and igniter selection. Low emission requirements may adversely affect starting performance, necessitating use of elaborate fuel/ignition systems, some recent developments are described. Author

N91-31153# General Electric Co., Peebles, OH.
COLD WEATHER JET ENGINE STARTING STRATEGIES MADE POSSIBLE BY ENGINE DIGITAL CONTROL SYSTEMS
R. C. WIBBELSMAN *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 14 p (SEE N91-31144 23-07) 1990
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The advent of the computing power of digital controls now makes it possible to achieve a major step forward in the controls systems ability to cope with the multiplicity of situations confronting the engine starting system designer. One of strategies that could be employed is presented, used by the GE and CFMI Commercial Family of large high bypass ratio turbofan engines. Numerous variations of this basic concept could be employed. Author

N91-31154# KHD Luftfahrttechnik G.m.b.H., Oberursel (Germany, F.R.). Thermodynamics and Performance Dept.
COLD START INVESTIGATION OF AN APU WITH ANNULAR COMBUSTOR AND FUEL VAPORIZERS
K. H. COLLIN *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 18 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The combustor of the APU (Auxiliary Power Unit) for the Tornado fighter aircraft is described. As this APU has to cope with the narrow space in the fuselage it must be of a small size. An annular combustor is favorable as it is short and can be integrated into the envelope of the outer diameter. The fuel vaporizing system is chosen because of its great advantages with combustion. The ignition process is described which is difficult because no fuel is actually vaporized when the start is initiated. Theoretical background and experimental steps of a development program are reported. The result was perfect starting of this system down to -40 C and a very high 'First Start Reliability' which means no false start leading to several start procedures. Author

N91-31155# Pratt and Whitney Aircraft, West Palm Beach, FL.
CONTROL SYSTEM DESIGN CONSIDERATIONS FOR STARTING TURBO-ENGINES DURING COLD WEATHER OPERATION
ROBERT R. POLLAK *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 10 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Starting turbo-engines at climatic extremes has always presented challenges to the systems engineer. The wide range of both ambient and engine internal temperatures experienced by many influential variables increase the complexity of the startup process both on the ground and in the air. The content of this paper provides the current status of advanced control methods designed specifically to address combustor ignition and quick, stall-free acceleration to idle. Sensitivity of combustor ignition limits to cold conditions as well as fuel types was accommodated by both the combustor fuel delivery system and control system design. Specific attention is also given to starting at cold altitude conditions with extremely hot as well as extremely cold internal engine temperatures. Successfully meeting these requirements was accomplished by designing the control system to automatically monitor external influential variables as well as engine internal parameters both prior to and during the actual startup cycle and using these data to continuously adjust fuel scheduling to obtain optimum startup characteristics. Author

N91-31156# Pratt and Whitney Aircraft of Canada Ltd., Mississauga (Ontario).
COLD START DEVELOPMENT OF MODERN SMALL GAS TURBINE ENGINES AT PRATT AND WHITNEY AIRCRAFT OF CANADA LTD.
D. S. BREITMAN and F. K. YEUNG *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 7 p (SEE N91-31144 23-07) 1990
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Engine cold start capability is essential for aircraft in Arctic or winter operations. Demonstration of this capability is part of the engine development and certification requirements. Variables such as the combustor design, the diffuser exit flow characteristics, and the compressor performance at sub-idle conditions all affect the cold start capability of an engine. How these factors are usually optimized is briefly described, and an overview of the successful PW305 Engine cold start development (with an electric starter) is presented. The PW305 is a new turbofan engine from Pratt & Whitney of Canada in the 5000 lb thrust range. Author

N91-31157# Wehrtechnische Dienststelle fuer Luftfahrzeuge, Manching (Germany, F.R.).
DESIGN CONSIDERATIONS BASED UPON LOW TEMPERATURE STARTING TESTS ON MILITARY AIRCRAFT TURBO ENGINES
H.-F. FEIG *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 16 p (SEE N91-31144 23-07) 1990
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Test experience on engine low temperature starting was obtained in the course of multinational and national trials to assess weapon system performance. The objective of the trials was to recommend a clearance for the weapon system. In order to carry out these tests adequately, the operational role of the weapon system had to be considered and the operational limits of the engines and associated systems had to be known. Parameters influencing low temperature start capabilities were reviewed and experience gained from the tests was discussed. Author

N91-31158# Canadian Forces Headquarters, Ottawa (Ontario).
CLIMATIC CONSIDERATIONS IN THE LIFE CYCLE MANAGEMENT OF THE CF-18 ENGINE
R. W. CUE and D. E. MUIR (GasTOPS Ltd., Ottawa, Ontario) *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 15 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Canadian Forces have developed an Engine Parts Life Tracking System (EPLTS) to define the scheduled maintenance requirement of CF-18 aircraft engine components. Up to 64 components are tracked by this system, 26 of which are life limited on the basis of 8 different Life Usage Indices defined by the engine manufacturer and evaluated during each operational mission by the aircraft's Inflight Engine Condition Monitoring System. Data on the rates of component life consumption collected by the EPLTS during a full 12 month time span were analyzed. The manner and extent to which seasonal effects might influence these life consumption rates and hence the life cycle management of the engine are presented and discussed. Author

N91-31159# Rolls-Royce Ltd., Leavesden (England).
APPLICATION OF A WATER DROPLET TRAJECTORY PREDICTION CODE TO THE DESIGN OF INLET PARTICLE SEPARATOR ANTI-ICING SYSTEMS
D. L. MANN and S. C. TAN (Cranfield Inst. of Tech., Bedford, England) In AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 11 p (SEE N91-31144 23-07) 1990 Sponsored in part by Ministry of Defence
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Over the past five years, a dust particle trajectory code has been developed. Recent work on the code to include an ice accretion prediction model suitable for use as a design aid for a wide variety of gas turbine engine inlets, but particularly for particle separator geometries is described. The calculation of the local heat transfer coefficient is seen to be critical to the success of the ice accretion prediction. The incorporation of a suitable model is described, and a series of validation tests, carried out on a full scale rig, were shown to satisfactorily verify the code. A second series of validation experiments, carried out in an icing facility, further shows the prediction model to be appropriate.　Author

N91-31160# General Motors Corp., Indianapolis, IN. Gas Turbine Div.
DEVELOPMENT OF AN ANTI-ICING SYSTEM FOR THE T800-LHT-800 TURBOSHAFT ENGINE
GARY V. BIANCHINI In AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 13 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The T900-LHT-800 is a modern technology 1200 hp (900 kW) class turboshaft engine developed for the U.S. Army's LH helicopter and various civil applications. One of its significant features is an integral inlet particle separator (IPS). The presence of an IPS significantly complicates development of an anti-icing system for protection against the hazards associated with ice formation during operation in environmental icing conditions. The T800 engine is described, and the anti-icing system requirements, design evolution, and validation testing are discussed. The final anti-icing system configuration resulting from the development effort is presented.
　Author

N91-31161# Rolls-Royce Ltd., Derby (England).
ENGINE ICING CRITICALITY ASSESSMENT
E. BROOK In AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 6 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Assessment of an engine design for icing risk is important at both the design stage and for development and certification testing. Icing must be included within aerodynamic and noise constraints during the design phase to minimize the risk of design change during development, and the compromise tested must be tested at the extremes of the atmospheric icing, and aircraft and engine operating envelopes most appropriate to the particular components. The type of assessment necessary is addressed and illustrated mainly by reference to high bypass ratio turbofans. The approach to identifying critical conditions is presented and areas where research can provide basic data for the development of design methods are discussed.　Author

N91-31162# General Electric Co., West Lynn, MA. Aircraft Engines Div.
ICE INGESTION EXPERIENCE ON A SMALL TURBOPROP ENGINE
L. W. BLAIR, R. L. MILLER, and D. J. TAPPARO In AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 9 p (SEE N91-31144 23-07) 1990 (AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests availal only from AGARD/Scientific Publications Execu e
Modern high technology turbine a craft engines often employ high rotor speed compressors with th dvanced blading designs to achieve better performance. The engine designer is faced with a tradeoff between optimum compressor performance and on-wing durability. During the engine/aircraft development stage, certain assumptions are made regarding the icing environment and the testing required to confirm compatibility with it. Often, the true impact of the design trade-off is not realized until the engine is exposed to its service environment. Despite successful engine test cell and aircraft natural icing certification tests, in 1984 General Electric Aircraft Engines Company began to experience an unacceptable level of foreign object damage (FOD) caused by ingested ice with its CT7-5/-7 family of turboprop engines.The purpose of this paper is to: (1) address the issue of Stage one compressor rotor blade ice FOD in the CT7 engine; (2) explain the methods and techniques used in assessing the icing environment; (3) explain the lessons learned from test and analysis; and (4) define the final resolution of the compressor maintenance problem which simultaneously created accelerated performance deterioration for the engine. The first part of this paper deals with the airframe icing environment and its impact on the engine inlet system. The second part concentrates on the design improvement and durability testing of the Stage one compressor blade.
　Author

N91-31163# Ministry of Defence, London (England).
FUELS AND OILS AS FACTORS IN THE OPERATION OF AERO GAS TURBINE ENGINES AT LOW TEMPERATURES
G. L. BATCHELOR In AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 7 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Two factors strongly influence the low temperature behavior of aero gas turbine fuels and oils: viscosity and state or phase change - i.e. whether the material is liquid or solid. In fact, the question is whether solids are, or are not, present because, although the whole may cease to flow at some designated temperature, the lighter components of hydrocarbon and other organic mixtures are likely to be liquids under all natural circumstances. Terms such as freezing point, pour point, and the like, will be familiar enough; the chemical and physical realities underlying such parameters are examined. and their impact on aero gas turbine engine performance is considered. For the purposes of this paper, fuels and oils will be treated quite separately.　Author

N91-31164# Southwest Research Inst., San Antonio, TX.
THE EFFECT OF FUEL PROPERTIES AND ATOMIZATION ON LOW TEMPERATURE IGNITION IN GAS TURBINE COMBUSTORS
D. W. NAEGELI, L. G. DODGE, and C. A. MOSES In AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 10 p (SEE N91-31144 23-07) 1990 Sponsored in part by Naval Air Propulsion Center
(Contract DAAK70-85-C-0007; DAAK70-87-C-0043)
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Experiments were conducted in a T63 engine combustor to gain a better understanding of the role played by volatility and atomization in low temperature ignition. Eight test fuels were used, some of which were specially blended to vary either viscosity or volatility while holding the other constant. Six atomizers were used to vary the fuel spray characteristics, and average drop sizes, represented by Sauter mean diameter (SMD), were measured. Air temperatures were varied from 235 to 310 K. Ignition comparisons were made by the minimum fuel-air ratios necessary to achieve

ignition. Significant results included: (1) viscosity, which determined atomization characteristics, was more important than volatility in the ignition process; (2) ignition depended more on achieving a critical drop size than on reaching the lean-limit fuel-air ratio; and (3) fuel temperature was found to be more important than air temperature for low-temperature ignition, an effect due principally to viscosity and atomization rather than evaporization. A practical implication is that fuel heating would give a much greater improvement in cold-start performance than heating the combustor inlet air. Author

N91-31165# Royal Military Coll. of Canada, Kingston (Ontario). Dept. of Mechanical Engineering.
THE INFLUENCE OF FUEL CHARACTERISTICS ON HETEROGENEOUS FLAME PROPAGATION
M. F. BARDON, J. E. D. GAUTHIER, and V. K. RAO *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 9 p (SEE N91-31144 23-07) 1990 (AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A theoretical study of flame propagation through mixtures of fuel vapor, droplets, and air under conditions representative of cold starting in gas turbines is discussed. Two previously developed models are described: one for heterogeneous flame propagation and the other for describing the complex evaporative behavior of real fuel blends. Both models were validated against experimental data. The combined model incorporates the effects of pressure, temperature, droplet diameter, turbulence intensity, delivered equivalence ratio, fuel prevaporization, and fuel type on flame propagation. Differences in the combustion performance of Jet A1, JP-4, and two single component reference fuels are compared. Conclusions are drawn regarding the use of pure compounds to represent real fuel blends, and the relative importance of various engine conditions and spray parameters on combustion. Author

N91-31166# Naval Air Propulsion Test Center, Trenton, NJ.
THE DEVELOPMENT OF A COMPUTATIONAL MODEL TO PREDICT LOW TEMPERATURE FUEL FLOW PHENOMENA
R. A. KAMIN, C. J. NOWACK, and B. A. OLMSTEAD (Boeing Military Airplane Development, Seattle, WA.) *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 13 p (SEE N91-31144 23-07) 1990 Sponsored by ONR
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Fuel availability studies indicated that the relaxation of the F-44 freeze point specification could greatly increase the yield of F-44 per barrel of crude. A thorough analysis was initiated to insure that the higher freeze point fuel would not form solid wax precipitates during low temperature operations that could impact aircraft mission performance. In order to evaluate the effects of a potential change in the freeze point specification over the entire inventory of United States naval aircraft, a general three dimensional computational fluid dynamics code, PHOENICS 84, was modified for use. Inputs into the code include tank geometry, mission profile, and fuel properties. Outputs from the model include fuel cooldown and holdup, as a function of time in the tank. The accuracy of the code was verified by experimental data obtained during flight and simulator testing of instrumented tanks. Author

N91-31167# Naval Air Propulsion Test Center, Trenton, NJ.
ENVIRONMENTAL ICING TESTING AT THE NAVAL AIR PROPULSION CENTER
WILLIAM H. REARDON and VITO J. TRUGLIO *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 18 p (SEE N91-31144 23-07) 1990 (AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A comprehensive Environmental Icing Simulation System developed by the Naval Air Propulsion Center (NAPC) is discussed. The system accommodates the testing of ducted and free stream mounted engines and free stream mounted engine inlets. The Navy specification icing test procedures, success criteria and rationale for the requirements are discussed. Also discussed are

the capabilities of the NAPC icing facilities in terms of critical icing cloud parameters such as liquid water content, mean effective droplet diameter, humidity and inlet air temperature. How the icing environment is established, calibrated prior to testing, and verified during testing are covered. NAPC test experience in the Navy qualification programs for the T406, T700, and F404, as well as demonstration and development test programs performed with the TOMAHAWK Cruise Missile inlet and the F-14A aircraft inlet duct are discussed. Author

N91-31168# Rolls-Royce Ltd., Derby (England).
ICING RESEARCH RELATED TO ENGINE ICING CHARACTERISTICS
S. J. RILEY *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 12 p (SEE N91-31144 23-07) 1990 (AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Physical properties and characteristics of ice formed by accretion were investigated experimentially to provide a database relevant to civil turbofan engine and powerplant surfaces. Part of that work, relating to unheated surfaces, including observations of ice accretion on various bodies over a range of conditions, and measurement of the adhesive strength of ice samples is discussed. Author

N91-31169# Centre d'Essais de Propulseurs, Orsay (France).
NUMERICAL MODEL OF EVOLUTION IN SUPERCOOLED CLOUD OF WATER DROPLETS IN A CASE OF ICING [MODELISATION NUMERIQUE DE L'EVOLUTION D'UN NUAGE DE GOUTTELETTES D'EAU EN SURFUSION DANS UN CAISSON GIVRANT]
PAUL CREISMEAS and JOEL COURQUET (Office National d'Etudes et de Recherches Aerospatiales, Toulouse, France) *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 10 p (SEE N91-31144 23-07) 1990 In FRENCH; ENGLISH summary (AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A computational tool, called M.A.GI.C., developed as a tool for icing tests is discussed. In order to compare numerical results from M.A.GI.C. to physical measurements, an analysis based on granulometry measurement of droplets inside a wind tunnel was performed. The results of the comparison were acceptable. Author

N91-31170# Sverdrup Technology, Inc., Arnold AFS, TN.
ICING TEST CAPABILITIES FOR AIRCRAFT PROPULSION SYSTEMS AT THE ARNOLD ENGINEERING DEVELOPMENT CENTER
C. SCOTT BARTLETT, J. RICHARD MOORE, NORMAN S. WEINBERG, and TED O. GARRETSON (Arnold Engineering Development Center, Arnold Air Force Station, TN.) *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 9 p (SEE N91-31144 23-07) 1990 (AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Icing test capabilities for the full scale turbine engine propulsion systems at the Engine Test Facility (ETF) at the Arnold Engineering Development Center (AEDC) are discussed. The methods and hardware used to inject liquid spray into a cold airstream to simulate in-flight icing conditions are discussed. The spray manifold systems and spray injection nozzles currently in use at AEDC are described. Test experiences in both direct and free-jet connect icing tests are addressed. Recent ice accretion scaling techniques and test results, and developments and observations in cloud liquid water content and droplet sizing are briefly discussed. Uses of real time ice accretion detectors for facility calibration and test article ice accretion rate monitoring are addressed. Author

N91-31171# Aero and Industrial Technology Ltd., Burnley (England). Combustion Technology Centre.
ICING TEST PROGRAMMES AND TECHNIQUES
E. CARR and D. WOODHOUSE *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 8 p (SEE N91-31114 23-07) 1990
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Described here are the capabilities of an altitude test facility with a main chamber 4m diameter by 12 m long and capable of providing air flows up to 5kg/s and simulating altitudes up to 15 km. The experience obtained on icing programs since the plant was commissioned in 1953 is described. Examples of the procedures used to establish the susceptibility of equipment to icing are given. The examples cover the use of scale models, the evaluation of probes, and the testing of complete helicopter engine intakes. Author

08

AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

N89-10048# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
GUIDANCE AND CONTROL SYSTEMS SIMULATION AND VALIDATION TECHNIQUES
WILLIAM P. ALBRITTON, JR., ed. (Amtec, Inc., Athens, Ala.) Jul. 1988 133 p In ENGLISH and FRENCH
(AGARD-AG-273; ISBN-92-835-0472-0; AD-A202493) Copyright Avail: NTIS HC A07/MF A01

This AGARDograph addresses simulation and validation techniques for guidance and control systems of tactical guided weapons. Many developments have taken place over the last few years. In particular, physical simulation using hybrid, hardware-in-the-loop techniques has assumed much more importance. The chapter on digital simulation techniques provides descriptions of digital simulation techniques for application to some of the more difficult aspects of tactical guided weapon guidance and control systems. Concerning hardware-in-the-loop (HITL) simulation techniques, descriptions are provided of facility design techniques for performing HITL simulation and particular information on radar simulation techniques. System Simulation and Validation Experience presenting lessons learned type information from some of the major programs are examined. The application of the techniques to guided weapon developments is presented. For individual titles, see N89-10049 through N89-10057.

N89-10053# Boeing Aerospace Co., Seattle, WA.
COST EFFECTIVE SIMULATION FOR MILLIMETER WAVE GUIDANCE SYSTEMS
VANCE H. MAPLES and GEORGE A. EASTMAN *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 7 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Copyright Avail: NTIS HC A07/MF A01

The introduction of millimeter wave (MMw) active-passive, air-to-surface missile seeker systems to counter the European armor threat has increased the need for simulators to evaluate the performance of this class of seeker. Existing simulation techniques have not proved to be cost effective, and are generally unable to obtain sufficient target spatial position control at millimeter wave frequencies to ensure high fidelity simulations. The conventional approach to simulating a target for seeker testing is to build a transponder which receives the transmitted signal to the seeker, delays it to represent range, modulates it to simulate the intended target signal, and retransmits it through an antenna array which positions the target spatially. Target modeling and position control are implemented using simulation components at the radar frequency. A concept for target simulation for FM/WC modulated radar sensors, uses the signal from the seeker transmitted to illuminate an array of target antennas. This radar

scene simulation technique provides a lower cost simulation method for evaluating FM/WC modulated millimeter wave seekers. This technique is equally effective for pulse modulated seeker simulation when a millimeter wave illuminating source is added to the system. In either case, it significantly reduces the high-cost/-marginal-performance millimeter wave hardware required in the simulator and can be applied to evaluation of both active and passive seeker modes. Author

N89-10055# Raytheon Co., Bedford, MA.
SIMULATION VALIDATION EXPERIENCE: PATRIOT GUIDANCE SYSTEM
WILLIAM C. MORTON *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 11 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Copyright Avail: NTIS HC A07/MF A01

The increased use of sophisticated simulations as performance prediction tools during the development of guided missiles has placed greater emphasis on comprehensive validation of the models used. Validation of several simulations was accomplished by Raytheon Company while developing the Army's PATRIOT air defense system. The validation experience is presented for two large-scale guidance simulations; the Hybrid Guidance System Simulation and the Guidance Test and Simulation Facility. Examples of the data collected are presented in the course of discussing the approach to validating all mathematical as well as hardware-in-the-loop simulations. Conclusions are drawn as to the most effective methods and the value of the validation process to the overall system development. Author

N89-21805# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
GUIDANCE AND CONTROL OF PRECISION GUIDED WEAPONS
RONALD S. VAUGHN (Department of the Navy, Washington, DC.) May 1988 16 p Presented at the 46th Symposium, Geilo, Norway, 3-6 May 1988
(AGARD-AR-259; CP-435; CP-435(S); ISBN-92-835-0494-1; AD-A206393) Copyright Avail: NTIS HC A03/MF A01

The Guidance and Control Panel's compilation of papers was published as Conference Proceedings CP-435 and CP-435(S). The papers were presented under the following headings: Operational requirements and considerations; Guidance sensors and components; Guidance and control techniques and signal processing; Effectiveness and system evaluation; Systems demonstration. Author

N90-10050# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
STABILITY AND CONTROL OF TACTICAL MISSILE SYSTEMS
Mar. 1989 332 p In ENGLISH and FRENCH Symposium held in Ankara, Turkey, 9-12 May 1988
(AGARD-CP-451; ISBN-92-835-0494-1; AD-A218094) Copyright Avail: NTIS HC A15/MF A02

With recent advances in missile seekers and processors, and in the analysis of missile dynamics motions and the associated control subsystem designs, missile maneuver envelopes have significantly expanded. It was therefore appropriate and timely that the stability and controllability of such missiles be examined, and the different techniques currently involved in dealing with the various aspects of this subject. A wide selection of topics are covered: from prediction, simulation and test, through to a look at current development experience. The subject was deliberately limited to tactical missiles, encompassing air-to-air, air-to-ground, and ground-to-air, but not ballistic missiles. For individual titles, see N90-10051 through N90-10073.

N90-10052# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PREDICTION OF THE AERODYNAMIC STABILITY OF MISSILES [PREVISION DE LA STABILITE AERODYNAMIQUE DES MISSILES]
P. CHAMPIGNY *In* AGARD, Stability and Control of Tactical Missile Systems 13 p (SEE N90-10050 01-08) Mar. 1989 In FRENCH; ENGLISH summary
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02

The development of new surface to air and air to air missiles with improved maneuverability in terms of load factor or time lag requires a better prediction of the aerodynamic coefficients, mainly those related to the static stability. Within this context, examples are presented of stability predictions based on several theoretical methods. Also underlined are the experimental problems for the evaluation of the static stability from wind-tunnel tests. Author

N90-10053# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
PREDICTION OF STABILITY DERIVATIVES FOR MISSILES USING THE HISSS PANEL CODE
L. FORNASIER and P. DESPINEY (Office National d'Etudes et de Recherches Aerospatiales, Paris, France) *In* AGARD, Stability and Control of Tactical Missile Systems 20 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02

The applicability of a higher order panel method code to the aerodynamic analysis of missile configurations is investigated. In a cooperative work between MBB and ONERA, the HISSS code (developed for the analysis of attached, subsonic and supersonic flow about complex aircraft configurations) was used for calculating a large variety of different missile geometries, including classical configurations, non-circular bodies and air-breathing configurations. Accuracy and limitations of the present theoretical approach are evaluated and discussed by comparison of calculated results with wind tunnel data available at ONERA. It is concluded that the method can be successfully used for the analysis of very complex missile geometries at both subsonic and supersonic Mach numbers, provided that the flow conditions prevent violation of the underlying linearized potential theory. Author

N90-10054# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
MISSILE DATCOM: ENHANCEMENTS FOR DESIGN APPLICATIONS
JERRY E. JENKINS and WILLIAM B. BLAKE *In* AGARD, Stability and Control of Tactical Missile Systems 16 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02

Missile Datcom, a stability and control prediction code tailored to conceptual and preliminary design applications, was developed. The program uses a component build-up approach based on the equivalent angle-of-attack concept. Simple vortex models are employed to allow for rapid and economical analyses. Two enhancements for design application were incorporated into the code. Experimental data substitution allows accuracy improvements to be attained by permitting the user to substitute experimental data for Missile Datcom predictions during the component build-up process. Its use is appropriate when more accurate data are available for vehicle components or for partial configurations. Configuration incrementing allows a user to more accurately investigate the effects of geometry changes on an existing configuration. In this case, experimental data for the complete baseline configuration are used to correct Missile Datcom predictions for the modified vehicle. Problem areas, in many cases related to vortex modeling, can degrade accuracy for some types of configurations. These are examined in the light of selected theory-to-test correlations. Finally, current efforts to improve existing methods and to develop new methods are briefly reviewed. Author

N90-10057# Nielsen Engineering and Research, Inc., Mountain View, CA.
VORTEX INDUCED CHARACTERISTICS OF MISSILES IN UNSTEADY MANEUVERS
MICHAEL R. MENDENHALL and STANLEY C. PERKINS, JR. *In* AGARD, Stability and Control of Tactical Missile Systems 13 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02

A preliminary design method to predict the nonlinear aerodynamic characteristics of tactical missiles in unsteady maneuvers at high angles of attack in subsonic flow is described. The approach is based on the accurate representation of the complex flow phenomena in the vicinity of the missile, including effects of forebody vortex shedding and lifting surface trailing vorticity. For specified motion of the missile, the time-dependent forces and moments on all missile components are calculated, including hysteresis effects due to vortex lag and the history of the motion, without the need for empirical information. This provides a capability to predict stability and control characteristics of advanced missile configurations for preliminary design analysis. When possible, comparison of experiment and theory are presented to validate the method. Author

N90-10058# Nielsen Engineering and Research, Inc., Mountain View, CA. Missile and Store Separation Aerodynamics.
AEROELASTIC TAILORING PROCEDURE FOR CONTROLLING FIN HINGE MOMENTS
M. F. E. DILLENIUS and S. C. MCINTOSH, JR. (McIntosh Structural Dynamics, Inc., Palo Alto, CA.) *In* AGARD, Stability and Control of Tactical Missile Systems 14 p (SEE N90-10050 01-08) Mar. 1989
(Contract N00019-86-C-0032)
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02

A combined static aeroelastic and optimization design method is presented which is aimed at controlling the center of pressure acting on a missile control fin made of composite material. Specifically, the material principal-axis directions of various segments of an orthotropic fin are varied in order to influence the chordwise location of the center of pressure through elastic fin deformation under nonlinear supersonic aerodynamic loading. The design problem is posed as an optimization problem, where the principal-axis directions are the design variables, and the objective is the difference between the current center of pressure location and its desired location. Constraints on flutter speeds, displacements, and natural frequencies are permitted, and the design variables have upper and lower bounds. Consistent fin deformations are obtained by iterating between the aerodynamic load and the fin displacement calculations. Results obtained by the present method are presented for a hypothetical supersonic missile control fin. An antisymmetric angle-ply layup of graphite fibers and epoxy is used for the fin material. The variation of chordwise center of pressure location with material principal-axis direction is mapped, and operation of the optimizer, with and without constraints, is demonstrated. The results demonstrate that locally optimum center of pressure locations can be calculated. Author

N90-10059# British Aerospace Dynamics Group, Hatfield (England). Systems Support Dept.
ALTERNATIVE POLAR HOMING STRATEGIES
M. S. GATE and R. S. RANDALL *In* AGARD, Stability and Control of Tactical Missile Systems 14 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02

The coupled lateral and roll requirements are considered for a twist-to-track missile which is constrained by the seeker to maintain the sight line at an approximately fixed polar angle from the body. Two alternative approaches, one based on roll profile optimization and the other on adopting a non-cruciform missile configuration, are described. Author

N90-10060# Selenia S.p.A., Rome (Italy). Missile System Div.
HOW TO CONTROL UNSTABLE MISSILE AIRFRAMES: METHODOLOGY AND LIMITATIONS
A. GAZZINA *In* AGARD, Stability and Control of Tactical Missile Systems 18 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02

The problem of controlling static unstable airframes of tactical missiles through the proper choice both of gains and of the autopilot

configuration is covered. Unlike other excellent treatments of the subject, the analytical description of the problem is simplified to the extreme in order to shorten the gap between the aerodynamicist and the control system designer. Classical feedback paths are described highlighting the key features of each of them and a method of direct synthesis is presented valid for both stable and unstable airframes. The maximum allowable instability of the airframe is derived. Author

N90-10061# Societe Francaise d'Equipments pour la Navigation Aerienne, Chatellerault (France).
MINIATURIZED TRIAXIAL LASER GYRO [GYROMETRE LASER TRIAXIAL MINIATURISE]
SERGE PETIT *In* AGARD, Stability and Control of Tactical Missile Systems 9 p (SEE N90-10050 01-08) Mar. 1989 In FRENCH
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
The operating principles and advantages of the axial laser gyro concept are described and a technical description of a triaxial sensor developed for small-diameter missiles is presented. The performance characteristics of two prototype triaxial laser gyros are reported. Stability, biases, and scale factor characteristics are addressed. Finally, a brief description of a miniature accelerometer unit is given. Transl. by M.G.

N90-10063*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
REMOTE CONTROL MISSILE MODEL TEST
JERRY M. ALLEN, DAVID S. SHAW, and WALLACE C. SAWYER *In* AGARD, Stability and Control of Tactical Missile Systems 12 p (SEE N90-10050 01-08) Mar. 1989
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CSCL 01/3
An extremely large, systematic, axisymmetric body/tail fin data base was gathered through tests of an innovative missile model design which is described herein. These data were originally obtained for incorporation into a missile aerodynamics code based on engineering methods (Program MISSILE3), but can also be used as diagnostic test cases for developing computational methods because of the individual-fin data included in the data base. Detailed analysis of four sample cases from these data are presented to illustrate interesting individual-fin force and moment trends. These samples quantitatively show how bow shock, fin orientation, fin deflection, and body vortices can produce strong, unusual, and computationally challenging effects on individual fin loads. Comparisons between these data and calculations from the SWINT Euler code are also presented. Author

N90-10065# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).
IDENTIFICATION OF STABILITY AND CONTROL PARAMETERS OF A BRILLIANT AMMUNITION
K.-F. DOHERR, G. LEHMANN, and H. SCHILLING (Rheinmetall G.m.b.H., Duesseldorf, Germany, F.R.) *In* AGARD, Stability and Control of Tactical Missile Systems 16 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
The efficient defense against armored ground vehicles depends heavily on precisely delivered warheads. New terminal guided warheads are under development presently which improve the hit accuracy and therefore the effectiveness drastically. One exampe is EPHRAM which employs a sophisticated detection and control system in order to achieve optimal results. A considerable part of the development of a brilliant ammunition is spent on the determination of its aerodynamic and control characteristics. For EPHRAM static and dynamic wind tunnel experiments were performed. A recoverable instrumented version was developed for the validation of the concept and the identification of aerodynamic parameters and thrust interference effects from flight tests. The test vehicle was dropped several times from a helicopter-lifted platform. During these first tests with reduced sensor equipment, which focused on the performance of EPHRAM, the desired footprint was achieved. An analysis of one of these flights confirmed the static wind tunnel results at low angle of attack. For the system identification at high angle of attack more flight tests are scheduled with complete instrumentation and selected thrust programs to fully excite the vehicle dynamics. Author

N90-10066# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Defense Systems Div.
VALIDATION OF MISSILE SIMULATION
WERNER BUB *In* AGARD, Stability and Control of Tactical Missile Systems 8 p (SEE N90-10050 01-08) Mar 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
One of the key findings of AGARDograph No. 279, Survey of Missile Simulation and Flight Mechanics in NATO, was that very little effort was expended in missile simulation validation. No standard or well-defined techniques were in use adequate to communicate confidence in missile simulations to persons not directly involved in the process of simulation development. Missile simulation validation and confidence building techniques were examined. A simulation terminology was recommended that should simplify the validation process. In addition a hierarchical model representation called CLIMB was recommended in order to organize and document the knowledge base for simulation development as well as the data bases used for simulation validation. Author

N90-10067# Naval Weapons Center, China Lake, CA. Propulsion Control Technology Program.
INVESTIGATIONS OF THRUST VECTOR CONTROL FOR HIGH-ALPHA PITCHOVER
A. O. DANIELSON and R. B. DILLINGER *In* AGARD, Stability and Control of Tactical Missile Systems 14 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
Historically, thrust vector control (TVC) system investigations at the Naval Weapons Center have touched on a wide variety of technologies. Emphasis is on two technologies, the movable-nozzle and the jet-vane TVD, whose performance capabilities demonstrate the significant maneuvers achievable by thrust vector controlled missiles. Investigations have revealed an especially notable result of testing in the high-alpha vertical-launch pitchover environment; that is, despite high-performance TVC capability, missile subsystems such as seeker, airframe, actuation, autopilot, and rocket motor can limit the potential benefits otherwise offered by thrust vectoring. Some lessons learned in approaching such limits are delineated and referenced to assist systems engineers and designers of tactical missile airframes and control systems. Author

N90-10068# Naval Weapons Center, China Lake, CA.
A STRUCTURED SINGULAR VALUE APPROACH TO MISSILE AUTOPILOT ANALYSIS 2
G. A. HEWER, RICHARD KLABUNDE, and CHARLES KENNEY *In* AGARD, Stability and Control of Tactical Missile Systems 7 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
A state space model for additive errors that is algebraically and dynamically equivalent to Doyle's structured singular value is presented. Using this theory a new algorithm based on a Monte Carlo eigenvalue search is presented. Some examples are included that illustrate the convergence properties of the Monte Carlo technique. Author

N90-10071# British Aerospace Dynamics Group, Hatfield (England). Systems Support Dept.
AEROELASTIC ANALYSIS OF MISSILE CONTROL SURFACES WITH STRUCTURAL NON-LINEARITY
D. SEPAHY *In* AGARD, Stability and Control of Tactical Missile Systems 12 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02
An aeroelastic procedure is presented to deal with structural non-linearity of a missile control surface using the concept of linearized equivalent structural stiffness. This approach enables the use of standard software packages such as NASTRAN for linear aeroelastic analysis, i.e., divergence, flutter and dynamic response analysis. An example, backed up with experimental validation, is given for a flexible control surface with structural non-linearity due to free play at the root connection. A time simulation technique is also discussed for solution of the problem. Author

N90-12623# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
GUIDANCE AND CONTROL PANEL SYMPOSIUM ON GUIDANCE AND CONTROL OF UNMANNED AIR VEHICLES
Technical Evaluation Report
CHARLES T. ELLIOTT (Semcor, Inc., Farmingdale, NJ.) Jul. 1989 20 p Presented at the Guidance and Control Panel 47tn Symposium, San Francisco, CA, 4-7 Oct. 1988
(AGARD-AR-260; ISBN-92-835-0521-2; AD-A212770) Copyright Avail: NTIS HC A03/MF A01
Papers were presented covering the following headings: operational concepts, requirements and systems, vehicle guidance and control, optical systems, systems external to the vehicles, and evaluation and test. Author

N90-15050# Aerospatiale, Toulouse (France).
HOW TO FLY WINDSHEAR USING THE FLY-BY-WIRE CONCEPT
J. L. BONAFE *In* AGARD, Flight in Adverse Environmental Conditions 16 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
In the past three years, Aerospatiale has developed windshear warning and guidance systems for the A310 and the A300-600; these systems are either newly designed or constructed around the Speed Reference System designed for the A300 and exploited in revenue flight since 1975; they are in accordance with certification rules; and were installed on board the A300-600 since April 1988. Aerospatiale's warning and guidance philosophy regarding the conventional AIRBUS is presented, then the fly-by-wire concept analyzed. The fly-by-wire concept improves the general aircraft situation, and advantage is taken of these new capabilities in the warning and guidance elaboration. Systems will be adapted for the A320 certified and installed onboard in the near future. Author

N90-15051# Instituto Superior Tecnico, Lisbon (Portugal).
A PITCH CONTROL LAW FOR COMPENSATION OF THE PHUGOID MODE INDUCED BY WINDSHEARS
I. M. B. C. CAMPOS, A. J. N. M. AGULAR, and J. R. C. AZINHEIRA *In* AGARD, Flight in Adverse Environmental Conditions 13 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
In a previous paper the development of a flight test facility in Portugal was described. This reference mentioned briefly some of the research projects for which the facility would be initially used, including among other studies in non-linear pitch stability and aircraft response to atmospheric disturbances. The purpose is to discuss in more detail the flight mechanical theory which underlies these research projects: the comparison of theory with flight test data will have to await the availability of the CASA 212 Aviocar aircraft, which is at present already has all sensors installed but is still undergoing final check-out of instrumentation describing pitch stability for flight along a constant glide slope, taking into account the phugoid but neglecting the short period mode. The model is solved to find pitch control laws for two problems: the non-linear problem of keeping an aircraft on a constant glide slope in still air starting from an arbitrary initial velocity, possibly for removed from the steady flight speeds; and the linearized problem of keeping an aircraft on a constant glide slope in the presence of longitudinal and vertical winds of peak velocity up to 30 percent of the aircraft velocity, which provide a representation of a moderately strong windshear. Author

N90-15053# Aeronautica Macchi S.p.A., Varese (Italy). Flight Mechanics and Automatic Control Dept.
CANARD VERSUS AFT-TAIL RIDE QUALITIES PERFORMANCE AND PILOT COMMAND RESPONSE
L. V. CIOFFI and L. MANGIACASALE *In* AGARD, Flight in Adverse Environmental Conditions 13 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
A comparison between a Close-Coupled configuration and a Close-Coupled Tail configuration was developed in terms of ride qualities and pilot command response in turbulence. Parameters of the study are the mass factor of the airplane, the static stability, and the sign of the trailing-edge flap effectiveness (only for the aft-tail airplane). The known ride quality criteria are used in order to assess the flying qualities of the airplane. Interesting conclusions are derived in terms of configuration sensitivity and attenuation capabilities. Further research is needed in order to add structural flexibility and unsteady aerodynamics to the design model. Pilot command responses are in agreement with the current flying qualities parameters, but a special purpose control law has to be designed for good tracking in presence of discrete gusts. Author

N90-15054# Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (Germany, F.R.). Dynamic Dept.
THE INTERFERENCE OF FLIGHTMECHANICAL CONTROL LAWS WITH THOSE OF LOAD ALLEVIATION AND ITS INFLUENCE ON STRUCTURAL DESIGN
M. MOLZOW and R. MOEBEST *In* AGARD, Flight in Adverse Environmental Conditions 20 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
Today modern A/C designs use fly-by-wire together with control laws to make the A/C comfortable for handling in service. In addition, this implies an attractive chance for a lot of protections and limitations with the aim to improve handling quality characteristics or to protect the aircraft against overloading. Examples are: overspeed protection; load factor protection; and stall protection. Another chance is the implementation of Load Alleviation Functions (LAF). To optimize the overall A/C design a close cooperation between the different disciplines like: systems, handling quality, aerodynamics, loads, and stressing is needed, not to cancel the benefits in one discipline by handicaps or additional weight in others. The different problems, which have carefully to be watched in relation of interference to each other to reach an overall optimum are described. Author

N90-15055# Oklahoma State Univ., Stillwater. Dept. of Mechanical and Aerospace Engineering.
TURBULENCE EFFECTS OF AIRCRAFT FLIGHT DYNAMICS AND CONTROL
ROBERT L. SWAIM *In* AGARD, Flight in Adverse Environmental Conditions 9 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
Design of aircraft flight control systems requires consideration of many factors including maneuvering, ride and handling qualities, stability augmentation, and control power requirements as well as several others. All the mentioned factors, however, are strongly influenced by the atmospheric turbulence environment through which the aircraft must fly. A unified analytical design method is described which systematically accounts for three-component gust velocity spatial distribution effects, handling qualities in terms of needed closed-loop stability augmentation systems, and the maneuvering and stabilization three-axis control power required. These factors are all interrelated. State variable formulations of modern system theory are used for the aircraft and turbulence dynamic models and in stability augmentation system synthesis. Both homogeneous and heterogeneous turbulence are considered. Homogeneous models are described in a statistical sense. Heterogeneous turbulence is discrete due to vortex patterns generated by obstacles such as trees, buildings, or mountains, and is known to result in aircraft upsets and structural failure. Author

08 AIRCRAFT STABILITY AND CONTROL

N90-15056# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
ACTIVE CONTROL SYSTEM FOR GUST LOAD ALLEVATION AND STRUCTURAL DAMPING
HARTMUT BOEHRET and JOACHIM WINTER *In* AGARD, Flight in Adverse Environmental Conditions 11 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Based on the Do-228 regional airliner, the improvement in passenger comfort provided by the gust load alleviation system Open Loop Gust Alleviation (OLGA) under adverse weather conditions is shown. The problem of excited structural vibrations is solved with an active structural damper, which eliminates the adverse effect of the gust load alleviation system on structural vibrations and, additionally, diminishes their excitation by maneuvers and gust loads. Author

N90-15057# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.
AIRCRAFT RESPONSE AND PILOT BEHAVIOUR DURING A WAKE VORTEX ENCOUNTER PERPENDICULAR TO THE VORTEX AXIS
REINHARD KOENIG *In* AGARD, Flight in Adverse Environmental Conditions 18 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Vortex systems can be hazardous to trailing aircraft which encounter them in flight. The greatest hazard occurs in areas where aircraft from a wide range of classes operate and where the flight paths are close to the ground. Upwash velocities induced by the wake vortices can be equivalent to the design gust velocities. Furthermore different types of hazardous effects exist when encountering the vortex system, such as imposed rolling and pitching moments, a loss of rate of climb, a loss of altitude and structural loads. Aircraft response and pilot behavior during takeoff are described when a wake vortex is encountered perpendicular to the vortex axis. The aircraft response is calculated by nonlinear digital simulation with a mathematical model of a wake vortex system close to the ground. This real-time vortex model is also used in the Boeing B-737 simulator of Deutsche Lufthansa in order to examine the pilot behavior. Close to the ground, the wake vortex system induces additional horizontal velocities. There exists a critical flight path where very large g-loads are induced by vertical and horizontal vortex velocities and normal vertical acceleration shortly after takeoff. Often the pilot will attempt to counteract these g-loads, but this produces only a small effect. Author

N90-15924# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
GUIDANCE AND CONTROL OF UNMANNED AIR VEHICLES
Aug. 1989 191 p In ENGLISH and FRENCH Symposium held in San Francisco, CA, 4-7 Oct. 1988
(AGARD-CP-436; ISBN-92-835-0523-9; AD-A215006) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The following topics were discussed: operational concepts, requirements and systems, vehicle guidance and control, optical systems, systems external to the vehicle, and evaluation and test. For individual titles, see N90-15925 through N90-15935.

N90-15925# Ecole Nationale de l'Aeronautique et de l'Espace, Toulouse (France).
SYNTHESIS OF CONTROL LAW, ON A RPV, IN ORDER TO MINIMIZE THE NUMBER OF SENSORS
JEAN-LUC BOIFFIER *In* AGARD, Guidance and Control of Unmanned Air Vehicles 17 p (SEE N90-15924 08-08) Aug. 1989 Sponsored by ENSAE and Centre d'Etudes et de Recherche, Toulouse, France
(AGARD-CP-436) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Two 25 kg Remotely Piloted Vehicles (RPVs) were built and the capabilities in flight were demonstrated. This RPV is equipped with a digital computer which enables the plane to be under automatic control for a sea skimmer flight. A 50 kg RPV project, with a 20 kg payload under 300 W, for a flight of 2500 m high and 6 hour flying time is now being developed. The first flight is planned for 1990. These specifications need to pay special attention to the weights. One kilo represents 15 percent of the performance. The airplane configuration was optimized to minimize the weights of the airframe and fuel. Optimal wing area, aspect ratio, area ratio between front and rear lifting surfaces, were found. The avionic systems were treated with the same effort. In particular, control laws were studied in order to reduce the number of sensors needed to control and guide the plane. A method is described for avoiding the installation of a vertical gyroscope, which is a heavy sensor, for this kind of RPV. The lighter the plane is, the more this proposition is interesting. The plane and turbulence are described, and the automatic lateral control is presented. The following topics are approached: adjustment of the natural mode of the plane in order to reduce the sensitivity of the plane under the effect of turbulence, basic control law by LQ method, installation of wash-out filters on the measurement to avoid drift sensors effect, optimization of the wash-out frequency, and general performances with and without bank and heading angle measurement. Author

N90-15926# METEOR Costruzioni Aeronautiche ed Elettroniche S.p.A., Ronchi dei Legionari (Italy).
MIRACH 100 FLIGHT CONTROL SYSTEM
ANES SBUELZ *In* AGARD, Guidance and Control of Unmanned Air Vehicles 17 p (SEE N90-15924 08-08) Aug. 1989
(AGARD-CP-436) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Mirach 100 air-vehicle is a multipurpose RPV-UMA, suited to intelligence missions of target recognition, acquisition, and identification up to 150 km. It is a high-subsonic speed, jet-powered drone having a ceiling altitude of 9000 m and 1 hour endurance. Different arrangements of the base air-vehicle allow higher altitudes or wider endurances according to the mission operational requirements. The flight control system of the Mirach 100 is mainly a compound of already tested in flight components. Autopilot function includes a full control system of stabilization on two axes, simply designed to improve reliability and safety of guidance. Mechanization is based on a simple analogic control circuit of the actuators that drive the control surfaces of the aircraft, stabilized through the vertical gyroscope feed-back; the gyroscope is installed in the air-vehicle fore structure. Guidance function includes a complete control system based on altitude, heading and velocity integrated in the flight controller which runs the whole aircraft, pay load included. Navigation function is based on a OMEGA/VLF receiver and navigator, suited to memorize a flight plan formed with up to 99 geographical points sequentially navigated, starting from any of it. From the computation a wind parameter is estimated which includes the on-board sensor errors, giving improved navigation performances even when the omega-receiver operates in marginal conditions. The drone is guided to follow the programmed flight plan. Complete avionics and aircraft itself were modeled on a computer for dynamic and static stability analysis and performance computations; the results obtained were compared with those recorded during the Mirach 100 test flights performed at the experimental range Salto di Quirra in Sardinia. Test flights gave excellent results about steering, guidance and navigation. The altitude and speed control were obtained with an accuracy that went far beyond the expectations, reaching the accuracy level of the sensor used in the testing program. Author

N90-18432# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
THE IMPLICATIONS OF USING INTEGRATED SOFTWARE SUPPORT ENVIRONMENT FOR DESIGN OF GUIDANCE AND CONTROL SYSTEMS SOFTWARE
EDWIN B. STEAR, ed. and JOHN T. SHEPHERD, ed. (GEC-Marconi Ltd., Borehamwood, England) 1990 192 p
(AGARD-AR-229; ISBN-92-835-0538-7; AD-A219101) Copyright Avail: NTIS HC A09/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The deliberations and conclusions of Working Group 8 of the Guidance and Control Panel of AGARD are summarized, which are: (1) to develop and consider a set of requirements for a high level language software support environment from a guidance and control systems viewpoint; (2) to evaluate the characteristics and capabilities offered by advanced language support environments, either existing or in the course of development, with respect to the requirements defined in 1; and (3) if necessary, to determine the modifications which would have to be contemplated to meet fully the needs expressed in 1. The Working Group attempted to consider all software design and development technologies which existed or were known to be under development at the time.
Author

N90-26012# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
TECHNICAL EVALUATION REPORT ON THE GUIDANCE AND CONTROL PANEL 49TH SYMPOSIUM ON FAULT TOLERANT DESIGN CONCEPTS FOR HIGHLY INTEGRATED FLIGHT CRITICAL GUIDANCE AND CONTROL SYSTEMS
BERNARD CHAILLOT (Direction des Recherches, Etudes et Techniques, Paris, France) May 1990 21 p Symposium held in Toulouse, France, 10-13 Oct. 1989
(AGARD-AR-281; ISBN-92-835-0559-X) Copyright Avail: NTIS HC A03/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Twenty-three papers were presented at the Guidance and Control Panel 49th Symposium including the keynote address, covering the following headings: trends in integrated flight critical systems; advanced fault tolerant design concepts; system architectures, mechanization, and integration issues; high integrity software design methodologies and algorithms; and system validation, simulation, and flight test experience. Author

N90-28515# British Aerospace Public Ltd. Co., Lancashire (England). Military Aircraft Div.
COMBAT AIRCRAFT CONTROL REQUIREMENTS
T. B. SAUNDERS and J. H. TUCKER In AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 20 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The various functions and requirements for combat aircraft controls which arise from consideration of the flight envelope, agility, handling qualities specifications, and control system design criteria are reviewed. Examples are drawn from supersonic and subsonic combat aircraft designed by British Aerospace including those employing powered lift (Harrier) and those which use a basically unstable airframe to enhance performance (EAP/EFA). The subject is discussed in terms of the basic functions of aircraft controls which are to trim, maneuver, and stabilize. These functions require certain forces and moments to be generated over the full design envelope of speed, Mach number, and angle of attack. A certain minimum level of linearity is desirable although, with some redundancy of controls, trim schedules can be chosen to avoid limited areas of ineffectiveness provided other constraints allow it. The achievable rate of application of control is an important variable which can have a serious impact on the sizing of actuators and power systems. Author

N90-28516*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CONTROL RESEARCH IN THE NASA HIGH-ALPHA TECHNOLOGY PROGRAM
WILLIAM P. GILBERT, LUAT T. NGUYEN, and JOSEPH GERA (National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.) In AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 18 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01/3
NASA is conducting a focused technology program, known as the High-Angle-of-Attack Technology Program, to accelerate the development of flight-validated technology applicable to the design of fighters with superior stall and post-stall characteristics and agility. A carefully integrated effort is underway combining wind tunnel testing, analytical predictions, piloted simulation, and full-scale flight research. A modified F-18 aircraft has been extensively instrumented for use as the NASA High-Angle-of-Attack Research Vehicle used for flight verification of new methods and concepts. This program stresses the importance of providing improved aircraft control capabilities both by powered control (such as thrust-vectoring) and by innovative aerodynamic control concepts. The program is accomplishing extensive coordinated ground and flight testing to assess and improve available experimental and analytical methods and to develop new concepts for enhanced aerodynamics and for effective control, guidance, and cockpit displays essential for effective pilot utilization of the increased agility provided. Author

N90-28517# Eidetics International, Inc., Torrance, CA.
COMBAT AIRCRAFT CONTROL REQUIREMENTS FOR AGILITY
JOSEPH R. CHODY, JOHN HODGKINSON, and ANDREW M. SKOW In AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 21 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The positive effect of increased aircraft agility on air-to-air combat effectiveness has created a need to quantify the impact of preliminary design on the agility potential of candidate aerodynamic configurations. Recently developed measures of agility can provide an important supplement to traditional energy maneuverability measures like specific excess power and turn rate. The very nature of agility, characterized by the combination of traditional energy maneuverability plus controllability, places additional controllability and departure resistance requirements on the aircraft design. Specific issues of aircraft controllability that require close attention during the preliminary design process are highlighted. This will help ensure that the agility potential of the final configuration is not compromised at some point in the design process due to inadvertent oversight. Methods for estimating agility potential early in the design process are given as well as extensions of currently used departure susceptibility prediction techniques. A brief synopsis of agility is given from a historical standpoint and several agility measures of merit currently being used, are discussed. The benefits of improved lateral agility are illustrated by mapping potential lateral agility improvements as a function of angle of attack onto a typical energy-maneuverability envelope showing regions of enhanced combat capability. Author

N90-28518# Aeronautica Macchi S.p.A., Varese (Italy).
AERODYNAMIC CONTROL DESIGN: EXPERIENCE AND RESULTS AT AERMACCHI
B. BUFACCHI, M. LUCCHESINI, L. MANFRIANI, and E. VALTORTA In AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 13 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A review of Aermacchi activities in the field of aerodynamic control design is presented. The aerodynamic balancing of the MB-326/339 elevator and of the AM-X control surfaces for the manual backup mode are described. The use of rotary balance wind tunnel testing and of simulation in assessing controllability at high angle of attack is discussed. Preliminary design studies of

unconventional layouts are described and some features of control techniques on an unstable canard design are illustrated using wing tunnel results and flow visualization. Author

N90-28521*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INNOVATIVE CONTROL CONCEPTS AND COMPONENT INTEGRATION FOR A GENERIC SUPERCRUISE FIGHTER
BRET A. MARKS (McDonnell Aircraft Co., Saint Louis, MO.) and DAVID E. HAHNE *In* AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 14 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive CSCL 01/3
The results of a series of low speed wind tunnel tests conducted in the NASA Langley Research Center (LaRC) 12 ft Low Speed Wind Tunnel (LSWT) are highlighted. The main objectives of the tests were to provide generalized component integration guidelines and to investigate a variety of innovative control concepts designed to improve the high angle of attack (AOA) controllability of a generic class of supercruise fighters. Author

N90-28522*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DEVELOPMENT OF NON-CONVENTIONAL CONTROL METHODS FOR HIGH ANGLE OF ATTACK FLIGHT USING VORTEX MANIPULATION
GERALD N. MALCOLM, T. TERRY NG, LIANE C. LEWIS (Eidetics International, Inc., Torrance, CA.), and DANIEL G. MURRI *In* AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 17 p (SEE N90-28513 23-05) Apr. 1990 Previously announced in IAA as A89-47653
(Contract F33615-86-C-3623)
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive CSCL 01/3
Methods of manipulating the forebody vortices on a generic fighter model to produce controlled yawing moments at high angles of attack were investigated. Forces and moments were measured on the complete configuration and on the isolated forebody. Two schemes for vortex control on the forebody were evaluated: individually-controlled tip strakes and individually-controlled blowing ports. The effectiveness of the forebody strakes in controlling forebody side forces was strongly dependent on the size and location of the strakes. A yawing moment can be produced by deploying the forebody strakes asymmetrically, or can be eliminated by deploying the strakes symmetrically. The most effective strake position was found to be near the primary separation point, between 105 and 120 deg from windward. Blowing on the surface of the model was also shown to have a strong effect on the yawing moment. Blowing either forward or aft tangential to the surface appears to be more effective than blowing normal to the surface. The most effective method to control the yawing moment on the forebody was to minimize the natural asymmetry with a pair of small symmetrically mounted tip strakes and to perturb the vortex system away from the symmetric condition with asymmetric blowing. Author

N90-28525# London Univ. (England).
UNSTEADY AERODYNAMICS OF CONTROLS
G. J. HANCOCK and D. G. MABEY (Royal Aerospace Establishment, Bedford, England) *In* AGARD, Aerodynamics of Combat Aircraft Controls and of Ground Effects 17 p (SEE N90-28513 23-05) Apr. 1990
(AGARD-CP-465) Copyright Avail: NTIS HC A15/MF A02; Non-NATO Nationals requests available only from
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The physics of quasi-steady aerodynamics are discussed. The concept of an aerodynamic rise time is defined, which indicates how quickly steady states are realized. Long rise times occur at low transonic speeds, but short rise times occur at high transonic speeds. Predictions of control surface characteristics compare poorly with experimental results. Experimental errors are possibly due to small gaps and wind tunnel wall interference while in the theoretical methods boundary layer approximations may be suspect. The interface of unsteady aerodynamics with control system design and validation is described. It is pointed out that

the unsteady aerodynamic input is limited to approximate and tailored forms of linearized aerodynamics. It is not clear how more accurate, nonlinear transonic aerodynamics can be incorporated in control design procedures. Author

N91-12682# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
FAULT TOLERANT DESIGN CONCEPTS FOR HIGHLY INTEGRATED FLIGHT CRITICAL GUIDANCE AND CONTROL SYSTEMS
Apr. 1990 263 p In ENGLISH and FRENCH The 49th symposium was held in Toulouse, France, 10-13 Oct. 1989
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Papers presented covered the following topics: trends in integrated flight critical systems; advanced fault tolerant design concepts; system architectures, mechanization and integration issues; high integrity software design methodologies and algorithms; and system validation, simulation and flight test experience. For individual titles, see N91-12683 through N01-12704.

N91-12683# General Dynamics/Fort Worth, TX.
FLIGHT CRITICAL DESIGN CONCEPTS FOR LOW-LEVEL TACTICAL GUIDANCE AND CONTROL
MICHAEL R. GRISWOLD *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 8 p (SEE N91-12682 04-08) Apr. 1990
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Low-level combat operations, such as might be typified by next generation close air support (CAS) aircraft, present new demands on the guidance and control system. The design must address not only the traditional flight-critical definitions related to system management, ground collision avoidance, and operational flight restrictions, but also the possibility of increased exposure to defensive countermeasures due to system failure. It is also clear that traditional guidance and control methods must be re-examined in light of total mission goals. For instance, employing an active sensor to aid in terrain avoidance may decrease overall combat survivability due to increased detectability by threats. Several of the elements of flight critical concepts are presented for low-level tactical operation. This includes classical elements as well as mission-specific considerations such as threat exposure and threat evasion. In both cases, system failure may compromise safety. The mission scenario for the discussions is the CAS mission using a fast moving, technologically advanced aircraft. The guidance and control strategies for the proposed application are discussed with emphasis on system integrity considerations and performance-versus-safety-issues. Terrain verification is a critical process for low-level operation when the digital terrain database is utilized for fundamental guidance and control information. Fault detection and management schemes are also examined. The application of previously developed system-wide integrity management design philosophies are considered for subsystem integrity monitoring and communications. These techniques are reviewed with an eye toward analytical and inductive redundancy techniques to achieve acceptable levels of detection without resorting to physical redundancy. Author

N91-12684# Aerospatiale, Toulouse (France).
CIVIL APPLICATIONS TRENDS
PASCAL TRAVERSE *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 17 p (SEE N91-12682 04-08) Apr. 1990 In FRENCH
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Flight control of Airbus A320 marked a stage in the history of aeronautics as well as in the history of fault tolerant information systems. This control system is examined along with its possible evolution. This evolution is detailed, especially the architecture of the computer, the architecture of the information system, use in optics, and the design of the systems. E.R.

N91-12687# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
THE ROLE OF TIME-LIMITED DISPATCH OPERATION IN FAULT-TOLERANT FLIGHT CRITICAL CONTROL SYSTEMS
DEBORAH F. ALLINGER, FRANK J. LEONG, PHILIP S. BABCOCK, IV, RICHARD F. LAPRAD, and GARY C. HORAN (Pratt and Whitney Aircraft, East Hartford, CT.)   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 12 p (SEE N91-12682 04-08)   Apr. 1990
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The use of fault-tolerant system design concepts to achieve otherwise unattainable levels of reliability in modern flight critical control systems is rapidly becoming commonplace. Fault-tolerant flight and propulsion control systems, for example, are now being deployed in modern aircraft, spacecraft, and submersibles. The characteristics of these systems pose new problems for the designers of such systems and afford new opportunities for their users. A basic motivation for introducing fault tolerance is to be able to preserve some level of functionality of the system in the wake of failures of some of the system's components. This property of fault-tolerant systems affords an opportunity to dispatch these systems with failed components for a limited time period. This mode of operation is referred to as time-limited dispatch. In time-limited dispatch operation, benefits related to both maintenance and operations can be realized. Aircraft maintenance actions can be deferred until a more convenient time or place, for example. Similarly, the sortie rates that can be realized in tactical situations can be increased. In order to determine optimal or near optimal dispatch policies for fault-tolerant systems, one must have a systematic means of establishing dispatch policies and be able to quantify the benefits that can be realized by adopting specific dispatch policies. A tractable methodology for doing so is described and illustrated.   Author

N91-12688# GEC Avionics Ltd., Rochester (England). Flight Control Div.
A FAULT TOLERANT FLY BY WIRE SYSTEM FOR MAINTENANCE FREE APPLICATIONS
R. W. DENNIS and A. D. HILLS   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 14 p (SEE N91-12682 04-08)   Apr. 1990
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A triplex primary flight computer system based on a reconfigurable architecture with extensive use of Application Specific Integrated Circuits (ASIC) is described. The system is under development and comprises fault tolerant Fly-by-Wire (FBW) computers which are triplex dissimilar in both software and hardware. These command Actuator Control Electronics (ACE) units .ia DATAC (ARINC 629) data buses. The Fly-by-Wire computers form the core of the full authority FBW system and perform all the computational commands for the pitch, roll and yaw surface actuation systems. The key requirements placed on the FBW computers are: the probability of loss of the FBW function due to random failure in the FBW computer system shall be less than 1.0E-10; the FBW system shall survive a generic failure which could arise from either hardware or software; and the system reliability shall have a design aim of 0.95 dispatch probability after at least 30,000 operating hours. The architectural design issues, in terms of integrity requirements and fault tolerance, are reviewed. The FBW computer architecture is based on dividing the basic path into three sub-functional elements. Each of these elements is then replicated to provide fault tolerance. Communication between any one element and its adjacent elements is via point to point bidirectional serial data buses. For a FBW computer to be operable only one of each element type needs to be functional. The internal element redundancy management function, performed both in hardware and software, is able to detect and isolate faulty elements and perform the necessary reconfiguration. Redundancy management is also addressed from a system viewpoint together with the implementation in terms of both hardware and software. The development hardware produced is described. The software structure and the use of dissimilarity is also addressed. The Fly-by-Wire system is being evaluated using an iron bird rig in

which FBW computers, DATAC buses, Actuator Control Electronics, and actuators were installed.   Author

N91-12690# Royal Signals and Radar Establishment, Malvern (England).
DEPENDABLE SYSTEMS USING VIPER
J. KERSHAW   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 7 p (SEE N91-12682 04-08)   Apr. 1990
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Computer systems are being used increasingly in applications where a malfunction could cause loss of life or massive environmental damage. Redundancy is used to guard against random hardware failure in such systems, but redundancy alone does not protect against design faults which might affect every channel at the same time: the classic Common-Cause Failure (CCF). The risk of CCF is all-pervasive. Latent faults can be inserted, over a period, into all the channels of a previously correct system. All these types of event have caused real system breakdowns. The most common defense against design error is diversity, the use of two or more different and separately designed channels which will be assumed to fail independently. This is expensive, and it still does not protect against errors in the original specification. True diverse implementation of software is surprisingly difficult: even when the specification of a program was cleanly separated from its implementation, design decisions usually leak from the specification into some or all of the implementations. At some point, all redundant systems need to decide which channel is faulty. This decision is critical to the operation of the whole system. A simple voter, which merely compares a few logical signals or takes a mean of 3 or 4 analog values, can be made extremely reliable. Digital versions of such a voter are less satisfactory than analog - deciding whether or not several values are within a reasonable tolerance of one another is much easier in the analog world. A really simple digital voter cannot tolerate diverse inputs. The more diverse the channels of a system are, the more complex the decision maker is likely to be. Obviously it must be substantially more reliable than any single channel, or it would compromise the integrity of the system as a whole. Ideally the voter should be distributed among the redundant channels of the system, to minimize the number of critical points at which a single failure would be disabling and to take advantage of diversity in the decision making as well as in the information processing. This leads to Byzantine voting protocols and massive overheads, and still leaves some risk of CCF through errors in the specification. Beyond a certain point, complexity may be self-defeating. Author

N91-12691# General Electric Co., Binghamton, NY. Dept. of Aircraft Control Systems.
FAULT-TOLERANT, FLIGHT-CRITICAL CONTROL SYSTEMS
TOM SADEGHI and GERRY MAYVILLE   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 12 p (SEE N91-12682 04-08)   Apr. 1990
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Two leading Fault-Tolerant, Flight-Critical Systems (FTFCSs) currently being developed are described and compared. These technologies, driven by the aircraft performance, reliability, and maintainability requirements, are: the Self-Repairing Flight Control System (SRFCS) and the Vehicle Management System (VMS). SRFCS has two technology thrusts: Control Reconfiguration Strategy (CRS) and Onboard Expert System (OES). VMS is focused on: Vehicle Management Computer (VMC) development and Integrated Diagnostics System (IDS). SRFCS has the potential to reduce brute force hardware redundancy, where the VMS is driven by increased functional complexity demands for increased hardware redundancy. A cursory examination of these technologies suggests that SRFCS can be considered as a complement to VMS development. Contrary to this view, the attributes of each of these technologies are examined and the needs for future development identified. The remaining challenge to be overcome by systems designers is finding the best balanced solution for the future FTFCS, utilizing a proper blend of SRFCS and VMS technologies.
                                                      Author

N91-12692# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Aircraft Div.
METHODS TO PRESERVE THE INTEGRITY OF A COMBAT AIRCRAFT FLIGHT CONTROL SYSTEM THROUGH MAJOR UPGRADE PROGRAMMES
M. ROESSLER and W. SCHMIDT   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 9 p (SEE N91-12682 04-08)   Apr. 1990
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    During the years of in-service operation, the Autopilot and Flight Director System/Terrain Following (AFDS/TF) subsystem of the PANAVIA TORNADO has gained a high level of confidence. Methods were developed, to keep control of the integrity of the flight critical system through plenty of modifications. As part of major upgrade programs of the weapon system TORNADO, several improvements will be introduced to the automatic flight control system. How the new elements can be integrated into the existing system architecture without jeopardizing the integrity and availability of the system and how the enhanced flight control system will be validated and put into operation are explained.   Author

N91-12694# Honeywell, Inc., Minneapolis, MN. Systems and Research Center.
INTEGRATED DIAGNOSTICS FOR FAULT-TOLERANT SYSTEMS
HARRY A. FUNK and MARK M. JEPPSON   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 9 p (SEE N91-12682 04-08)   Apr. 1990
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    An integrated approach to the maintainability of high-reliability fault-tolerant flight control systems is presented. Modern aircraft provide designers of maintenance systems a tremendous amount of data on the health of subsystem elements. Examples include initiated built-in-test, continuous built-in-test, redundancy management status, reconfiguration status, and time-stress measurement data. Advances in both on-aircraft and off-aircraft diagnostic hardware and software provide the designer with a wide range of partitioning options to most effectively use these data. An integrated maintenance approach is discussed using both a portable maintenance aid at the flight line and on-aircraft in-flight diagnostic resources. An implementation strategy for each of these systems is presented along with a technique that ensures designed-in commonality between the on-aircraft and off-aircraft systems. The proper use of these systems in addressing particular maintenance problems (re-test okays and cannot-duplicates) is discussed.   Author

N91-12700# Grumman Aerospace Corp., Bethpage, NY. Aircraft Systems Div.
PILOTED SIMULATION VERIFICATION OF A CONTROL RECONFIGURATION STRATEGY FOR A FIGHTER AIRCRAFT UNDER IMPAIRMENTS
RICHARD MERCADANTE   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 24 p (SEE N91-12682 04-08)   Apr. 1990
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    Piloted simulation performed at the USAF large amplitude multi-mode aerospace research simulator (LAMARS) verified the capability of a reconfiguration strategy to improve aircraft controllability. USAF Tactical Air Command pilots and test pilots from a number of organizations evaluated the characteristics of a next-generation fighter aircraft subjected to control surface damage and/or actuation failures. Tests were performed both with and without the aid of the reconfiguration strategy. For the aircraft configuration simulated, pilot opinions, ratings, and target tracking scores demonstrated the capability of the system to improve aircraft response for a large variety of control surface impairments throughout the subsonic flight envelope. Results ranged from slight to dramatic improvement and departure prevention.   Author

N91-12702*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
FLIGHT DEMONSTRATION OF A SELF REPAIRING FLIGHT CONTROL SYSTEM IN A NASA F-15 FIGHTER AIRCRAFT
JAMES M. URNES, JAMES STEWART, and ROBERT ESLINGER (Wright Research Development Center, Wright-Patterson AFB, OH.)   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 17 p (SEE N91-12682 04-08)   Apr. 1990
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    Battle damage causing loss of control capability can compromise mission objectives and even result in aircraft loss. The Self Repairing Flight Control System (SRFCS) flight development program directly addresses this issue with a flight control system design that measures the damage and immediately refines the control system commands to preserve mission potential. The system diagnostics process detects in flight the type of faults that are difficult to isolate post flight, and thus cause excessive ground maintenance time and cost. The control systems of fighter aircraft have the control power and surface displacement to maneuver the aircraft in a very large flight envelope with a wide variation in airspeed and g maneuvering conditions, with surplus force capacity available from each control surface. Digital flight control processors are designed to include built-in status of the control system components, as well as sensor information on aircraft control maneuver commands and response. In the event of failure or loss of a control surface, the SRFCS utilizes this capability to reconfigure control commands to the remaining control surfaces, thus preserving maneuvering response. Correct post-flight repair is the key to low maintainability support costs and high aircraft mission readiness. The SRFCS utilizes the large data base available with digital flight control systems to diagnose faults. Built-in-test data and sensor data are used as inputs to an Onboard Expert System process to accurately identify failed components for post-flight maintenance action. This diagnostic technique has the advantage of functioning during flight, and so is especially useful in identifying intermittent faults that are present only during maneuver g loads or high hydraulic flow requirements. A flight system was developed to test the reconfiguration and onboard maintenance diagnostics concepts on a NASA F-15 fighter aircraft.   Author

N91-12703# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugfuehrung.
FLIGHT TESTING OF A REDUNDANT FBW/FBL HELICOPTER CONTROL SYSTEM
H. BECKER, K. BENDER, K. D. HOLLE, and G. MANSFELD   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 13 p (SEE N91-12682 04-08)   Apr. 1990
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    The DLR has designed and developed an experimental fault-tolerant four-axes flight control computer system for helicopters named DISCUS. The acronym stands for Digital Self-healing Control for Upgraded Safety. The main objective for the design of this computer system was to get a tool for various research tasks related to fault-tolerance, control law design and flight testing of new technologies. The design features of the DISCUS flight control computer system, the hardware realization, the software functions implemented so far and results of flight tests, all this performed in close cooperation with German industry are described. Although the hardware and the executive software of the flight control computer system are designed for four-axes applications, in the reported phase the DISCUS system is first of all flight tested in the yaw-axis control mode only.   Author

N91-13436# Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (Germany, F.R.). Intelligent Systems Div.
MIDCOURSE GUIDANCE TECHNOLOGIES FOR ADVANCED TACTICAL MISSILES SYSTEMS
ULRICH HARTMANN *In* AGARD, Missile Interceptor Guidance System Technology 27 p (SEE N91-13434 05-05) Sep. 1990
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Midcourse guidance techniques can significantly improve operational aspects as well as overall performance of tactical missile systems. Operational requirements such as conformal carriage in the case of air-to-air missiles or canister launch in the case of ship-based systems can only be met by a lock-after-launch capability of the guidance system. On the other hand, seeker acquisition ranges may not be able to match the kinematic capabilities of the missile for a variety of reasons which may include adverse weather conditions and countermeasures. A number of operational aspects are addressed which are relevant to the design of midcourse guidance systems and the essential prerequisites for their application. Basic options of midcourse guidance, such as pure inertial, updated inertial, and aided inertial as well as the fundamental elements including inertial navigation and target prediction are discussed. Proper initialization and alignment of the guidance and navigation system are presented as further key issues. The alignment problem is defined and a number of methods to achieve adequate alignment are described. A review of different techniques for the performance assessment and the most important criteria for handover from midcourse to terminal guidance is presented. Author

N91-13437# Hughes Aircraft Co., Canoga Park, CA.
FLIGHT CONTROL DESIGN ISSUES IN BANK-TO-TURN MISSILES
W. A. KAUFMANN *In* AGARD, Missile Interceptor Guidance System Technology 16 p (SEE N91-13434 05-05) Sep. 1990
Also presented at the Workshop on Bank-to-Turn Controlled Terminal Homing Missiles, 19-20 Sep. 1984
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Design issues encountered in the synthesis of bank-to-turn autopilots are discussed for several proposed air-launched tactical guided missile configurations. Some approaches to dealing with these issues are also discussed. Much of the material was developed from experience gained in the design of an autopilot for a medium range air-to-air missile configuration incorporating an integral rocket-ramjet propulsion system. Therefore, emphasis is placed on that type of system. None of the bank-to-turn autopilots were flight tested, so only simulation results can be presented. The first issue discussed is why a designer would consider bank-to-turn control instead of the conventional skid-to-turn control used by most tactical missiles. The advantages and disadvantages of each approach are related to the performance of the airframe, propulsion, guidance, and autopilot subsystems. Several bank-to-turn control laws are presented. The relative merits of each are discussed with respect to the type of airframe, propulsion, and guidance required for the missile mission under consideration. Performance penalties are presented along with the advantages of including a skid-to-turn capability. Simulation studies have shown that some performance penalties may be incurred using bank-to-turn control for some types of missions, particularly for anti-air engagements, but these penalties are frequently small compared to other performance benefits derived from its utilization. These simulation studies and their results are discussed in appropriately general terms. Author

N91-13438# Electronique Marcel Dassault, Saint Cloud (France).
GUIDNACE SIMULATION MODEL OF ANTISEA-SKIMMER UTILIZATION FOR WEAPON SYSTEM DEFINITION
G. VALLAS and F. BUREL (Aerospatiale, Chatillon, France) *In* AGARD, Missile Interceptor Guidance System Technology 32 p (SEE N91-13434 05-05) Sep. 1990
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The way of quantifying the main parameters which size an antisea-skimmer missile by using numerical simulations is summarized. The ammunition-sizing can only be correctly defined when a sufficient number of iterations is achieved with the modelization tools, taking into account the specification of the threat and cost constraints. A method of evaluation of the main parameters is described and the primary function of the simulation during the various phases of the project is specified. Author

N91-13439# Royal Aerospace Establishment, Farnborough (England). Defensive Systems Dept.
ADVANCED MISSILE GUIDANCE
R. V. LAWRENCE *In* AGARD, Missile Interceptor Guidance System Technology 9 p (SEE N91-13434 05-05) Sep. 1990
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The problem of bringing a missile into collision with a moving target is discussed. The zero-control miss (ZCM) guidance concept is introduced. It is shown how errors in the estimates of the current system state and the future zero-control response of the system lead to errors in estimating the ZCM, and consequently how the missile suffers an aiming error. The missile generally suffers a miss, because of its limited ability to follow the changing error, due to restricted bandwidth and control saturation. Optimal control laws based on the ZCM are derived, and expressions for the idealized terminal miss obtained. The equations suggest how the target might choose an optimal evasion strategy to maximize the miss. This leads to some discussion of game theory, and the basis for multiple hypothesis guidance. Author

N91-13440# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
MICRO BASED TECHNOLOGY: A NEW TOOL FOR MISSILE GUIDANCE SYSTEM DESIGN AND VISUALIZATION
PAUL ZARCHAN *In* AGARD, Missile Interceptor Guidance System Technology 16 p (SEE N91-13434 05-05) Sep. 1990
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How simulation output can be generated and enhanced, in real time, with the computational horsepower and graphics visualization technology which is currently available with microcomputers is shown. Examples are presented which demonstrate how microcomputer based technology offers the designer a visualization which not only gives a deeper insight into the problem being solved, but in addition allows and encourages rapid iteration in order to get an acceptable design. Author

N91-13441# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
INTERACTIONS BETWEEN BATTLE MANAGEMENT AND GUIDANCE LAW DESIGN FOR A STRATEGIC INTERCEPTOR
OWEN L. DEUTSCH *In* AGARD, Missile Interceptor Guidance System Technology 16 p (SEE N91-13434 05-05) Sep. 1990
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The design of strategic interceptor systems presents many challenges. Considering a space-based system with orbiting interceptors, performance requirements may included near-zero miss distances, nearly complete coverage of many simultaneous threat launches, and successful interception against maneuvering targets. Cost constraints, on the other hand, will limit the interceptor weight and the numbers deployed. Also, the interceptor may operate at an acceleration disadvantage with respect to target, the range and time-to-go may not be precisely known, and there may be substantial prediction errors for the initial flyout. All of these factors conspire to place great importance on an integrated system design process that provides visibility into the interactions

between battle management functions (e.g., sensor management, weapon-target assignment, and fire control) and the interceptor guidance law and component technologies. In particular, guidance-related issues must be taken into account in the weapon-target assignment and fire-control functions of the battle manager. As an example, the minimum time for lateral guidance (with limited acceleration capability) to null out heading errors resulting from prediction error must be accounted for in the timeline decisions of the assignment and fire-control processes. The battle manager may select assignments that avoid unfavorable engagement geometries, where possible. Finally, the fire control manager may select between different guidance laws based on engagement conditions. Once there is visibility into the existence and phenomenology of potential guidance problems, there may be easy opportunities for correction by system-level solutions.

Author

N91-13442# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
GUIDANCE METHODS FOR TACTICAL AND STRATEGIC MISSILES
PAUL ZARCHAN *In* AGARD, Missile Interceptor Guidance System Technology 16 p (SEE N91-13434 05-05) Sep. 1990
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Methods of guidance which are applicable to both tactical and strategic missiles are reviewed. It is shown how the various guidance law technologies are related. 'Rules of thumb', which were originally developed for the tactical world, are extended for application to the strategic world not only to gain insight but also to predict strategic interceptor fuel consumption and performance. Numerous examples are presented to clarify and illustrate concepts.

Author

N91-14325# National Aeronautical Establishment, Ottawa (Ontario).
WIND TUNNEL INVESTIGATION AND FLIGHT TESTS OF TAIL BUFFET ON THE CF-18 AIRCRAFT
B. H. K. LEE, D. BROWN, M. ZGELA, and D. POIREL *In* AGARD, Aircraft Dynamic Loads Due to Flow Separation 26 p (SEE N91-14324 06-05) Sep. 990
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Investigations of tail buffet on the CF-18 were conducted at the National Aeronautical Establishment (NAE) and the Aerospace Engineering Test Establishment (AETE). Flow visualization of the vortex burst phenomenon was carried out in a low speed water tunnel using a modified 1/72 scaled plastic model. In wind tunnel tests, a rigid 6 percent model was used for measurements in the NAE 5 x 5 ft Trisonic Tunnel. Unsteady pressure measurements on the vertical fin were made by means of 24 fast response transducers on each surface. Results of the acceleration experienced by the fin are presented. The vortex flow structure was studied with the aid of a 49 pressure-sensor-rake mounted behind the fin. In addition to measuring steady pitot pressure values, to deduce pressure contours, unsteady pressure fluctuations were obtained from 13 fast response transducers. The leading edge extension (LEX) was also instrumented with pressure orifices and fast response transducers. The investigation was carried out with LEX fences on and off to note their effect on tail buffet loads. Flight tests were conducted at AETE on a test aircraft with accelerometers installed on the vertical fins and horizontal stabilators and strain gauges mounted on the aft fuselage structures and fin root attachment stubs. Flight test data are presented showing the effectiveness of the LEX fence in reducing aft fuselage structural response to buffet loads.

Author

N91-14326# McDonnell Aircraft Co., Saint Louis, MO.
A UNIFIED APPROACH TO BUFFET RESPONSE OF FIGHTER AIRCRAFT EMPENNAGE
M. A. FERMAN, S. R. PATEL, and N. H. ZIMMERMAN *In* AGARD, Aircraft Dynamic Loads Due to Flow Separation 18 p (SEE N91-14324 06-05) Sep. 1990
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A unified approach was derived for predicting buffet response of fighter aircraft empennage operating in high angle of attack maneuvering conditions. Since the advent of high angle of attack flight using controlled vortex flows, incidences of severe structural stress, and in some cases, damages have resulted. This was pronounced on twin tailed aircraft, including McDonnell's F-15 and F/A-18 aircraft which required structural beef-ups to their empennage. Two concepts are shown for predicting buffet response of empennage. The first approach uses elastically scaled models in wind tunnel tests to provide full scale prediction. The second approach is based on calculations using measured pressure data from wind tunnel tests. The latter method is more versatile. Detailed applications are shown for the F/A-18 empennage, while other applications at McDonnell are noted. This work covers many years and is believed to be a mature approach.

Author

N91-14327# National Aeronautical Establishment, Ottawa (Ontario).
EFFECTS OF TRAILING-EDGE FLAP ON BUFFET CHARACTERISTICS OF A SUPERCRITICAL AIRFOIL
B. H. K. LEE *In* AGARD, Aircraft Dynamic Loads Due to Flow Separation 14 p (SEE N91-14324 06-05) Sep. 1990
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The buffet characteristics of a 16 percent thickness-to-chord ratio supercritical airfoil were investigated in the High Reynolds Number Two-Dimensional Test Facility of the National Aeronautical Establishment. The trailing-edge flap dimension was 13.5 percent chord and it was deflected at various angles to study the effect of modifying the downstream pressure on controlling flow separation over the airfoil. The unsteady normal force was measured and the buffet boundary was determined from the divergence of the fluctuating normal force. The investigation was conducted quite deep into the buffet regime. Spectral analyses of the normal force were carried out and the frequencies of shock wave oscillations were measured. They were found to be Mach number dependent and varied between 50 to 80 Hz for M = 0.612 to 0.792. The effects of varying the flap angles on the shock wave position and drag of the airfoil were also investigated. Results for an off-design Mach number of 0.812 were given in some details.

Author

N91-14328# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Institut fur · Experimentelle Stroemungsmechanik.
EXPERIMENTAL INVESTIGATION OF BUFFET ONSET AND PENETRATION ON A SUPERCRITICAL AIRFOIL AT TRANSONIC SPEEDS
E. STANEWSKY and D. BASLER (holltonic G.m.b.H., Ottersberg, Germany, F.R.) *In* AGARD, Aircraft Dynamic Loads Due to Flow Separation 11 p (SEE N91-14324 06-05) Sep. 1990
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An experimental investigation was carried out on the supercritical airfoil CAST 7/DOA1 to determine the influence of three parameters, Mach number, angle of attack and most of all Reynolds number, on the buffet process and especially on the shock oscillation frequency and amplitude. For this investigation, the model was equipped with regular pressure orifices, dynamic pressure transducers and hot-film sensors, the latter utilized to determine transition location and regions of separation. The flow field was observed by a holographic high-speed real-time interferometer. The analysis of the results revealed that the buffet process is essentially driven by the interaction of the upper surface shock wave with the boundary layer, especially as it influences the development of the shock-induced separation bubble, and the resultant change in flow conditions at the airfoil trailing edge and

that, within the domain of intensive buffet, the shock oscillation frequency decreases with Reynolds number while the amplitude increases. It was furthermore found that the amplitude of the shock oscillation, hence the magnitude of the change in the dynamic load on the airfoil, seems to be dependent on the airfoil geometry. Author

N91-14329# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Aeroelasticity.
EXPERIMENTAL INVESTIGATIONS OF BUFFET EXCITATION FORCES ON A LOW ASPECT RATIO TRAPEZOIDAL HALF WING IN INCOMPRESSIBLE FLOW
P. BUBLITZ and H. ZINGEL (Deutsche Airbus G.m.b.H., Bremen, Germany, F.R.) In AGARD, Aircraft Dynamic Loads Due to Flow Separation 19 p (SEE N91-14324 06-05) Sep. 1990
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The problem of determining the steady and unsteady airloads is determined for swept wings of low aspect ratios at high incidences. Despite great progress in the field of computational fluid dynamics (CFD), this problem is not yet accessible to computer-supported methods, at least with respect to unsteady airloads. First, the information will be discussed which is necessary for buffeting prediction. The reasons for performing pressure measurements are outlined. Then, a brief description of the test set-up and instrumentation will be given. The steady and unsteady test results will be presented and their strong mutual interdependency will be demonstrated. The question as to whether it is possible to separate the unsteady pressures due to flow separation from those due to oscillatory motion of the model will be answered on the basis of experimental results. The usefulness of such investigations and their limitations with respect to the buffeting problem will be discussed. Author

N91-14330# Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.).
EXPERIMENTAL INVESTIGATION AND SEMI-EMPIRICAL PREDICTION OF THE DYNAMIC RESPONSE OF A LOW-ASPECT-RATIO TRAPEZOIDAL WING DUE TO FLOW SEPARATION
H. ZINGEL. In AGARD, Aircraft Dynamic Loads Due to Flow Separation 16 p (SEE N91-14324 06-05) Sep. 1990
(AGARD-CP-483) Copyright Avail: NTIS HC/MF A12;
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The buffet response of a low-aspect-ratio trapezoidal half-wing model was measured in the low speed wind tunnel of the DLR-Research Center in Goettingen at different model natural frequencies of pitch and roll both separately and coupled and at different angles of incidence up to 40 degrees. On the basis of linear aeroelastic equations of motion and measured structural dynamic and unsteady aerodynamic input data, the buffet response was calculated and compared with the measurement. The comparison shows a satisfactory coincidence. Consequently the adopted way for the semi-empirical calculation of the buffet response proves to be practicable. Author

N91-14332# Bristol Univ. (England). Dept. of Aerospace Engineering.
THE FORWARD MOUNTED SPOILER AS A SOURCE OF BUFFET EXCITATION
P. G. MYERS and D. L. BIRDSALL. In AGARD, Aircraft Dynamic Loads Due to Flow Separation 13 p (SEE N91-14324 06-05) Sep. 1990 Sponsored by Department of Trade and Industry, England
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Tests were made with fixed transition at low Reynolds Numbers (usually 0.56 x 10(exp 6), based on chord) on a wing with a spoiler of length 8 percent chord hinged at 13 percent chord. Different classes of flow leading to differing spoiler performance have been identified. However signal analysis has shown that the non-dimensional frequency n(sub 1) can be used to correlate results from these classes of flow and that the peak frequencies will lie within a narrow band. Now n(sub 1) = fl(sub b)/V where f is the frequency, l(sub b) the length of separated flow from the spoiler free edge lying over the wing (in the case of a closed bubble,

l(sub b) is the bubble length) and V the freestream velocity. Since n(sub 1) depends on l(sub b), a good idea of the nature of buffet excitation can be formed from an observation of the scale of separated flow lying over the wing. With one class of flow, there was no change in steady state lift following spoiler deployment, but the formation of a separation bubble over much of the wing upper surface led to a high level of buffet excitation. This underlines the difficulty of trying to deduce the fluctuating component of lift from a steady mean. Author

N91-14333# National Aerospace Lab., Amsterdam (Netherlands).
INVESTIGATION OF A SEMI-EMPIRICAL METHOD TO PREDICT LIMIT CYCLE OSCILLATIONS OF MODERN FIGHTER AIRCRAFT
J. J. MEIJER and R. J. ZWAAN In AGARD, Aircraft Dynamic Loads Due to Flow Separation 8 p (SEE N91-14324 06-05) Sep. 1990
(AGARD-CP-483) Copyright Avail: NTIS HC/MF A12;
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Requirements of modern fighter aircraft to operate with high maneuverability in the transonic speed regime may lead under certain conditions to limit cycle oscillations (LCO), produced by a structural/aerodynamic interaction. Conditions of transonic LCO are moderate angel of attack and Mach numbers ranging from 0.9 to 1.1. An analysis of steady wind tunnel data, obtained for a fighter type aircraft in a typical configuration, has indicated that shock-induced separation plays a dominant role. A semi-empirical prediction method is presented which makes use of these steady data, and some results are shown. Possibilities are discussed to extend the method to the use of unsteady wind tunnel data. Author

N91-14335*# General Dynamics Corp., Fort Worth, TX.
PREDICTIONS OF F-111 TACT AIRCRAFT BUFFET RESPONSE
ATLEE M. CUNNINGHAM, JR. and CHARLES F. COE (Coe Engineering, Inc., Los Altos, CA.) In AGARD, Aircraft Dynamic Loads Due to Flow Separation 16 p (SEE N91-14324 06-05) Sep. 1990
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A summary is presented for the prediction method development and correlations of predicted response with flight test measurements. The prediction method was based on refinements to the method described by Cunningham. One improvement made use of direct time integration of the correlated fluctuating pressure data to obtain buffet excitation for the various modes of interest. Another improvement incorporated a hybrid technique for scaling measured wind tunnel damping data to full-scale for the modes of interest. A third improvement made use of the diagonalized form of the fully coupled equations of motion. Finally, a mechanism was described for explaining an apparent coupling between the aircraft wing torsion modes and shock induced trailing edge separation that led to very high wing motion on the aircraft that was not observed on the wind tunnel model. Author

N91-14336# National Aeronautical Establishment, Ottawa (Ontario).
THE EFFECT OF WING PLANFORM ON LOW SPEED BUFFET
S. J. ZAN and D. J. MAULL (Cambridge Univ., England) In AGARD, Aircraft Dynamic Loads Due to Flow Separation 15 p (SEE N91-14324 06-05) Sep. 1990 Sponsored by Department of Trade and Industry, England
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A parametric experimental investigation into low speed buffet is presented. The influence of wing generalized mass, reduced frequency, aspect ratio, dynamic pressure and wing sweep on the buffet excitation parameter, the square root of nG(n), was studied for a simple wing model with sharp leading and trailing edges. The investigation was limited to buffeting response in the fundamental bending mode. The angle of incidence range for the experiments was 0 to 40 deg, however the paper will concentrate

on results at 10 deg incidence (near stall) and at 30 deg incidence. The influence of aspect ratio on the buffet excitation parameter was found to be significant at high incidences at values of reduced frequency below those common for subsonic flight. Author

N91-14337# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NEW METHOD TO DETERMINE IN WIND TUNNEL THE BUFFETING FORCES
ROGER DESTUYNDER and ROLAND BARREAU (Aerospatiale, Toulouse, France) In AGARD, Aircraft Dynamic Loads Due to Flow Separation 16 p (SEE N91-14324 06-05) Sep. 1990 In FRENCH; ENGLISH Summary
(AGARD-CP-483) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Among the usual criteria used to qualify the airplane buffet onset, it is classical to use the acceleration values measured at the pilot seat and limited at + or - 0.2g. This acceleration is the result of two excitation systems. The first one, due to the external forces, is created by the random unsteady field of pressure on the airplane and acting in a large frequency range. The second excitation is due to the induced pressures coming from the airplane motions and characterizing principally the eigen modes of the structure. It seems interesting to separate the two pressure fields to improve the buffet knowledge not only to have the correct buffet onset forces but also to obtain the forces distribution. For this target a closed loop system using a parameter of the wing (unsteady bending moment or accelerometers) permits in wind tunnel to reduce the wing motion introducing damping forces, in the model with the help of actuator. It is necessary to translate these results to the aircraft, the static deformation of the model and aircraft being similar. In a second phase, always under buffet conditions, sinusoidal excitations are applied on the wind tunnel model, giving a field of pressure uncorrelated with the buffeting pressure. In this manner the possibility of extraction, using an FFT, is given for the induced complex pressure and forces. Some examples are given. Author

N91-14338# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
COUPLED AERODYNAMIC LOADS DUE TO UNSTEADY STALL ON A LARGE ASPECT RATIO WING OSCILLATING AT GREAT AMPLITUDE [FORCES AERODYNAMIQUES COUPLEES DUES AU DECROCHAGE INSTATIONNAIRE SUR UNE AILE DE GRAND ALLONGEMENT OSCILLANT A GRANDE AMPLITUDE]
J.-J. COSTES and D. PETOT In AGARD, Aircraft Dynamic Loads Due to Flow Separation 15 p (SEE N91-14324 06-05) Sep. 1990 In FRENCH; ENGLISH Summary
(AGARD-CP-483) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Experimental results which were obtained on a rectangular wing oscillating in pitch around the quarter chord line are presented. Normal flow as well as skewed flow cases were investigated. The comparison with a simple theory used in helicopter applications showed the influence of the tip wing vortex and the importance, in the skewed flow case, of the component of the wind velocity directed along the wing span. Author

N91-14339# Lockheed Missiles and Space Co., Sunnyvale, CA.
UNSTEADY SEPARATED FLOW PHENOMENA CAUSING SELF-EXCITED STRUCTURAL OSCILLATIONS
L. E. ERICSSON In AGARD, Aircraft Dynamic Loads Due to Flow Separation 16 p (SEE N91-14324 06-05) Sep. 1990
(AGARD-CP-483) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Because of steadily increasing performance demands both aircraft and missiles operate at high angles of attack where separated flow often has a dominant influence on especially the unsteady aerodynamics. The penetration of the buffet boundary usually changes the structural response from the buffet-type to the self-excited type. This transfer occurs when the structural response starts interacting with the unsteady flow separation, generating negative aerodynamic damping. Separated flow aerodynamics are usually very nonlinear, and the self-excited

response frequently takes the form of a limit-cycle oscillation. Author

N91-22107# National Research Council of Canada, Ottawa (Ontario).
OSCILLATORY TEST TECHNIQUES
E. S. HANFF and C. O. OLEARY (Royal Aircraft Establishment, Bedford, England) In AGARD, Special Course on Aircraft Dynamics at High Angles of Attack: Experiments and Modelling 12 p (SEE N91-22104 14-05) Mar. 1991
(AGARD-R-776) Copyright Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A small-amplitude oscillatory wind tunnel test technique and some small amplitude oscillatory rigs for the measurement of stability derivatives are discussed. The concentration here is on the forced-oscillation technique which is commonly used to obtain stability data. One degree of freedom oscillatory rigs and a recently developed pitch/yaw rig are described as well as the data reduction procedures used and to obtain the pertinent stability derivatives. Author

N91-23113# British Aerospace Public Ltd. Co., Prestcn (England). Military Aircraft Div.
THE DEVELOPMENT OF ALTERNATE CRITERIA FOR FBW HANDLING QUALITIES
J. C. GIBSON In AGARD, Flying Qualities 13 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Provision of robust flight control systems and structural mode stability margins and carefree handling in highly unstable combat aircraft with a wide range of store loading requires new methods for handling qualities optimization. The possibilities for new control modes and task-tailored handling were greatly enhanced by modern controls. This has led to development of many alternate criteria which were tried and tested in two digital fly by wire (FBW) research aircraft, the Experimental Aircraft Program (EAP) and Jaguar FBW, and were further developed for use in European fighter aircraft (EFA). They cover the field of flight path and attitude bandwidth, tracking dynamics and sensitivity, pilot-induced oscillation (PIO) prevention, and enhanced lateral directional damping. Derived as design guidelines with the facility to design for optimum rather than merely acceptable handling, more research is needed into formal boundaries for levels 1, 2, and 3 specifications. The criteria are reviewed and some are illustrated by example. Author

N91-23114# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.
DEVELOPMENT OF MIL-8785C INTO A HANDLING QUALITIES SPECIFICATION FOR A NEW EUROPEAN FIGHTER AIRCRAFT
E. BUCHACKER, H. GALLEITHNER, R. KOEHLER, and M. MARCHAND In AGARD, Flying Qualities 16 p (SEE N91-23108 15-05) Feb. 1991
(AGARD-CP-508) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

For the development of the Tornado, which started in the sixties, a draft version of MIL 8785B was used as a guideline and specification for the flying qualities the airplane should have. No consideration was given at that time to the fact that requirements, which were based on mathematical models of the airplane, only considered the flight mechanics of the bare airframe. In most cases, a new airplane is sold on performance promises. The fact that a pilot has to be able to fly an airplane safely and efficiently in order to achieve full performance, especially in a combat airplane, is often forgotten. The Armed Forces are repeatedly disappointed with their aircraft when it becomes clear that it is impossible to achieve the promised performance for reasons of conflicting flying qualities issues which demand other than performance optimal trim schedules. This, coupled with the fact that there was not a lot of flying qualities research within the nations participating in the Tornado program, led to the situation that it is was more or less only during flight tests that the user realized the problems involved with full authority full time flight control systems. In the meantime, however, some research efforts have been initiated by

government and industry that have provided some second thoughts on flying qualities requirements for highly augmented airplanes with a basically unstable pitch axis. Together with industry, the four nations involved in the European Fighter Aircraft (EFA) Program decided to initiate an effort to generate a flying qualities specification for EFA based on the MIL-F-8785C. Some of the issues discussed include the following: the equivalent system approach, high order requirements for the pitch axis, the carefree handling issue, roll performance, small lateral directional inputs, air combat, and stall and spin.   Author

N91-23116# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).
HANDLING QUALITIES OF HIGHLY AUGMENTED UNSTABLE AIRCRAFT SUMMARY OF AN AGARD-FMP WORKING GROUP EFFORT
HORST WUENNENBERG   In AGARD, Flying Qualities 6 p (SEE N91-23108 15-05)   Feb. 1991
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    Methods and criteria which were found to be useful as design guides and for the evaluation of handling qualities of highly augmented aircraft are presented. It was the unanimous opinion of the members of the working group that no one method or criterion is adequate by itself, and that several or even all of the recommended criteria should be checked. Experience has shown that one metric may not show a deficiency that will be exposed by other criteria. Alternately, a configuration that passes several of the proposed criteria has a high probability of being accepted as desirable by most pilots. The major topics covered by the working group's report are listed.   Author

N91-23117#   Wright   Research   Development   Center, Wright-Patterson AFB, OH.
THE HANDLING QUALITIES OF THE STOL AND MANEUVER TECHNOLOGY DEMONSTRATOR FROM SPECIFICATION TO FLIGHT TEST
DAVID J. MOORHOUSE, KEVIN D. CITURS, RICHARD W. THOMAS, and MARK R. CRAWFORD (Air Force Flight Test Center, Edwards AFB, CA.)   In AGARD, Flying Qualities 9 p (SEE N91-23108 15-05)   Feb. 1991
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    The STOL and Maneuver Technology Demonstrator (S/MTD) development from the initial specification through current flight test results is discussed. Lessons learned with respect to individual specification criteria and design methodology are presented. Two areas are identified in which it is considered that the current criteria are inadequate: pitch axis requirements as a function of touchdown dispersion and the directional axis requirement for target tracking.   Author

N91-23119#   Royal   Aerospace   Establishment,   Bedford (England).
HANDLING QUALITIES GUIDELINES FOR THE DESIGN OF FLY-BY-WIRE FLIGHT CONTROL SYSTEMS FOR TRANSPORT AIRCRAFT
O. P. NICHOLAS, H. T. HUYNH, W. P. DEBOER, J. A. J. VANENGELEN, and D. SHAFRANEK (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany, F.R.)   In AGARD, Flying Qualities 12 p (SEE N91-23108 15-05)   Feb. 1991
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    The work of the GARTEUR Flight Mechanics Action Group 01 is summarized. The objectives, which concentrated on longitudinal control, are outlined. The flight control systems and the simulator trials are discussed. Existing handling qualities criteria and the Action Group's tentative proposals for handling qualities measures which can be applied to flight path control and system changeover are assessed. Finally, the Group's guidelines and recommendations for further work are reviewed.   Author

N91-23123#   National Aeronautical Establishment, Ottawa (Ontario). Flight Research Lab.
AN INVESTIGATION INTO THE USE OF SIDE-ARM CONTROL FOR CIVIL ROTORCRAFT APPLICATIONS
S. W. BAILLIE and S. KERELIUK   In AGARD, Flying Qualities 12 p (SEE N91-23108 15-05)   Feb. 1991   Prepared in cooperation with FAA, Atlantic City, NJ
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    An evaluation of the handling qualities of civil rotorcraft incorporating force or displacement sensing side-arm controllers with varying degrees of control integration was carried out on the NAE Bell 205 Airborne Simulator. Evaluators were certification pilots from the FAA and Transport Canada. The results indicate that integrated 4-axis side-arm control is a viable option for civil rotorcraft operations, even when used in conjunction with very low levels of stability and control augmentation.   Author

N91-23124#   National Aeronautical Establishment, Ottawa (Ontario).
DETERMINATION OF DECISION-HEIGHT WINDOWS FOR DECELERATING IMC APPROACHES IN HELICOPTERS
ROGER H. HOH (Hoh Aeronautics, Inc., Lomita, CA.), S. W. BAILLIE, S. KERELIUK, and JOSEPH J. TRAYBAR   In AGARD, Flying, Qualities 17 p (SEE N91-23108 15-05)   Feb. 1991 Prepared in cooperation with Federal Aviation Administration, Atlantic City, NJ
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    The basic limitations were defined of the pilot plus rotorcraft in making the transition from a very low decision height to a steady hover over the helipad. The term 'decision-height window' is defined as the limits of glideslope/localizer tracking errors, and groundspeed variations, that can exist at breakout to allow a safe visual transition to hover. The dimensions of the decision-height window can have a significant impact on the required rotorcraft handling qualities, and for setting autopilot coupler and flight director performance standards for decelerating instrument approaches in rotorcraft.   Author

N91-23125# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).
INTEGRATION OF HANDLING QUALITY ASPECTS INTO THE AERODYNAMIC DESIGN OF MODERN UNSTABLE FIGHTERS
PETER MANGOLD   In AGARD, Flying Qualities 30 p (SEE N91-23108 15-05)   Feb. 1991
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    The following subject areas are covered: flightmechanical design of unaugmented stable configurations; design criteria for modern configurations with unstable characteristics in pitch; development of specific criteria for modern fighter configurations; and aerodynamic/flightmechanical pecularities of configurations.
                    Author

N91-25139#   National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
A KNOWLEDGE-BASED SYSTEM DESIGN/INFORMATION TOOL FOR AIRCRAFT FLIGHT CONTROL SYSTEMS
DALE A. MACKALL and JAMES G. ALLEN (Draper, Charles Stark Lab., Inc., Cambridge, MA)   In AGARD, Knowledge Based System Applications for Guidance and Control 14 p (SEE N91-25121 17-04)   Apr. 1991
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    Research aircraft have become increasingly dependent on advanced electronic control systems to accomplish program goals. These aircraft are integrating multiple disciplines to improve performance and satisfy research objective. This integration is being accomplished through electronic control systems. Systems design methods and information management have become essential to program success. The primary objective of the system design/information tool for aircraft flight control is to help transfer flight control system design knowledge to the flight test community.

By providing all of the design information and covering multiple disciplines in a structured, graphical manner, flight control systems can more easily be understood by the test engineers. This will provide the engineers with the information needed to thoroughly ground test the system and thereby reduce the likelihood of serious design errors surfacing in flight. The secondary object is to apply structured design techniques to all of the design domains. By using the techniques in the top level system design down through the detailed hardware and software designs, it is hoped that fewer design anomalies will result. The flight test experiences are reviewed of three highly complex, integrated aircraft programs: the X-29 forward swept wing; the advanced fighter technology integration (AFTI) F-16; and the highly maneuverable aircraft technology (HiMAT) program. Significant operating technologies, and the design errors which cause them, is examined to help identify what functions a system design/informatin tool should provide to assist designers in avoiding errors.   Author

N91-26150#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
MANUAL ON THE FLIGHT OF FLEXIBLE AIRCRAFT IN TURBULENCE
JOHN C. HOUBOLT, ed.   May 1991   173 p   In FRENCH and ENGLISH
(AGARD-AG-317; ISBN-92-835-0617-0; AD-A237949)   Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
In the course of the past few years, the Structures and Materials Panel of AGARD has considered a number of aspects of the turbulence problem as it affects aircraft. The presented publication constitutes a review document in which is distilled the experience of specialists from amongst the aircraft manufacturing nations of NATO. It is aimed at those in design offices concerned with the problems of turbulences and resultant loads. For individual titles, see N91-26151 through N91-26158.

N91-26152#   National   Aerospace   Lab.,   Emmeloord (Netherlands).
ACQUISITION OF STATISTICAL GUST LOAD DATA BY COMMERCIAL AIRPLANES
J. B. DEJONGE   In AGARD, Manual on the Flight of Flexible Aircraft in Turbulence p 31-40 (SEE N91-26150 18-08)   May 1991
(AGARD-AG-317)   Copyright   Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Knowledge about the nature and properties of atmospheric turbulence was and is being obtained from measurements with specially instrumented 'research' aircraft. On the other hand, statistical information on the frequency of occurrence and intensity of gusts is largely based on relatively simple measurements, using simple recording devices, obtained over a period of more than half a century in commercial aircraft during normal operations. These measurements are of an indirect nature, that means not the gust velocity itself but the aircraft response due to the gust is measured. Universally, the c.g vertical acceleration was taken as the response quantity to be measured. This choice is quite understandable: in the first place the incremental vertical acceleration is directly proportional to the incremental lift force due to the gust and thus an obvious measure of gust strength; in the second place, the c.g acceleration is easy to measure with simple and reliable instrumentation. A brief review is presented of 'historical' acceleration recording programs carried out by NACA (and its successor NASA) and the RAE. Next, more recent recording programs making use of acceleration data recorded with so-called ACMS (Aircraft Collision Monitoring System) is discussed. The methods used to reduce the acceleration data to 'gust velocities' is briefly described with specific reference to the differences in the various programs. In a summarizing discussion the possibility and desirability to extend the gust data base using 'routine' ACMS recorded c.g acceleration data will come forward. To compared data from different sources it is essential that agreement on data reduction procedures be reached. It is argued that for this, a reduction method based on a continuous gust concept and an aircraft response including pitch appears the most appropriate.
          Author

N91-26153#   Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
IMPROVED REDUCTION OF GUST LOADS DATA FOR GUST INTENSITY
GABRIEL COUPRY   In AGARD, Manual on the Flight of Flexible Aircraft in Turbulence p 41-57 (SEE N91-26150 18-08)   May 1991
(AGARD-AG-317)   Copyright   Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The reduction of load factor data to turbulence data, in view of proposing improved statistics of gusts is examined. The different methods available to achieve this process are reviewed. A comprehensive analysis is made to highlight the shortcomings and their consequences on the regulations. The renewal of interest in turbulence comes from the new problems industry has to face: large aspect ratio commercial aircraft, penetration of military aircraft at low altitude and high velocity, active control of flight and of loads, and justification of increased fatigue life of existing commercial aircraft. The philosophy underlying the data reduction is examined, and it raises the question of the meaning of a gust deduced from acceleration data. Some of the methods are then described. Finally, the shortcomings (especially those due to the effect of pilot maneuvers) and their impact on the requirements are highlighted.   Author

N91-26154#   Federal Aviation Administration, Seattle, WA.
CERTIFICATION PROCEDURES AND REQUIREMENTS
TERENCE J. BARNES and VICTOR CARD (Civil Aviation Authority, Redhill, England)   In AGARD, Manual on the Flight of Flexible Aircraft in Turbulence p 58-65 (SEE N91-26150 18-08)   May 1991
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The mathematical models of aircraft and atmospheric turbulence and their rationale are described. Emphasis is given to the revisions and refinements made starting in the 1920s up to the present time. The major steps, beginning with the sharp edged gust formulate, are traced through the modified formula specifying ramp-platform gusts and later to one-minus-cosine gusts and finally to criteria for continuous gust analyses. The influence of aircraft design developments on design criteria development needs is also addressed. A brief summary of military criteria is included. Significant discussion is devoted to measurements that have been made, including onboard recordings, to provide an extensive data base of: (1) atmospheric turbulence experience in routine flight operations; (2) specifically-instrumented research aircraft measurements to provide atmospheric characterization for various flight and meteorological conditions; and (3) comparisons of measured and calculated aircraft responses in turbulence.
          Author

N91-26155#   Deutsche Airbus G.m.b.H., Hamburg (Germany, F.R.).
GUST DESIGN PROCEDURES
HELMUT LUSEBRINK and RAINER SONDER   In AGARD, Manual on the Flight of Flexible Aircraft in Turbulence p 66-116 (SEE N91-26150 18-08)   May 1991
(AGARD-AG-317)   Copyright   Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
One of the most important structural design conditions for civil and military transport aircraft are the vertical and lateral gust loads, which the aicraft experiences, when flying in a turbulent atmosphere. Complying with U.S. and European Airworthiness Regulations, the aircraft manufacturer has to consider two basic gust concepts or models: the discrete gust model, and the continuous turbulence power spectrum density (PSD) gust models. During the years of application, the gust shape and intensities changed and are now the well-known truncated 1-cos shape with a constant gust gradient distance (USA/Europe) or a variable one for U.K. The aircraft manufacturer has to apply both the Discrete and one of the PSD methods to find the most critical one for each aircraft component and then design the structure for the envelope loads. The dynamic gust load analysis should be performed in the frequency domain by means of transfer or frequency response function. The PSD methods cannot be directly

applied to nonlinear dynamic models. Approximative methods which have the statistical characteristics given in the requirements have to be applied. Acceptance of the airworthiness authorities will be obtained, if the linearization methods provide conservative design loads. The influence of automatic control systems on structural loads due to discrete gust and PSD methods, including their failed and degraded states, has to be investigated. From the variety of unsteady aerodynamic theories, the 3-dimensional doublet lattice method was selected. Time plane analysis of the dynamical gust problem has to be performed for modern aircraft with digital flight control and alleviation systems containing a variety of nonlinear elements. For this purpose, the unsteady aerodynamic forces have to be transformed from the frequency plane to the time plane. This is achieved by approximating the elements of the modalized unsteady aerodynamic force matrix by PADE-type approximants, which allow generations of the Delta-pulse response matrix kernels used in the convolution integral representation of the unsteady aerodynamic forces in the time plane.   B.G.

N91-26156# Boeing Canada, Toronto (Ontario).
ANALYSIS BY THE STATISTICAL DISCRETE GUST METHOD
JOHN GLASER   *In* AGARD, Manual on the Flight of Flexible Aircraft in Turbulence p 117-134 (SEE N91-26150 18-08)   May 1991
(AGARD-AG-317) Copyright Avail: NTIS HC/MF A08;
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The general formulation of the Statistical Discrete Gust (SDG) model for atmospheric turbulence proposed by J. Glynn Jones for the von Karman spectrum in its higher frequency range is defined and illustrative results are presented. The equivalence of the two models, SDG PSD (power spectrum density), is confirmed by showing that the dynamic response ratios, bar gamma/bar A, for both rigid and elastic aircraft loads are reasonably constant and approximately equal to the expected value of 10.4 ft.(sup 1/3). Although the SDG method is more complex to implement and more costly to run than the PSD method of FAR/JAR 25, its implementation for routine calculations of linear aircraft structures is confirmed by the present study. The SDG model offers an alternative time domain analysis method for calculating response loads to continuous turbulence for both linear and nonlinear aircraft structures (active controls). In addition, the ADG method can potentially provide a more representative model for extreme gust processes, but this requires further development.   Author

N91-26157#   National   Aerospace   Lab.,   Amsterdam (Netherlands).
MATCHING OF PSD-DESIGN LOADS
ROEL NOBACK   *In* AGARD, Manual on the Flight of Flexible Aircraft in Turbulence p 135-149 (SEE N91-26150 18-08)   May 1991
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The PSD (power spectrum density) method as described in the requirements produces the design loads, however not the mutual relation or phasing. For stressing purposes and also for testing, realistic load combinations or design load conditions are needed. In the discrete gust case design load conditions almost naturally consist of the loads occurring at the same time, usually at the time that one of the loads reaches its maximum values. The PSD method is based on statistical considerations and PSD degree load conditions should have the same basis. A method to generate design load conditions or to match design loads, obtained with the design envelope analysis of the PSD method is described. The method is based on the statistical correlation between outputs (loads) of a linear system, the aircraft, to a common input, atmospheric turbulence. For design loads obtained with the mission analysis such a direct relationship does not exist and the generation of design load conditions is more involved and will not be treated here. An approximate method is proposed. A design load condition should be in equilibrium, that is the equations of equilibrium should be valid for these loads. This is proven for the design load conditions as generated with the described method. The derivation of the design load conditions will be given for the case that only two loads are involved. The derivation for the general case with N loads is given. Only the results are presented.   Author

N91-26158#   Civil Aviation Authority, Redhill (England).
TRENDS IN CERTIFICATION PROCEDURES AND DESIGN ANALYSIS
VICTOR CARD and TERENCE J. BARNES (Federal Aviation Administration, Seattle, WA.)   *In* AGARD, Manual on the Flight of Flexible Aircraft in Turbulence p 150-160 (SEE N91-26150 18-08) May 1991
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In the past various gust load formulas were developed for the calculation of design gust loads on aircraft. Since the time it was first published in 1954, the alleviation factor approach of Pratt and Walker has gained almost universal acceptance. The problem of using the gust load requirements is discussed. Discrete gust statistics and power spectral density (PSD) concept are explained.   B.G.

N92-12458# Sener Ingenieria y Sistemas S.A., Madrid (Spain).
A METHODOLOGY FOR SOFTWARE SPECIFICATION AND DEVELOPMENT BASED ON SIMULATION
G. FERNANDEZDELAMORA, R. MINGUEZ, S. KHAN, and J. R. VILLA   *In* AGARD, Software for Guidance and Control 5 p (SEE N92-12449 03-61) Sep. 1991
(AGARD-CP-503) Copyright Avail: NTIS HC/MF A11;
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AGARD/Scientific Publications Executive
The methodology is discussed which is presently used for specification and development of guidance and control software (GCS) referred to as the phased approach. This methodology is shown to present basic shortcomings in relation with the requirements specification phase: long development time, reverse engineering tasks, and inadequate handling of errors. In order to solve these problems, a new methodology, the simulation based approach, is presented. This new methodology is based on the fact that any requirements specification for control software is preceded by a simulation task, that includes the design, code, and test of the GCS. As a consequence, the GCS is developed twice, once in the simulation, and then in the flight software. The new methodology proposed to build the GCS only once, and through the use of two basic tools: simulation and rapid prototyping, cuts through the main shortcomings of the phased approach.   Author

N92-12466# Royal Aerospace Establishment, Bedford (England). Flight Systems Dept.
THE DEVELOPMENT OF A REQUIREMENT SPECIFICATION FOR AN EXPERIMENTAL ACTIVE FLIGHT CONTROL SYSTEM FOR A VARIABLE STABILITY HELICOPTER: AN ADA SIMULATION IN JSD
GARETH D. PADFIELD, STEPHEN P. BOWATER, ROY BRADLEY, and ALAN MOORE (LBMS Proprietary Ltd. Co., London, England) *In* AGARD, Software for Guidance and Control 13 p (SEE N92-12449 03-61) Sep. 1991
(AGARD-CP-503) Copyright Avail: NTIS HC/MF A11;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
In the field of helicopter flight control and handling qualities, the potential benefits offered by Active Control Technology (ACT) are considerable. The described ATC system include full authority fly by wire actuation and fail-operate/fail-safe hardware architecture. The impact of the required functionality on the systems requirements dictated a need for a precise yet versatile specification of the system, and Jackson System Development (JSD) was selected as a design method since it provides a formal modeling of the pilot interface, and also operates at a sufficient level of detail necessary to ensure completeness and resolution of ambiguities.   Author

N92-14065# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel

KNOWLEDGE BASED SYSTEM APPLICATIONS FOR GUIDANCE AND CONTROL

FRANCO CANEPA (Alenia, Torino, Italy) Jul. 1991 18 p Presented at the 51st Symposium, Madrid, Spain, 18-21 Sep. 1990

(AGARD-AR-284; ISBN-92-835-0624-3; CP-474; AD-A241357) Copyright Avail: NTIS HC/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

An evaluation of the technical papers contributed as part of the Guidance and Control Panel's symposium on knowledge based system applications is presented. The objectives of the symposium are outlined and each of the five sessions comprising the symposium is briefly summarized. These sessions addressed representative guidance and control applications, design concepts and synthesis techniques, related methods and techniques, information processing and system architecture, and mechanization and integration issues. General conclusions related to integration between artificial intelligence (AI) technologies and between AI and conventional technologies are given. All papers presented at the symposium were compiled as conference proceedings AGARD-CP-474. M.G.

N92-17166# Army Aviation Systems Command, Moffett Field, CA. Aeroflightdynamics Directorate.

SYSTEM IDENTIFICATION REQUIREMENTS FOR HIGH-BANDWIDTH ROTORCRAFT FLIGHT CONTROL SYSTEM DESIGN

MARK B. TISCHLER In AGARD, Rotorcraft System Identification 12 p (SEE N92-17153 08-05) Oct. 1991 Previously announced in IAA as A90-45333

(AGARD-LS-178) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The application of system identification methods to high-bandwidth rotorcraft flight control system design is examined. Flight test and modeling requirements are illustrated using flight test data from a BO-105 hingeless rotor helicopter. The proposed approach involves the identification of nonparametric frequency-response models, followed by parametric (transfer function and state space) model identification. Results for the BO-105 show the need for including coupled body/rotor flapping and lead-lag dynamics in the identification model structure to allow the accurate prediction of control system bandwidth limitations. Lower-order models are useful for estimating nominal control system performance only when the flight data used for the identification are bandlimited to be consistent with the frequency range of applicability of the model. The flight test results presented in this paper are consistent with theoretical studies by previous researchers. Author

N92-18791*# Eidetics International, Inc., Torrance, CA.

AERODYNAMIC CONTROL OF FIGHTER AIRCRAFT BY MANIPULATION OF FOREBODY VORTICES

GERALD N. MALCOLM and T. TERRY NG In AGARD, Manoeuvring Aerodynamics 22 p (SEE N92-18778 09-05) Nov. 1991

(Contract NAS2-13155; F33615-86-C-3623) (AGARD-CP-497) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Methods of enhancing aircraft controllability and maneuverability at high angles of attack by manipulating the forebody vortices are discussed. Pneumatic control methods including jet blowing, slot blowing, and suction, and mechanical control methods using forebody and nose tip strakes are reviewed. The potential of various control devices in controlling the forebody flow, and thus, providing controlled yawing moments at high angles of attack are illustrated using wind tunnel results from a generic fighter and water tunnel results from an F/A-18. Author

N92-18792# Wright Lab., Wright-Patterson AFB, OH.

FOREBODY VORTEX CONTROL AEROMECHANICS

ROBERT W. GUYTON, RUSSELL F. OSBORN, and SCOTT P. LEMAY In AGARD, Manoeuvring Aerodynamics 14 p (SEE N92-18778 09-05) Nov. 1991

(AGARD-CP-497) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Forebody vortex flow characteristics are discussed in terms of the forebody flowfield aerodynamics and the impact of this flow on the resulting forces and moments that limit combat maneuverability. Test results are presented for several pneumatic forebody vortex control designs applied to a 1/8 scale X-29 model, a 1/15 scale F-16 model, and a 55 degree cropped delta/chined forebody model representative of future fighter configurations. Author

N92-18793# Royal Aerospace Establishment, Farnborough (England). Aerodynamics Dept.

DYNAMIC WIND TUNNEL TESTS ON CONTROL OF FOREBODY VORTICES WITH SUCTION

A. JEAN ROSS, E. B. JEFFERIES, and GERALDINE F. EDWARDS In AGARD, Manoeuvring Aerodynamics 12 p (SEE N92-18778 09-05) Nov. 1991

(AGARD-CP-497) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Extensive static and dynamic experiments were made in low speed wind tunnels to investigate the possibility of using the yawing moment due to asymmetric forebody vortices for control at high angles of attack. The relative positions of the two vortices arising near the nose apex can be changed by applying differential suction through two small holes very near the tip. The resulting forces and moments measured in static tests were analyzed for the effects of forebody diameter and slenderness ratio. The Royal Aeronautical Establishment (RAE) High Incidence Research Model was controlled successfully on a free-to-yaw rig, indicating that the system could be used in flight. However, it could be expected that there are significant lags in the generation of the aerodynamic forces and moments. Experiments were conducted on a simple missile model mounted on a string rig, to measure the responses in yawing moment and sideforce due to sinusoidal variation over a range of frequencies of flow rates through suction holes. The implications of these results for the proposed free-flight model tests are discussed. Author

N92-18795# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).

AEROSERVOELASTIC STABILITY OF AIRCRAFT AT HIGH INCIDENCE

JUERGEN BECKER In AGARD, Manoeuvring Aerodynamics 20 p (SEE N92-18778 09-05) Nov. 1991

(AGARD-CP-497) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The aeroservoelastic stability of a fighter type aircraft is investigated at high angle of attack. The effects of nonlinear, incidence dependent unsteady aerodynamic forces of elastic modes and of control surface deflections on the structural coupling are demonstrated for low and high subsonic speeds for different incidences. The difference of open loop frequency response functions calculated with linear and with high angle of attack unsteady aerodynamics documents the necessity of the introduction of high incidence effects for aeroservoelastic stability calculations. Nonlinear effects are introduced using unsteady pressures of wind tunnel experiments on an oscillating model by correction of theoretical pressures. Author

N92-20026# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel Working Group 9.
VALIDATION OF FLIGHT CRITICAL CONTROL SYSTEMS
GORDON BELCHER, ed., DUNCAN E. MCIVER, ed., and KENNETH J. SZALAI, ed. Dec. 1991 136 p
(AGARD-AR-274; ISBN-92-835-0650-2) Copyright Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The objectives of the research is the following: (1) to provide guidance to those concerned in the Flight Critical Control System (FCCS) validation, namely systems designers and certification authorities; and (2) to identify the areas of research which need to be explored to enable validation of the next generation of FCCS. An attempt was made to review all flight critical control system validation activities which had been completed or were under active consideration, in Europe and the U.S.   Author

09

RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tubes; and aircraft engine test stands.

N89-10054# Boeing Aerospace Co., Seattle, WA.
RANGE DELAY TECHNIQUES FOR RADAR TARGET SIMULATORS
LELAND C. BUSE In AGARD, Guidance and Control Systems Simulation and Validation Techniques 9 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Copyright Avail: NTIS HC A07/MF A01

It was recognized that the Radar Guided Seeker and countermeasure development using flight tests as a primary evaluation tool is costly and insecure from interception of signal and telemetry emenations. Radar Target Simulators were developed which provide the capability both to evaluate actual radar guided seeker hardware and software and to evaluate countermeasures against the actual seeker hardware in a secure environment. Experience with these simulators has demonstrated that with adequate simulator hardware, valid closed-loop performance evaluations can be conducted which will accurately reflect flight test performance. A critical issue in the implementation of such systems is the simulation of radar pulse range delay. This must be accomplished with sufficient fidelity to represent a range-delayed target of ECM signal credible to modern seeker signal processors. Various range delay techniques as applied to Radar Target Simulators are presented. In particular, a digital approach to the solution of the range delay problem is developed from basic concepts through actual hardware implementation.   Author

N90-10064# Selenia S.p.A., Rome (Italy). Missile Systems Div.
WIND TUNNEL TESTS: THE ROLE OF THE MODEL
S. MAZZUCA and B. PIACENTINI In AGARD, Stability and Control of Tactical Missile Systems 10 p (SEE N90-10050 01-08) Mar. 1989
(AGARD-CP-451) Copyright Avail: NTIS HC A15/MF A02

The role of the model in the overall wind tunnel test program is highlighted. Depending on the specific task to be achieved (i.e., improvement of an existing missile or a new missile development), the cost-effectiveness analysis leads to the best solution in terms of: scale of the model; number of configurations to be tested; degree of likelihood; wind tunnel facilities to be used; interoperability among different test sites; overall test time; and test time of each subphase. A further very important role is related to the test philosophy adopted in order to minimize the number of measurements while retaining the capability to obtain from the test useful information. A proper design of the model can fulfill these constraints, minimizing overall test time and the related costs.   Author

N90-10883# Naval Air Test Center, Patuxent River, MD.
AIR COMBAT ENVIRONMENT TEST AND EVALUATION FACILITY (ACETEF)
R. R. SMULLEN and S. D. HARRIS In AGARD, Flight Test Techniques 3 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03

Recent combat experience has brought to light a critical need to assess the mission effectiveness of Naval aviation weapons systems and vehicles against a myriad of new threats. Flight testing is the primary source of data on the effectiveness of our aircraft and weapons, but flight testing is costly, and limited to only a few of the most crucial questions. Flight testing is also inherently a public event; it can be observed with impunity. Hence, flight testing is patently unsatisfactory for dealing with some issues related to national security interests. Senior decision-makers in the Department of Defense (DOD) require objective, quantitative assessments of the effectiveness of the weapons and people against literally thousands of possible combinations of threat and contingency planning conditions. A revolutionary approach is needed to obtain the requisite data. The Naval Air Test Center (NAVAIRTESTCEN) has begun to develop an innovative system, known as the Air Combat Environment Test and Evaluation Facility (ACETEF), to meet this need.   Author

N90-10886# Aerodata Flugmesstechnik G.m.b.H., Brunswick (Germany, F.R.).
REALTIME PROCESSING AND DISPLAY
A. REDEKER In AGARD, Flight Test Techniques 7 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03

Concept and realization of a data system for airborne research and development applications are presented. Aspects of hardware architecture and software organization are discussed. The system is used for prototype testing and certification and is also layed out for the operation of research aircraft, where sensor configurations and measuring instruments are varying from one experiment to another. All system users have access to a pool of common sensor- and software resources. Special hard- and software interfaces were defined for a simple integration of individual sensor signals and computation algorithms. The system performs realtime processing, recording, and on-line monitoring of sensor data. It is the aim of the system design to enable the operator to perform quick error detection as well as to optimize the flight conditions for an experiment. Examples for flight-mechanical and meteorological system applications are given.   Author

N90-10887# British Aerospace Public Ltd. Co., Preston (England). Flight Test Instrumentation Data Processing Dept.
FLIGHT TEST INSTRUMENTATION AND DATA PROCESSING AT BRITISH AEROSPACE, WARTON, U.K.
ROGER E. PORTER and MICHAEL F. ARMOUR In AGARD, Flight Test Techniques 16 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03

British Aerospace Warton was engaged in the development and testing of a wide range of military fighter aircraft including Jaguar, Tornado and the E.A.P. During the next decade Warton will be a major flight test center for the European Fighter Aircraft (EFA). An overview is given of the instrumentation and data processing facilities in current use, planned development for the next 10 years covering the proposed instrumentation system for EFA. It describes the ground station, computing hardware, specialized analysis capability, onboard equipment, the extensive use of telemetry for real time processing and intermaneuvre analysis in real time. Also included are the facilities for integration of airborne data aquisition systems, together with procurement, automated calibration, and design and development.   Author

09 RESEARCH AND SUPPORT FACILITIES (AIR)

N90-15939# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON ADVANCES IN CRYOGENIC WIND TUNNEL TECHNOLOGY
Nov. 1989 373 p Course held in Rhode-Saint-Genese, Belgium, 5-9 Jun. 1989
(AGARD-R-774; ISBN-92-835-0532-8; AD-A217716) Copyright
Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Current concerns with trying to build and use cryogenic wind tunnels are addressed as specifically as possible. This course covered both the theory and practice of cryogenic wind tunnel design, operation, and use. A brief review is provided for the development and early use of cryogenic tunnels and then covered all aspects of the design and operation of cryogenic tunnels and then covered all aspects of the design and operation of cryogenic tunnels. Among the areas covered were: cryogenic engineering and safety, properties of materials at cryogenic temperatures, tunnel design requirements, model design and construction, automatic tunnel control, data acquisition, data accuracy, flow visualization, productivity, and costs of models and operation. The status of cryogenic wind tunnel projects in AGARD countries and in the rest of the world was also presented. For individual titles, see N90-15940 through N90-15962.

N90-15940# Southampton Univ. (England). Dept. of Aeronautics and Astronautics.
INTRODUCTION TO CRYOGENIC WIND TUNNELS
M. J. GOODYER In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 11 p (SEE N90-15939 08-09) Nov. 1989
(AGARD-R-774) Copyright Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The cryogenic wind tunnel was conceived as a way of increasing Reynolds number in a wind tunnel while avoiding an increase in its size. This it does very effectively and with some other surprisingly beneficial effects. Important among these is a reduction of tunnel drive power and the ability for the first time in a wind tunnel test to identify the separate effects of Reynolds number, Mach number and dynamic pressure. A brief introduction at the fundamental level highlighting some of the characteristics of cryogenic wind tunnels and their flows is presented. Author

N90-15941*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE NASA LANGLEY 0.3-METER TRANSONIC CRYOGENIC TUNNEL
EDWARD J. RAY In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 21 p (SEE N90-15939 08-09) Nov. 1989
(AGARD-R-774) Copyright Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 14/2
The Langley 0.3-Meter Transonic Cryogenic Tunnel (0.3-m TCT) was placed in operation at NASA's Langley Research Center in 1973. This facility was the world's first cryogenic pressure tunnel. The 0.3-m TCT can operate from ambient to cryogenic temperatures at absolute pressures ranging from about 1 to 6 atmospheres. Three major test section concepts were developed and refined in this unique facility. The 0.3-m TCT was a leader in the evolution of cryogenic pressure wind tunnel test techniques, instrumentation, control strategy and model technology. An overview is presented of the evolution and 15 years of experience with the 0.3-m TCT. The historical background concentrates on the technical challenges and proof-of-concept validations during the establishment of the first cryogenic pressure wind tunnel. The various test section concepts are described. Highlights of operational experience and test results determined from these first time exploratory tests are presented. Operating costs and effective test techniques for the 0.3-m TCT are discussed. Finally, current and future plans for the facility are presented. Author

N90-15942*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE US NATIONAL TRANSONIC FACILITY, NTF
WALTER E. BRUCE, JR. and BLAIR B. GLOSS In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 27 p (SEE N90-15939 08-09) Nov. 1989
(AGARD-R-774) Copyright Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 14/2
The construction of the National Transonic Facility was completed in September 1982 and the start-up and checkout of tunnel systems were performed over the next two years. In August 1984, the Operational Readiness Review (ORR) was conducted and the facility was declared operational for final checkout of cryogenic instrumentation and control systems, and for the aerodynamic calibration and testing to commence. Also, the model access system for the cryogenic mode of operation would be placed into operation along with tunnel testing. Since the ORR, a host of operating problems resulting from the cryogenic environment were identified and solved. These range from making mechanical and electrical systems functional to eliminating temperature induced model vibration to coping with the outgassing of moisture from the thermal insulation. Additionally, a series of aerodynamic tests have demonstrated data quality and provided research data on several configurations. Some of the more significant efforts are reviewed since the ORR and the NTF status concerning hardware, instrumentation and process controls systems, operating constraints imposed by the cryogenic environment, and data quality are summarized. Author

N90-15943# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).
THE KRYO-KANAL KOELN (KKK): DESCRIPTION OF THE TUNNEL CONVERSION. THERMAL INSULATION, INSTRUMENTATION, OPERATIONAL EXPERIENCE, TEST RESULTS AND OPERATING COSTS
F. VIEHWEGER In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 17 p (SEE N90-15939 08-09) Nov. 1989
(AGARD-R-774) Copyright Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The construction of the Kryo-Kanal Koeln was completed in May 1985. After check out of all systems the aerodynamic and cryogenic calibration was started one year later and completed in the third quarter of 1988. During this time operating problems in the circuit and in the subsystems resulting from the cryogenic mode of operation were identified and solved. Some basic tests were performed to understand the physics of the desorption of moisture from the internal insulation. The aerodynamic tests demonstrated the flow quality in the test section. The experimental experience and the test results gathered during the calibration phase are reviewed. Author

N90-15944# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).
AUTOMATIC CONTROL OF KKK: REQUIREMENTS, SENSORS, ACTUATORS, AND CONTROL PERFORMANCE RESULTS
R. KRONEN In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 11 p (SEE N90-15939 08-09) Nov. 1989
(AGARD-R-774) Copyright Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
After the modification of the low speed wind tunnel at the DLR Research Center at Cologne to a cryogenic wind tunnel a new control system was necessary. For lay out of the control system and for studying the tunnel behavior some mathematical models were developed. The models and the controller were tested by computerized simulations. Furthermore the control system was tested with the real tunnel for the run-up, testing, run-down phases. Author

N90-15945#   ETW G.m.b.H., Cologne (Germany, F.R.).
THE EUROPEAN TRANSONIC WINDTUNNEL (ETW)
XAVIER BOUIS   *In* AGARD, Special Course on Advances in
Cryogenic Wind Tunnel Technology 16 p (SEE N90-15939 08-09)
Nov. 1989
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   The construction phase of the European Transonic Wind Tunnel
started recently at Cologne, West Germany. Ambitious goals in
aerodynamic quality and cost-effectiveness are reflected in the
design philosophy. The main features of the future facility are
presented.   Author

N90-15946#   Centre d'Etudes et de Recherches, Toulouse
(France). Dept. d'Aerothermodynamique.
THE CRYOGENIC INDUCTION TUNNEL T2 AT TOULOUSE
JEAN-PIERRE ARCHAMBAUD   *In* AGARD, Special Course on
Advances in Cryogenic Wind Tunnel Technology 12 p (SEE
N90-15939 08-09)   Nov. 1989
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   The activity of the ONERA-CERT in the aerodynamic cryogenic
experimental branch is presented. Firstly, the T2 induction wind
tunnel is described, acting in cryogenic conditions since 1981,
and the flow characteristics are indicated. Then the hollow model
conception and its cooling during the run are developed and the
importance of the wall temperature measurements underlined. The
presence of ice particles in the flow, tripping the transition on the
model, is discussed; an efficient solution is given, providing fairly
good results on a laminar profile at high Reynolds number. Finally
cryogenic test results on a three-dimensional model are shown.
   Author

N90-15947#   Deutsche Forschungsanstalt fuer Luft- und
Raumfahrt, Goettingen (Germany, F.R.). Inst. fuer Experimentelle
Stroemungsmechanik.
THE CRYOGENIC LUDWIEG TUBE TUNNEL AT GOETTINGEN
G. HEFER   *In* AGARD, Special Course on Advances in Cryogenic
Wind Tunnel Technology 7 p (SEE N90-15939 08-09)   Nov.
1989
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   At the Research Center Goettingen of the DLR a cryogenic
Ludwieg tube wind tunnel for transonic operation was constructed.
The tunnel, having an effective run time of 1 second, a test section
of 0.4 x 0.35 m squared, and a maximum stagnation pressure of
10 bars, is to be operated with nitrogen at temperatures between
ambient and 120 K, achieving a Reynolds number of 70 x 10(exp
6) based on a model chord of 0.15 m. This lecture gives a brief
review of the Ludwieg tube concept, the main design features of
the tunnel, and the status of the project and presents the first
results of the calibration.   Author

N90-15948*#   National Aeronautics and Space Administration.
Langley Research Center, Hampton, VA.
OTHER CRYOGENIC WIND TUNNEL PROJECTS
ROBERT A. KILGORE   *In* AGARD, Special Course on Advances
in Cryogenic Wind Tunnel Technology 12 p (SEE N90-15939
08-09)   Nov. 1989
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   The first cryogenic tunnel was built in 1972. Since then, many
cryogenic wind-tunnel projects were started at aeronautical
research centers around the world. Some of the more significant
of these projects are described which are not covered by other
lecturers at this Special Course. Described are cryogenic
wind-tunnel projects in five countries: China (Chinese Aeronautical
Research and Development Center); England (College of
Aeronautics   at   Cranfield,   and   Royal   Aerospace
Establishment-Bedford); Japan (National Aerospace Laboratory,
University of Tsukuba, and National Defense Academy); United
States (Douglas Aircraft Co., University of Illinois at
Urbana-Champaign and NASA Langley); and U.S.S.R. (Central
Aero-Hydronamics Institute (TsAGI), Institute of Theoretical and

Applied Mechanics (ITAM), and Physical-Mechanical Institute at
Kharkov (PMI-K).   Author

N90-15949#   Cryogenic, Marine and Materials Consultants,
Southampton (England).
CRYOGENIC ENGINEERING AND MATERIALS
D. A. WIGLEY   *In* AGARD, Special Course on Advances in
Cryogenic Wind Tunnel Technology 18 p (SEE N90-15939 08-09)
Nov. 1989
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   The effects of cryogenic temperatures on the mechanical and
physical properties of materials are summarized. Heat capacity
and thermal conductivity are considered in the context of
conservation of liquid nitrogen, thermal stability of the gas stream
and the response time for changes in operating temperature.
Particular attention is given to the effects of differential expansion
and failure due to thermal fatigue. Factors affecting safety are
discussed, including hazards created due to the inadvertent
production of liquid oxygen and the physiological effects of
exposure to liquid and gaseous nitrogen, such as cold burns and
asphyxiation. The preference for using fcc metals at low
temperatures is explained in terms of their superior toughness
and the limitations on the use of ferritic steels is also considered.
Nonmetallic materials are discussed, mainly in the context of their
LOX compatibility and their use in the form of foams and fibers
as insulants, seals, and fiber-reinforced composites.   Author

N90-15950#   Office National d'Etudes et de Recherches
Aeronautiques, Paris (France).
INSTRUMENTATION FOR CRYOGENIC WIND TUNNELS
MAURICE BAZIN   *In* AGARD, Special Course on Advances in
Cryogenic Wind Tunnel Technology 31 p (SEE N90-15939 08-09)
Nov. 1989
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   The possibilities of adapting existing instrumentation for use in
the ETW cryogenic wind tunnel were investigated. These efforts
must be continued, especially for balances, but recent work was
devoted to systems with a direct impact on the design of the
wind tunnel test section. This is the case in particular for all the
optical methods whose use in ETW for flow visualization (external
flow-field and transition detection), accurate model attitude
measurements and deformation measurements will contribute to
the quality of the tests.   Author

N90-15951#   Centre d'Etudes et de Recherches, Toulouse
(France). Dept. d'Aerothermodynamique.
**FUNDAMENTAL CONSIDERATIONS IN TESTING IN
CRYOGENIC WIND TUNNELS**
ANDRE MIGNOSI   *In* AGARD, Special Course on Advances in
Cryogenic Wind Tunnel Technology 12 p (SEE N90-15939 08-09)
Nov. 1989
(AGARD-R-774)   Copyright   Avail: NTIS HC A16/MF A03;
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   The cryogenic technology for wind tunnel testing is strongly
connected with the aerodynamic requirements. A number of
aerodynamic problems mainly related to cryogenic testing are
examined. The various factors are described which are involved
in achieving the best similarity possible between an aircraft in
flight and the model in the wind tunnel. The second part covers
the analysis of these factors: effect of a non-adiabatic wall,
boundary layer transition, two-dimensional and three-dimensional
tests, effects of the Reynolds number. It is attempted to alternate
theoretical considerations with practical examples in order to
illustrate the importance of experimental/theoretical correlations.
   Author

N90-15952*#   National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TEST TECHNIQUES FOR CRYOGENIC WIND TUNNELS
PIERCE L. LAWING   *In* AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 12 p (SEE N90-15939 08-09) Nov. 1989
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Some of the testing techniques developed for transonic cryogenic tunnels are presented. Techniques are emphasized which required special development or were unique because of the opportunities offered by cryogenic operation. Measuring the static aerodynamic coefficients normally used to determine component efficiency is discussed. The first topic is testing of two dimensional airfoils at transonic Mach numbers and flight values of Reynolds number. Three dimensional tests of complete configurations and sidewall mounted wings are also described. Since flight Reynolds numbers are of interest, free transition must be allowed. A discussion is given of wind tunnel and model construction effects on transition location. Time dependent phenomena, fluid mechanics, and measurement techniques are examined. The time dependent, or unsteady, aerodynamic test techniques described include testing for flutter, buffet, and oscillating airfoil characteristics. In describing non-intrusive laser techniques, discussions are given regarding optical access, seeding, forward scatter lasers, two-spot lasers, and laser holography. Methods of detecting transition and separation are reported and a new type of skin friction balance is described.   Author

N90-15953#   Southampton Univ. (England). Dept. of Aeronautics and Astronautics.
FLOW VISUALIZATION IN THE CRYOGENIC WIND TUNNEL
M. J. GOODYER   *In* AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 11 p (SEE N90-15939 08-09) Nov. 1989
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A range of flow visualization methods for possible application to model testing in the large cryogenic wind tunnel is described. Desirable features are outlined, including the flow details which should be revealed by the various methods. The risks of model and tunnel contamination are discussed, also the coverage of the model surface to be expected, the advance planning and complexity of model design and tunnel equipment required by the visualization method, and the prospects of generating multiple flow images during one tunnel run. The methods to be outlined are at an early stage of development but in all cases there is some cryogenic experience to support their consideration for use in the cryogenic environment. None is well established for use at the highest Reynolds number conditions attainable in the cryogenic pressure tunnel.   Author

N90-15954#   Cryogenic, Marine and Materials Consultants, Southampton (England).
MATERIALS AND TECHNIQUES FOR MODEL CONSTRUCTION
D. A. WIGLEY   *In* AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 19 p (SEE N90-15939 08-09) Nov. 1989
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The problems confronting the designer of models for cryogenic wind tunnel models are discussed with particular reference to the difficulties in obtaining appropriate data on the mechanical and physical properties of candidate materials and their fabrication technologies. The relationship between strength and toughness of alloys is discussed in the context of maximizing both and avoiding the problem of dimensional and microstructural instability. All major classes of materials used in model construction are considered in some detail and in the Appendix selected numerical data is given for the most relevant materials. The stepped-specimen program to investigate stress-induced dimensional changes in alloys is discussed in detail together with interpretation of the initial results. The methods used to bond model components are considered with particular reference to the selection of filler alloys and

temperature cycles to avoid microstructural degradation and loss of mechanical properties.   Author

N90-15955#   Cryogenic, Marine and Materials Consultants, Southampton (England).
SOME RECENT DEVELOPMENTS IN MATERIALS AND TECHNIQUES FOR MODEL FABRICATION
D. A. WIGLEY   *In* AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 10 p (SEE N90-15939 08-09) Nov. 1989
(AGARD-R-774)   Copyright   Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Three topics are considered: the laminated thin sheet technology used in fabrication of a model of the X29A canard that enabled a uniquely high number of pressure orifices to be placed in a thin airfoil; the different configurations of sample used for studies on materials and fabrication techniques for model construction; and the long term objective of creating a handbook, database or expert system to bring together the information already available and indicate those areas where further work is needed.   Author

N90-15956*#   National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MODELS FOR CRYOGENIC WIND TUNNELS
PIERCE L. LAWING   *In* AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 14 p (SEE N90-15939 08-09) Nov. 1989
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Model requirements, types of model construction methods, and research in new ways to build models are discussed. The 0.3-m Transonic Cryogenic Tunnel was in operation for 16 years and many 2-D airfoil pressure models were tested. In addition there were airfoil models dedicated to transition detection techniques and other specialized research. There were also a number of small 3-D models tested. A chronological development in model building technique is described which led to the construction of many successful models. The difficulties of construction are illustrated by discussing several unsuccessful model fabrication attempts. The National Transonic Facility, a newer and much larger tunnel, was used to test a variety of models including a submarine, transport and fighter configurations, and the Shuttle Orbiter. A new method of building pressure models was developed and is described. The method is centered on the concept of bonding together plates with pressure channels etched into the bond planes, which provides high density pressure instrumentation with minimum demand on parent model material. With care in the choice of materials and technique, vacuum brazing can be used to produce strong bonds without blocking pressure channels and with no bonding voids between channels. Using multiple plates, a 5 percent wing with 96 orifices was constructed and tested in a transonic cryogenic wind tunnel. Samples of test data are presented and future applications of the technology are suggested.   Author

N90-15957*#   National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AUTOMATIC CONTROL OF CRYOGENIC WIND TUNNELS
S. BALAKRI·   *In* AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 15 p (SEE N90-15939 08-09) Nov. 1989
(AGARD-R-774)   Copyright   Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 14/2

Inadequate Reynolds number similarity in testing of scaled models affects the quality of aerodynamic data from wind tunnels. This is due to scale effects of boundary-layer shock wave interaction which is likely to be severe at transonic speeds. The idea of operation of wind tunnels using test gas cooled to cryogenic temperatures has yielded a quantum jump in the ability to realize full scale Reynolds number flow similarity in small transonic tunnels. In such tunnels, the basic flow control problem consists of obtaining and maintaining the desired test section flow parameters. Mach number, Reynolds number, and dynamic pressure are the three flow parameters that are usually required to be kept constant

during the period of model aerodynamic data acquisition. The series of activity involved in modeling, control law development, mechanization of the control laws on a microcomputer, and the performance of a globally stable automatic control system for the 0.3-m Transonic Cryogenic Tunnel (TCT) are discussed. A lumped multi-variable nonlinear dynamic model of the cryogenic tunnel, generation of a set of linear control laws for small perturbation, and nonlinear control strategy for large set point changes including tunnel trajectory control are described. The details of mechanization of the control laws on a 16 bit microcomputer system, the software features, operator interface, the display and safety are discussed. The controller is shown to provide globally stable and reliable temperature control to + or - 0.2 K, pressure to + or - 0.07 psi and Mach number to + or - 0.002 of the set point value. This performance is obtained both during large set point commands as for a tunnel cooldown, and during aerodynamic data acquisition with intrusive activity like geometrical changes in the test section such as angle of attack changes, drag rake movements, wall adaptation and sidewall boundary-layer removal. Feasibility of the use of an automatic Reynolds number control mode with fixed Mach number control is demonstrated. **Author**

N90-15958*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIENCE WITH STRAIN-GAGE BALANCES FOR CRYOGENIC WIND TUNNELS
M. SUSAN WILLIAMS In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 14 p (SEE N90-15939 08-09) Nov. 1989
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The U.S. National Transonic Facility (NTF) is a cryogenic wind tunnel build to meet the United States' needs for high Reynolds number testing. The facility was declared operational in August 1984, and since that time numerous models were tested in the NTF using unheated strain-gage balances to measure aerodynamic forces. The difficulty in accurately measuring forces and moments of models in conventional wind tunnels becomes more challenging at cryogenic conditions. The Force and Strain Instrumentation Section of the Instrument Research Division at NASA Langley Research Center designed and fabricated the balances to measure forces at cryogenic temperatures without thermally controlling the balance temperature. Presented are balance results from a recent cryogenic test program in the NTF. The data indicated the accuracy with which aerodynamic forces are determined using current instrumentation and test methods as well as identified areas for future research. **Author**

N90-15959*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CRYOGENIC BALANCES FOR THE US NTF Status Report
ALICE FERRIS In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 10 p (SEE N90-15939 08-09) Nov. 1989
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Force balances were used to obtain aerodynamic data in the National Transonic Facility (NTF) wind tunnel since it became operational in 1983. These balances were designed, fabricated, gaged, and calibrated to Langley Research Center's specifications to operate over the temperature range of -320 F to +140 F without thermal control. Some of the materials and procedures developed to obtain a balance that would perform in this environment are reviewed. The degree of success in using these balances thus far is reported. Some of the problem areas that need additional work are specified and some of the progress addressing these problems is described. **Author**

N90-15960*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SAFETY AND CRYOGENIC WIND TUNNELS
EDWARD J. RAY In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 18 p (SEE N90-15939 08-09) Nov. 1989
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The Langley 0.3-Meter Transonic Cryogenic Tunnel (0.3-m TCT) was placed in operation at NASA's Langley Research Center in 1973 as the world's first cryogenic pressure tunnel. The 0.3-m TCT can operate from ambient to cryogenic temperatures over an absolute pressure range from about 1 to 6 atmospheres. Three major test section concepts were developed and refined in this unique facility. The 0.3-m TCT is a leader in the development of various cryogenic pressure wind tunnel experimental techniques, instrumentation, control, model technology and safety standards. The safety experience gained is examined. During this period of advanced research, new operating techniques, training policies, and procedures had to be established. The paper deals with the Do's and Don'ts of cryogenic wind tunnel testing. Hazards and safety requirements which are unique to cryogenic testing are discussed. Highlights of experience and lessons learned with the 0.3-m TCT are reviewed. **Author**

N90-15961# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
PRODUCTIVITY AND CRYOGENIC WIND TUNNELS
J. CHRISTOPHE In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 14 p (SEE N90-15939 08-09) Nov. 1989
(AGARD-R-774) Copyright Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
After a brief review of the situation of existing cryogenic wind tunnels, the thermal balance of five wind tunnels is discussed. This discussion of the thermal balance is then generalized to suggest guidelines for the designers of future cryogenic wind tunnels. Finally, with the same concern, unconventional schemes are examined. **Author**

N90-15962*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ENERGY MANAGEMENT AND RECOVERY
PIERCE L. LAWING In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 9 p (SEE N90-15939 08-09) Nov. 1989
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Energy management is treated by first exploring the energy requirements for a cryogenic tunnel. The requirement is defined as a function of Mach number, Reynolds number, temperature, and tunnel size. A simple program and correlation is described which allow calculation of the energy required. Usage of energy is also addressed in terms of tunnel control and research operation. The potential of a new wet expander is outlined in terms of cost saved by reliquefying a portion of the exhaust. The expander is described as a potentially more efficient way of recovering a fraction of the cold nitrogen gas normally exhausted to the atmosphere from a cryogenic tunnel. The role of tunnel insulation systems is explored in terms of requirements, safety, cost, maintenance, and efficiency. A detailed description of two external insulation systems is given. One is a rigid foam with a fiber glass and epoxy shell. The other is composed of glass fiber mats with a flexible outer vapor barrier; this system is nitrogen purged. The two systems are compared with the purged system being judged superior. **Author**

N90-26838#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Fluid Dynamics Panel.
FLUID DYNAMICS PANEL WORKING GROUP 12 ON ADAPTIVE WIND TUNNEL WALLS: TECHNOLOGY AND APPLICATIONS
Apr. 1990   153 p
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Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   The results of a study by Working Group 12 of the Fluid Dynamics Panel of AGARD on adaptive-wall wind tunnels are presented. The history and state of the art of adaptive-wall technology are reviewed with regard to both the various streamlining algorithms and the existing adaptive-wall facilities; limitations and open questions of adaptive-wall methods are discussed and compared with passive-wall correction techniques; residual wall interferences are assessed; the prospects are presented for high-productivity and unsteady flow testing with adaptive walls; and recommendations are made for future developments. For individual titles, see N90-26839 through N90-26845.

N90-26839#   Southampton Univ. (England).
THE AIMS AND HISTORY OF ADAPTIVE WALL WIND TUNNELS
MICHAEL J. GOODYER, ed., J. P. CHEVALLIER, J. C. ERICKSON, JR., M. C. LEWIS, PETER B. S. LISSAMAN, H. H. PEARCEY, E. W. E. ROGERS, and W. F. HILTON (National Physical Lab., Teddington, England)   *In* AGARD, Fluid Dynamics Panel Working Group 12 on Adaptive Wind Tunnel Walls: Technology and Applications p 1-7 (SEE N90-26838 21-09)   Apr. 1990
(AGARD-AR-269)   Copyright   Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   The adaptive wall test section has its roots in the area when flight speeds were beginning to approach transonic on the level or in dives, that is the 1930s. The object of this historical review is to place on record the more important steps in the evolution of the adaptive wall test section in its various forms from these early times up to about 1975 when the first examples of all of the modern varieties were well on their way.   Author

N90-26840*#   National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FACILITIES INVOLVED IN ADAPTIVE WALL RESEARCH
CHARLES L. LADSON, ed.   *In* AGARD, Fluid Dynamics Panel Working Group 12 on Adaptive Wind Tunnel Walls: Technology and Applications p 8-20 (SEE N90-26838 21-09)   Apr. 1990
(AGARD-AR-269)   Copyright   Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 14/2
   During the first meeting of the Working Group, it was apparent that the assessment and interpretation of the current level of the technology could be achieved most easily provided the information in a common format. This would also minimize any danger of misinterpretation by third parties of existing published information. As a result, the Group developed a questionnaire and distributed it to all involved in adaptive wall research. The questionnaire solicited information on the mechanical details of the facilities as well as details of the adaptation strategy itself. The scope of testing accomplished and future plans were included. The information contained in the responses is summarized. This information was the source for much of the data. Because some of the data contained in these questionnaires is not discussed elsewhere, they are reproduced in their entirety as an Appendix. The questionnaire is also presented to serve as a guide to the written responses.   Author

N90-26841*#   National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STREAMLINING ALGORITHMS FOR COMPLETE ADAPTATION
J. C. ERICKSON, JR., ed., J. P. CHEVALLIER, MICHAEL J. GOODYER, HANS G. HORNUNG, ANDRE MIGNOSI, WILLIAM R. SEARS, J. SMITH, and ERICH H. WEDEMEYER (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany, F.R.)   *In* AGARD, Fluid Dynamics Panel Working Group 12 on Adaptive Wind Tunnel Walls: Technology and Applications p 21-41 (SEE N90-26838 21-09)   Apr. 1990
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   For purposes of the adaptive-wall algorithms to be described, the modern era is considered to have begun with the simultaneous, independent recognition of the concept of matching an experimental inner flow across an interface to a computed outer flow by Chevallier, Ferri, Goodyer, Lissaman, Rubbert, and Sears. Fundamental investigations of the adaptive-wall matching concept by means of numerical simulations and theoretical considerations are described. An overview of the development and operation of 2D adaptive-wall facilities from about 1970 until the present is given, followed by similar material for 3D adaptive-wall facilities from approximately 1978 until the present. A general formulation of adaptation strategy is presented, with a theoretical basis for adaptation followed by 2D flexible, impermeable-wall applications; 2D ventilated-wall applications; 3D flexible, impermeable-wall applications; and 3D ventilated-wall applications. Representative experimental and 3D results are given, with 2D, followed by a discussion of limitations and open questions.   Author

N90-26842*#   National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TESTING OF 3-D MODELS IN 2-D ADAPTIVE WALL TEST SECTIONS
ERICH H. WEDEMEYER, ed., CHARLES L. LADSON, J. SMITH, MICHAEL J. GOODYER, ANDRE MIGNOSI, and HANS G. HORNUNG (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany, F.R.)   *In* AGARD, Fluid Dynamics Panel Working Group 12 on Adaptive Wind Tunnel Walls: Technology and Applications p 42-58 (SEE N90-26838 21-09)   Apr. 1990
(AGARD-AR-269)   Copyright   Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 14/2
   Considerable effort was devoted to the development of two-dimensional adaptive wall test sections. The development of fully three-dimensional test sections, however, has not had this same level of effort expended. The limitations on three-dimensional research are the result of the complexity of both the mechanical design and operational aspects. Typical of the mechanical complexities are lack of readily available model and flow visualization access, and problems of sealing between adjacent walls for multi-wall types of test sections. The operational aspects are complicated by the necessity for many measurements of the boundary conditions which can be very time consuming. In three-dimensional testing, it is impossible to remove all of the boundary interference. It will be necessary, therefore, to apply residual corrections to the data. The more complex the test section shape, the more complex the calculation of the residual corrections becomes. From both the viewpoint of test section complexity and of ease of residual corrections, a simplified test section geometry is desirable. To aid in the design of simplified test sections, several researchers investigated the capability of using two-dimensional adaptive wall test sections to perform three-dimensional testing. By use of this type of design, the inherent complications and limitations of the fully three-dimensional design are avoided. Strategies of adaptation used for this application are described, as well as, sample results and a discussion of some limitations of the technique.   Author

N90-26843#   National   Aerospace   Lab.,   Amsterdam (Netherlands).
HIGH PRODUCTIVITY TESTING
J. SMITH, ed., ERICH H. WEDEMEYER, and ANDRE MIGNOSI (Centre d'Etudes et de Recherches, Toulouse, France) *In* AGARD, Fluid Dynamics Panel Working Group 12 on Adaptive Wind Tunnel Walls: Technology and Applications p 59-65 (SEE N90-26838 21-09) Apr. 1990
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Considering investment cost, running cost, operational versatility and flow quality, the present feeling is that a two-dimensional flexible wall test section is a near-optimum solution for production windtunnels, up to high subsonic Mach numbers. For near-sonic test conditions, ventilated walls are still unrivalled. High productivity implies the requirement of continuous testing, i.e., performing measurements while the test conditions are gradually, but continuously, varying in a controlled way. One Step Methods are not by themselves suited for continuous testing. In order to anticipate the ever varying test conditions, the necessary wall adaptation strategy must also to some extent be predictive. Such strategies are presently not well established. Therefore a possible high productivity strategy has been discussed in a somewhat speculative fashion, although supported by a little experimental and numerical evidence.   Author

N90-26844*#   National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LIMITS OF ADAPTATION, RESIDUAL INTERFERENCES
MIROSLAV MOKRY, ed., J. C. ERICKSON, JR., MICHAEL J. GOODYER, ANDRE MIGNOSI, GIUSEPPE P. RUSSO, J. SMITH, ERICH   H.   WEDEMEYER   (Deutsche   Forschungs-   und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany, F.R.), and PERRY A. NEWMAN   *In* AGARD, Fluid Dynamics Panel Working Group 12 on Adaptive Wind Tunnel Walls: Technology and Applications p 66-90 (SEE N90-26838 21-09) Apr. 1990
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Methods of determining linear residual wall interference appear to be well established theoretically; however they need to be validated, for example by comparative studies of test data on the same model in different adaptive-wall wind tunnels as well as in passive, ventilated-wall tunnels. The GARTEur CAST 7 and the CAST 10/DOA 2 investigations are excellent examples of such comparative studies. Results to date in both one-variable and two-variable methods for nonlinear wall interference indicate that a great deal more research and validation are required. The status in 2D flow is advanced over that in 3D flow as is the case generally with adaptive-wall development. Nevertheless, it is now well established that for transonic testing with extensive supercritical flow present, significant wall interference is likely to exist in conventional ventilated test sections. Consequently, residual correction procedures require further development hand-in-hand with further adaptive-wall development.   Author

N90-26845#   Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.).
ADAPTATION FOR UNSTEADY FLOW
HANS W. FOERSCHING, ed. and R. VOSS   *In* AGARD, Fluid Dynamics Panel Working Group 12 on Adaptive Wind Tunnel Walls: Technology and Applications p 91-99 (SEE N90-26838 21-09) Apr. 1990
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Wind tunnel wall interference in unsteady flow has not been as thoroughly investigated as in steady flow. In the case of unsteady flow the wind tunnel wall interference problem is much more complicated   by   additional   parameters   describing   the time-dependent variation of the unsteady flow field. With the recent development of adaptive wind tunnel walls, by which steady wall effects are eliminated or significantly reduced by actively controlling flow near the walls, new possibilities for correction of wind tunnel wall interference have also emerged for unsteady flow. Prospects and concepts of experimental and analytical techniques for

correction of unsteady wind tunnel wall effects, appearing with aerodynamic and aeroelastic measurements of oscillating lifting systems and bodies, are presented. First, some fundamental relations of motion-induced unsteady flow fields, basic to a physical understanding   and   analytical   treatment   of   unsteady   flow phenomena, are explained. Then the principal causes of unsteady wind tunnel interference are described and the practicability of adaptive wind tunnel walls to eliminate unsteady aerodynamic wall interference effects in unsteady aerodynamic and aeroelastic wind tunnel model measurements is discussed. Finally prospective wind tunnel wall corrections for motion-induced unsteady flow, applying steady flow wall adaptation and CFD-techniques, are outlined.
                                                                    Author

N90-29404#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
WORKSHOP ON LOW LEVEL FLIGHT TRAINING
1990   79 p   Workshop Held in Ottobrunn, Fed. Republic of Germany, 23-27 Oct. 1989
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The workshop investigates and reports on whether flight simulation technology might help resolve problems associated with low level flight training and suggests how AGARD might proceed in this area. Specifically the workshop: registers the existing requirements for low level flight training for mission events in which flight simulator technology shows the greatest potential for reducing the environmental impact of flight training while maintaining combat readiness; identifies ways that simulator technology can be applied to reduce the undesirable impact of low level flight training; investigates new training concepts that use alternative flight training in connection with simulators to meet flight training requirements; identifies ways to measure the effectiveness of simulator training in meeting operational training requirements; and suggests possible topics for follow-on technology studies or aerospace applications studies through which AGARD might contribute to a solution to the issue.   Author

N91-10975#   Technische Univ., Brunswick (Germany, F.R.). Inst. of Flight Guidance and Control.
WIND MODELS FOR FLIGHT SIMULATION
K.-U. HAHN, T. HEINTSCH, B. KAUFMANN, G. SCHAENZER, and M. SWOLINSKY   *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 1. Part 1: Fundamentals. Part 2: Flight in Critical Atmospheric Conditions. Part 3: Impact of New On-Board Technologies on Aircraft Operation 32 p (SEE N91-10967 02-04) Mar. 1990 Sponsored by DFG
(AGARD-AG-301-VOL-1-PT-1-3) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Wind shear, downdraft, and turbulence can endanger takeoff and landing approach. The effects of wind results in a modified dynamic response of the aircraft as well as in flight performance variation. In each case flight path deviation can occur, more or less controlled by the pilot. For the analysis of the aircraft behavior in a changing wind field, a mathematical model of the aircraft is used including the wind effects. It can be said, that gusts and turbulence will have more influence on the pilot workload and reaction to this short scale wind disturbances. Large scale wind variations can produce significant flight path safety problems. An important aspect for the flight safety is the energy situation of an aircraft affected by wind. Therefore this was chosen as a useful criterion for the determination of the influences of the wind and wind variation.   Author

N91-11771#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel, Working Group 22.
AIRCRAFT OPERATIONS ON REPAIRED RUNWAYS
DUNCAN J. ECKFORD, ed.   Aug. 1990   119 p
(AGARD-R-731; ISBN-92-835-0574-3; AD-A228898) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The results of an AGARD Working Group, (WG.22) directed by the Structures and Materials Panel are presented. The Working Group was tasked to develop design requirements and qualification methods, the application of which, across NATO, would improve

aircraft utilization and interoperabi. The subject of repaired-runway operation is developed and illustrated; its sections reflect the various aims of the Working Group while the appendices amplify particular aspects. Throughout, topics are discussed from fundamentals so that it may provide an introduction to the structural and dynamical implications of repaired-runway operation, as well as a statement of the current level of development of techniques in design, assessment, and operational clearance. Author

N91-21156# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
ROTARY-BALANCE TESTING FOR AIRCRAFT DYNAMICS
1991 267 p
(AGARD-AR-265; ISBN-92-835-0597-2; AD-A235179) Copyright
Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The results of a study on rotary-balance testing for aircraft dynamics are presented. Both the experimental techniques used to obtain rotary-flow aerodynamics data and the procedures involved in using this type of data in the mathematical modeling of the dynamic behavior of a maneuvering fighter aircraft are examined. A special effort was made to summarize experiences involving correlation of dynamic behavior predictions with the observed motions of free-flight models and aircraft in flight. Specific hardware and problems encountered in rotary-balance experiments were addressed for experimental facilities in several countries and advanced applications were noted. Author

N91-31173# Royal Aerospace Establishment, Farnborough (England). Propulsion Dept.
DEVELOPMENTS IN ICING TEST TECHNIQUES FOR AEROSPACE APPLICATIONS IN THE RAE PYESTOCK ALTITUDE TEST FACILITY
M. HOLMES, V. E. W. GARRATT, and R. G. T. DRAGE In AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 15 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16, Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The altitude test facilities at the Royal Aerospace Establishment at Pyestock are used in support of clearance of aero-engines, intakes, and helicopter rotors to operate under severe icing conditions. An important aspect of the work is the simulation of the wet icing cloud in terms of water concentration, mean droplet size and spectrum. Water spray rakes or booms were developed for this activity and individual nozzles were calibrated in a wind tunnel built for this purpose. A laser particle sizer was used to calibrate typical spray nozzles and attempts were made to establish a traceable standard. The development of cloud simulations is discussed as well as facilities for monitoring ice formation and shedding. Author

12

ASTRONAUTICS (GENERAL)

N90-14417# National Defence Academy, Yokosuka (Japan). Dept. of Electrical Engineering.
HYBRID PE-RAY-MODE FORMULATION OF HIGH FREQUENCY PROPAGATION IN A BILINEAR TROPOSPHERIC SURFACE DUCT
T. ISHIHARA and L. B. FELSEN (Polytechnic Univ., Farmingdale, NY.) In AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 15 p (SEE N90-14405 06-32) Sep. 1989 Sponsored by Naval Ocean Systems Center, San Diego, CA
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
Prediction of signal strengths due to high frequency sources in the presence of a tropospheric surface or elevated duct poses a problem of substantial complexity because the propagation environment is generally heterogeneous in height as well as in the lateral domain. A prediction algorithm should not only furnish

adequate accuracy but also incorporate a parameterization in terms of physical observables so that the output can be properly interpreted. Relevant physical observables include ray fields, normal (trapped) and leaky mode fields, and beam-like (parabolic) propagators. These observables are employed here in self-consistent hybrid combination to model propagation in a laterally homogeneous surface duct with bilinear refractive index profile in height. A reference solution, which was generated by normal and leaky mode summation, is interpreted qualitatively in terms of the corresponding ray field plot. Work is in progress on a quantitative reconstruction of the reference data via the hybrid algorithm. Author

13

ASTRODYNAMICS

Includes powered and free-flight trajectories; and orbital and launching dynamics.

N90-14432# Centre National d'Etudes des Telecommunications, Lannion (France).
CORRECTION OF IONOSPHERIC EFFECTS FOR THE PRECISE ORBIT DETERMINATION OF SATELLITES
F. FOUCHER, R. FLEURY, and P. LASSUDRIE-DUCHESNE In AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 12 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
In the near future, space missions in altimetry, geodesy, or precise positioning will often require satellite orbits to be determined with subdecimetric accuracies. In orbit determination systems extensive use is made of Doppler measurements performed on radio signals propagating between the satellite and ground stations. Such systems, however, are highly sensitive to propagation errors brought about by the atmosphere. The effects of the ionosphere on Doppler measurements is assessed and a model of the ionospheric error is described. A correction scheme is examined for orbit determination systems based on Doppler data. Particular emphasis is placed on the post-processing of the Doppler data from the DORIS system, a precise orbit determination system designed for remote sensing satellites of the new generation. Simulation results show that the major part of the ionospheric error can be removed by model correction. Author

N90-27745# Telespazio, S.p.A., Rome (Italy).
POSSIBLE TRAJECTORY PROFILES TO ACHIEVE THE GEOSTATIONARY ORBIT WITHOUT ANY DRIFT PHASE
GIOVANNI VULPETTI In AGARD, Space Vehicle Flight Mechanics 12 p (SEE N90-27741 22-18) Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Two mission strategies are examined for achieving a station longitude on the geostationary earth orbit (GEO) starting from either a low earth orbit (LEO) or from ground with no parking in LEO. Such trajectory profiles are somewhat different from the conventional ones used for targeting a longitude position in GEO for, typically, a telecommunication satellite. Neither of profile types presented requires a drift orbit. The new strategy would fully exploit the liquid bipropellant engines and additional capabilities of some of the current commercial launchers for inserting a satellite beyond GEO. The final goal of these strategies is to reach the desired station longitude in a time ranging from tens of hours to a few days, at most, with no additional propellant consumption with respect to the traditional trajectory profiles involving drifts. The new profiles may result in a significant increase of mission success probability together with less workload for the ground control center. Author

N90-27746# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.).
REENTRY TRAJECTORY OPTIMIZATION AND CONTROL
P. STROHMAIER, A. KIEFER, D. BURKHARDT, and K. HORN
In AGARD, Space Vehicle Flight Mechanics 12 p (SEE N90-27741 22-18) Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

There are several possible methods to increase the cross range capability of a winged reentry vehicle, for instance, skip trajectories, a powered cruise phase, or high lift/drag ratio flight. However, most of these alternative descent strategies have not yet been investigated sufficiently with respect to aero-thermodynamic effects and the design of the thermal protection system This problem is treated by two different means. First, a nominal reentry trajectory is generated based on a phase concept, and then the same problem is again solved using a numerical optimization code to determine the control functions. The nominal reentry trajectory design presented first subdivides the total reentry trajectory into several segments with partially constant control/state parameters such as maximum heat flux and deceleration. The optimal conditions for a given segment can then be selected. In contrast, the parameterized optimization code selects the control functions freely. Both approaches consider a mass point simulation which uses realistic model assumptions for atmosphere, earth and gravity. Likewise, both approaches satisfy all flight regime limitations and boundary conditions such as thermal constraints throughout the flight path and specified speed and altitude at the final time. For the optimization of high cross reentry trajectories the cross range per total absorbed heat represents an appropriate cost function. The optimization code delivers quite a different flight strategy than that usually generated by the nominal reentry design program, first flying longer along the temperature boundary at highest possible angle of attack (AOAs) (utilizing higher average turn ates), and afterwards performing flare-dive segments to reduce heat flux and to increase range. Finally, the aspect of guiding the nominal or optimized reentry trajectory during a cross range flight is considered. The vertical guidance is performed with both angles of attack and roll angle control. The roll angle is primarily used for controlling sink speed, thus correcting the altitude/speed profile to the predetermined nominal profile. Range control can be affected by AOA modulation using predetermined gradients as a function of range-to-go. Author

N90-27747# Aerospatiale, Les Mureaux (France).
HERMES EMERGENCY REENTRY TRAJECTORIES CONSEQUENCES ON THE ARIANE 5 TRAJECTORIES
PH. DELATTRE and A. WAGNER (Centre National d'Etudes Spatiales, Paris, France) *In* AGARD, Space Vehicle Flight Mechanics 19 p (SEE N90-27741 22-18) Jun. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Hermes emergency reentry trajectories occur in case of any failure during that part of the launch phase from jettisoning the burn-out solid propellant boosters till the ignition of the MPH. In that case the Crew Escape Module cannot be used because of high Mach numbers and very severe constraints that would result of its low lift coefficient. The maximum constraints on the Hermes space plane are obtained in the atmospheric reentry phase of the emergency trajectories. Their important level is due to the deep flight path angle attained during the ballistic arc of the trajectory. Their values are depending on the instant of launch abort. These maximum constraints are very depending on the launch trajectory. The maximum Hermes constraints were represented in the altitude-velocity plane as a maximum altitude boundary for the Ariane 5 launch trajectory. Unfortunately a performance loss is the result of the requirement for a reduction of the culmination altitude. This has lead to a launch trajectory optimization that will be detailed in this paper. As an out-come of this study two important decisions have been made by CNES: choice of a L6 for the Hermes propulsion module; and the choice of the boundary that constraints the launch trajectory. Important efforts were made on Hermes in order to reduce the maximum constraints, in the field of aerodynamics (moment coefficient reduction, increase of the

maximum angle of attack), center of gravity location (in order to reduce control surfaces hinge-moments and temperatures) and elevon-body-flap differential deflection. Author

N90-27749# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
AN INTRODUCTION TO SPACE TRAJECTORIES [UNE INTRODUCTION AUX TRAJECTOIRES SPATIALES]
J.-P. MAREC *In* AGARD, Space Vehicle Flight Mechanics 54 p (SEE N90-27741 22-18) Jun. 1990 In FRENCH
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

This introductory session on trajectories is designed to review the basic concepts of the study of spacial trajectories, natural and optimal, and presents other issues from the session. It is divided into 5 parts. The first three parts review the different well known formalisms: Newtonian, Lagrangian, and Hamiltonian, along with their applications, standard comparison, and resolution. In the first part, the Newtonian formula establishes the perturbation formula of Gauss, which is applied to the study of orbital perturbations due to atmospheric braking. In the second part, the Lagrangian formalism leads to the Lagrange perturbation formula, which is used to study orbital perturbation due to asymmetry of the earth potential. In the third part, the Hamiltonian formalism is used to obtain the canonical formula of perturbation and introduces the method of von Zeidel. The fourth part emphasizes the connection between the mechanical variations and a Modern Optimization Method (the maximum principle of Contenson-Pontryagin). Finally, in the fifth part, the optimization method is applied to the study of the problem of optimal space trajectories (transfers and optimal rendezvous, optimal orbital corrections, etc.) Transl. by E.R.

N90-27750# Centre National d'Etudes Spatiales, Toulouse (France).
ORBIT COMPUTATION [CALCUL D'ORBITES]
P. EXERTIER, P. SENGENES, and G. TAVERNIER *In* AGARD, Space Vehicle Flight Mechanics 16 p (SEE N90-27741 22-18) Jun. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

For many years, CNES has been involved in orbit computation. At the beginning these calculations were made for experimental purposes. Then, they were improved for operational projects such as low earth orbiting satellites, geostationary satellites and interplanetary probes. More recently, CNES has decided to work (in collaboration with USA) on TOPEX-POSEIDON project which is realized for oceanic circulation determination. The use of a very accurate (5 cm) on-board altimeter requires a very accurate orbit estimation (some centimeters on altitude). Some aspects of modern technics of orbit determination are presented. Author

N90-27751# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
OPTIMIZATION OF THE DEPLOYMENT OF A PAIR OF SATELLITES IN INCLINED ECCENTRIC GEOSYNCHRONOUS ORBITS [OPTIMISATION DE LA MISE A POSTE D'UN COUPLE DE SATELLITES SUR DES ORBITES GEOSYNCHRONES, EXCENTRIQUES ET INCLINEES]
J. BOUCHARD and C. AUMASSON *In* AGARD, Space Vehicle Flight Mechanics 10 p (SEE N90-27741 22-18) Jun. 1990 In FRENCH Original language document was announced in IAA as A90-22442
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The problem of deploying a pair of satellites from GTO to highly inclined eccentric geosynchronous orbits is investigated analytically, with a focus on the CNES Sycomores satellites (relay satellites for communication between land vehicles). The general problem involves minimization of the fuel required for two or three powered maneuvers, and a generalized gradient-type parametric optimization algorithm is applied. It is shown that the difficulty of the problem is greatly increased if the satellites are placed in GTO using a single Ariane launch. The transfer trajectories of the two satellites must then be different, and each requires more fuel

than the optimal trajectory for separately launched satellites. Maps, diagrams, and graphs are included.   Author

N90-27752#   Wright Research Development Center, Wright-Patterson AFB, OH.
NONCOPLANAR ORBIT TRANSFER OPTIMIZATION FOR AN AEROASSISTED SORTIE VEHICLE
H. A. KARASOPOULOS and R. B. NORRIS   *In* AGARD, Space Vehicle Flight Mechanics 17 p (SEE N90-27741 22-18)   Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Noncoplanar orbital plane change trajectories for an aeroassisted sortie vehicle (ASV) from a 220 nautical mile circular orbit at 28.5 degrees inclination to a 150 nautical mile circular polar orbit were optimized, subject to nose stagnation temperature constraints. Both synergetic and two-impulse-deorbit aeroassist trajectories were successfully optimized. The baseline aeroassisted sortie vehicle, a double-delta lifting body, had a maximum hypersonic L/D of 3.4. The ASV was powered by a liquid hydrogen/oxygen rocket engine. The optimized synergetic plane change trajectory resulted in the delivery of more pounds of payload to polar orbit than the two-impulse-deorbit aeroassist trajectory. The propulsive delta V expended by the ASV during the baseline trajectory was less than half the propulsive delta V required by a two-impulse, all-propulsive orbital transfer maneuver. By adding propellant drop tanks of approximately half the gross weight of the ASV, the payload weight to polar orbit was almost tripled with an optimal two-impulse-deorbit aeroassist trajectory. This trajectory provided more payload to the final orbit for this ASV configuration than a synergetic maneuver preceded by an exoatmospheric propulsive plane change. To fully utilize an L/D capability greater than 3, the ASV must be able to sustain maximum nose stagnation temperatures up to 4500 F.   Author

N90-27753#   MATRA Espace, Toulouse (France). Dept. of Dynamics and Control.
HERMES RENDEZVOUS WITH THE SPACE STATION
MICHEL CALDICHOURY, CALIXTE CHAMPETIER, and ERIC DESPLATS   *In* AGARD, Space Vehicle Flight Mechanics 21 p (SEE N90-27741 22-18)   Jun. 1990
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An overview of the requirements and concepts for the Hermes rendezvous system is presented. A review of the mission requirements and constraints, mainly dictated by safety rules and man involvement, is first performed to highlight the impact of the vehicle configurations and environment on the definition of the Guidance, Navigation and Control (GNC) subsystem. The whole Rendezvous (RV) scenario from the end of the transfer phase up to the docking is described. A particular attention is devoted to the elaboration of guidance and control strategies for the homing and the final approach phases. The navigation system selected and designed for Hermes is presented, with some emphasis on the GPS navigation dedicated to the homing and closing phases and the optical navigation during the final approach. The redundant philosophy for the RV system and the crew involvement in the GNC and management process are also discussed.   Author

15

LAUNCH VEHICLES AND SPACE VEHICLES

Includes boosters; operating problems of launch/space vehicle systems; and reusable vehicles.

N90-27761#   British Aerospace Public Ltd. Co., Preston (F ' d). Military Aircraft Div.
ASCENT AND DESCENT OPTIMIZATIONS OF AN AIR-BREATHING LAUNCH VEHICLE
S. G. FURNISS and I. M. WALTERS (British Aerospace Public Ltd. Co., Stevenage, England)   *In* AGARD, Space Vehicle Flight Mechanics 16 p (SEE N90-27741 22-18)   Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The design of an air-breathing winged launcher vehicle is a highly interactive process. The optimum (minimum mass) vehicle is determined by a trade-off involving fuselage shape and its influence on drag and structural efficiency (mass/volume) together with the rocket and air-breathing propulsion mode of operation and system sizing. These effects must be coupled with the most efficient mission profile. Contained are details of the ascent and descent optimization which must be conducted for a single-stage-to-orbit vehicle. Those parameters which have a significant influence on the selection of the air-breathing ascent, the rocket ascent, and the re-entry and autoland trajectories are described. The strong interactions between the various phases of flight, and their influence on the vehicle design and performance, are discussed. The launcher design mission is shown to have a significant impact on the ascent profile and the optimum configuration.   Author

N90-27762#   Aerospatiale, Les Mureaux (France).   Direction Etudes et Essais Systemes.
GLOBAL OPTIMIZATION OF AIR BREATHING LAUNCH VEHICLE TRAJECTORIES
F. MARTEL   *In* AGARD, Space Vehicle Flight Mechanics 9 p (SEE N90-27741 22-18)   Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A trajectory global optimization method for single stage to orbit (SSTO) air breathing launch vehicle is presented. This method was involved in STS 2000 Aerospatiale studies to compare various air breathing candidate solutions, assess their performances, and contribute to the definition of an optimized SSTO global design.
                                                            Author

16

SPACE TRANSPORTATION

Includes passenger and cargo space transportation, e.g., shuttle operations; and space rescue techniques.

N90-27748#   Rockwell International Corp., Downey, CA. Space Transportation Systems Div.
SPACE SHUTTLE DESCENT FLIGHT VERIFICATION BY SIMULATION: A CHALLENGE IN IMPLEMENTING FLIGHT CONTROL SYSTEM ROBUSTNESS
VIET H. NGUYEN, JOHN T. NISHIMI, THOMAS H. PAYNE, and EARL W. WOOSLEY   *In* AGARD, Space Vehicle Flight Mechanics 17 p (SEE N90-27741 22-18)   Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The Space Shuttle flight control system (FCS) is a digital fly-by-wire system that provides vehicle stability, response, and handling qualities necessary to return safely from orbit, ending with a pinpoint landing on a 300 by 15,000-foot (90 by 4,600-meter) runway. Furthermore, on its first flight, it had to fly successfully

the entire envelope-manned. Thus, the FCS was subjected to one of the most extensive programs of certification by analysis and simulation ever conducted. An overview of the entry and landing FCS is presented along with the requirements and considerations used in the design process. The network of simulation programs used in the FCS design and verification are addressed. The flight test results and the current issues related to landing and roll-out are presented. **Author**

17

SPACE COMM., SPACECRAFT COMM., COMMAND & TRACKING

Includes telemetry; space communications networks; astronavigation and guidance; and radio blackout.

N92-12456# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). GRECO Informatique.
FORMAL SPECIFICATION OF SATELLITE TELEMETRY: A PRACTICAL EXPERIENCE
JEAN-MICHEL HUFFLEN and MICHEL LEMOINE *In* AGARD, Software for Guidance and Control 9 p (SEE N92-12449 03-61) Sep. 1991 Sponsored in part by IMAG/LIFIA, Grenoble, France; and ONERA-CERT/DERI, Toulouse, France
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An experience is reviewed of using formal algebraic specifications, conducted with aeronautical industry collaboration. The objective is to provide a reuseable specification for processing telemetry results. This family of spatial applications is described by means of generic formal specifications, from which telemetry could be formed. Reuse possibilities are supported by the framework. A general survey is given of this experience, including its story, the method followed for establishing the generic specifications which are the system's core, and reuse aspects provided. **Author**

18

SPACECRAFT DESIGN, TESTING AND PERFORMANCE

Includes satellites; space platforms; space stations; spacecraft systems and components such as thermal and environmental controls; and attitude controls.

N90-20066# Martin-Baker Aircraft Co. Ltd.. Denham (England).
SPACECRAFT ESCAPE
B. A. MILLER *In* AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 7 p (SEE N90-20054 13-03) Feb. 1990
(AGARD-CP-472) Copyright Avail: NTIS HC A06/MF A01;
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The currently preferred option from among the designs so far studied are described. Alternatives for seat design will still be studied to identify systems which offer the best possible approach with minimum design risk. Martin-Baker will continue to study the overall design and also initiate more detailed studies of the main elements, such as drogue stabilization, temperature extremes protection, and rocket motor thrust vectoring. The study of program management and the testing and qualification of such a system will also be initiated. It is already apparent that the test program would, at some point, require testing of the seat under actual conditions, if the required level of confidence is to be achieved. The Hermes Management Team are meeting the crew safety challenge by initiating and funding wide ranging feasibility studies. They are placing equal emphasis on the Crew Escape Module concept and this study is also most promising. Hermes has the

enormous advantage of hindsight which, we all know is perfect, and this valuable experience is being put to good use. This is believed to be pioneering work, whether by CEM or encapsulated ejection seats can provide an effective and efficient means of safe crew escape. Such a valuable prize will however not be obtained without continuing to commit the necessary resources and dedication. **Author**

N90-27452# Defense Communications Agency, Washington, DC. Military Satellite Communications System Office.
THE POST-2000 MILSATCOM ARCHITECTURE
ROBERT L. DRUMMOND and GREGORY B. FRICK *In* AGARD, Tactical Applications of Space Systems 7 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
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Military satellite communications (MILSATCOM) systems presently in use and those under development will provide service to a variety of users until the end of the 20th century. What MILSATCOM systems should be fielded for the post-2000 time frame is the subject of an intense study called The Alternative MILSATCOM Architectures (TAMA). The present MILSATCOM architecture, including those systems scheduled to begin operation in the early 1990's are examined; how the TAMA study was conducted is discussed; and insights are presented as to what the 2010 MILSATCOM Architecture should look like. **Author**

N90-27453# Massachusetts Inst. of Tech., Lexington. Lincoln Lab.
LIGHTWEIGHT EHF COMMUNICATIONS SATELLITES
DAVID R. MCELROY, DEAN P. KOLBA, and MARILYN D. SEMPRUCCI *In* AGARD, Tactical Applications of Space Systems 10 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
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Current and planned Military Satellite Communications (MILSATCOM) systems, which typically employ a few, large satellites operating in synchronous altitude circular orbits, provide good fundamental service. However, there are concerns among some users regarding the potential for localized capacity shortfalls, particularly for anti-jam tactical service. Due to the large size of the currently planned satellites, there is no capability to rapidly augment capacity through timely and survivable launches of additional space assets. Small EHF satellites can significantly complement the anti-jam service of basic MILSATCOM space segments. Mobile/survivable launch vehicles with rapid launch preparations can be utilized to deploy these satellites into high altitude elliptical or circular orbits. In these orbits, only a few satellites are needed for high duty cycle coverage of critical areas. Through the use of standard EHF waveforms, the complementary satellites will be compatible with existing EHF terminals. Advanced technology allows the development of the highly capable, lightweight payloads required for this role. Some of the key technologies for these complementary satellites include high speed, low power digital processing subsystems, lightweight frequency hopping synthesizers, and efficient solid-state transmitters. These same technologies are also applicable in reducing the size of the large, fundamental-service space segments or in implementing highly capable secondary EHF payloads. **Author**

N90-27741# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
SPACE VEHICLE FLIGHT MECHANICS
Jun. 1990 485 p In ENGLISH and FRENCH Symposium held in Luxembourg, 13-16 Nov. 1989
(AGARD-CP-489; ISBN-92-835-0567-0; AD-A226987) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

In the last thirty years a great increase has been seen in both manned and unmanned space flights for scientific studies, for communication and navigation, and for military purposes. The possible uses of flight at near-space conditions are also under consideration and, at these heights, many of the technical problems have a common basis with those of space vehicles during the launch, recovery and transatmospheric phases. In all these areas,

many problems remain only partly resolved and the relevant technologies are developing rapidly. The symposium included the control and trajectory aspects of launch and recovery, in-orbit dynamics, trans-atmospheric flight, the dynamic aspects of assembly and operation in space, and simulation and flight test. For individual titles, see N90-27742 through N90-27771.

N90-27742*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLIGHT CONTROL ISSUES OF THE NEXT GENERATION SPACE TRANSPORTATION LAUNCH VEHICLES
RICHARD W. POWELL, J. CHRISTOPHER NAFTEL, and CHRISTOPHER I. CRUZ *In* AGARD, Space Vehicle Flight Mechanics 15 p (SEE N90-27741 22-18) Jun. 1990
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Some of the issues that affect the flight control and guidance system designs for vertical-takeoff and horizontal-takeoff vehicles were investigated. A two-stage all-rocket vehicle was used to represent the vertical-takeoff system and a generic aerospace plane concept to represent the horizontal-takeoff vehicle. Two flight control issues for the vertical-takeoff rocket were uncovered. The first was the large gimbal angle range required for pitch trim when using parallel mated vehicles. The second was control during staging. Two issues were also identified for the air-breathing vehicle. The first is that the drag losses due to aerodynamic trim are a significant fraction of the total ideal velocity required to achieve orbit. The second issue is that since the vehicle flies at high dynamic pressure for most of the ascent, the guidance system design will be more difficult to ensure accurate insertion than that for the vertical-takeoff rocket system. Author

N90-27743# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany, F.R.). Inst. for Flight Systems Dynamics.
ASCENT AND DESCENT TRAJECTORY OPTIMIZATION OF ARIANE 5/HERMES
C. JAENSCH, K. SCHNEPPER, and K. H. WELL *In* AGARD, Space Vehicle Flight Mechanics 27 p (SEE N90-27741 22-18) Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An overview over the state-of-the-art of trajectory optimization of aerospace vehicles is given with emphasis on applications to Ariane 5 ascent trajectories and Hermes reentry trajectories. Some of the numerical methods used in the past are briefly reviewed. Two relatively new methods under development, both of which need efficient sequential quadratic programming for solving the associated nonlinear programming problems are described in more detail. A detailed description of the equations of motion, the boundary conditions and the flight path constraints for the Ariane 5 ascent and the Hermes reentry is presented and numerical results are given for an optimal ascent into geostationary transfer orbit, into a sun-synchronous orbit, into a 28.5 degree transfer orbit for the Ariane 5/Hermes combination, and an optimal reentry from a 28.5 degree orbit to Istres. Trajectory optimization of space vehicles with airbreathing engines is considered. Author

N90-27744# Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH.
ADVANCED LAUNCH VEHICLE CONFIGURATIONS AND PERFORMANCE TRADES
PETER R. GORD, KEVIN J. LANGAN, and MICHAEL E. STRINGER *In* AGARD, Space Vehicle Flight Mechanics 13 p (SEE N90-27741 22-18) Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A concept for a near-term multi-stage space launch system has been proposed. The configuration incorporated full reusability, horizontal take-off and landing characteristics, and a payload goal of 50,000 lbs into a 100 n mi circular airbreathing propulsion system, augmented by conventional rocket propulsion as required. The second stage (orbiter) featured a high lift-to-drag ratio aerodynamic design with a dedicated high volume payload bay. Propulsion for the second stage was provided by a conventional rocket engine.

The orbiter component was carried nestled within the booster mold lines and staged through a bottom drop mode. Sensitivity studies were performed on the synergisms between elements of the boost propulsion system; dynamic pressure effects on system performance; degraded ramjet thrust at high Mach numbers; and booster weight at staging. The configuration evolution and results from the sensitivity studies are described in detail. Author

N90-27754# British Columbia Univ., Vancouver. Dept. of Mechanical Engineering.
SPACECRAFT ATTITUDE DYNAMICS: EVOLUTION AND CURRENT CHALLENGES
V. J. MODI *In* AGARD, Space Vehicle Flight Mechanics 26 p (SEE N90-27741 22-18) Jun. 1990
(Contract NSERC-STR-32682)
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Complex interactions are reviewed between flexibility, deployment, environmental forces and attitude dynamics during both steady state and transient phases. The available literature on the subject is cited through several review papers which would give fair understanding of its present state. Parametric studies suggest that critical combinations of system variables can drive the spacecraft unstable, however, suitable control strategies are available to restore equilibrium. Emphasis throughout is on methodology of approach to complex dynamical systems and analysis of results to gain better physical appreciation as to their response character. To that end mathematical details are purposely avoided. Evolution of the field and current challenges are illustrated through examples involving a variety of configurations of contemporary interest. Author

N90-27755# Rome Univ. (Italy).
A MODEL OF THE PERTURBED SPINNING MOTION OF THE SAN MARCO 5TH SPACECRAFT
CARLO ARDUINI, GIOVANNI LANEVE, DANIELE MORTARI, and A. DEMICCO (Aeronautica Militare Italiana, Rome.) *In* AGARD, Space Vehicle Flight Mechanics 16 p (SEE N90-27741 22-18) Jun. 1990
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Models of the spin axis of a spacecraft are described moving in sub-equatorial orbit in a relatively dense atmosphere, and under non negligible gravity gradient and magnetic torque. These drift models were used in the design of the San Marco Utafiti-5 aeronomy satellite for obtaining the most stable pointing condition and, also, for the refinement of the attitude measurements of the same spacecraft. The method of fitting is described and some results shown. Author

N90-27757# Wright Research Development Center, Wright-Patterson AFB, OH.
FLEXIBLE STRUCTURE CONTROL AND RIGID BODY DYNAMICS
V. B. VENKAYYA *In* AGARD, Space Vehicle Flight Mechanics 6 p (SEE N90-27741 22-18) Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The main interest is to promote the objectives of Control-Structure Interaction (CSI) in vibration suppression and attitude control of large space structures. Integration of multibody dynamics, flexible structures and control system design is considered extremely important in CSI research. The concepts of decentralized controls and optimization of lightly damped systems are the promising approaches for realistic applications. Author

N90-27758# Padua Univ. (Italy). Dept. of Mechanical Engineering.
DYNAMICS AND DYNAMICS EXPERIMENTS IN TSS-1
SILVIO BERGAMASCHI   *In* AGARD, Space Vehicle Flight Mechanics 11 p (SEE N90-27741 22-18)   Jun. 1990 Sponsored by Agenzia Spaziale Italiana
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TSS-1 (Tethered Satellite System-1) is the first retrievable space system to be tethered to the Shuttle in order to conduct scientific experiments. The nominal profile of the mission will consist of: a deployment phase, where the tether is reeled out from the Shuttle until the satellite is 20 km above it; stationkeeping, in which the tether length is almost constant and the scientific activity reaches its maximum; and retrieval, where the tether is reeled in, until the satellite is recovered in the cargo bay. Two of the research proposals selected in 1984 by a joint U.S.-Italy commission are dedicated to the study of the dynamics of this novel system. The purpose of this paper is: to comment the mathematical models implemented so far to simulate TSS-1 dynamics; and to present the rationale of the investigation activity (being) carried out at the University of Padua and to survey its functional objectives.
Author

N90-27759*# National Aeronautics and Space Administration, Washington, DC.
NATIONAL AERO-SPACE PLANE: FLIGHT MECHANICS
DUNCAN E. MCIVER and FREDERICK R. MORRELL (National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.)   *In* AGARD, Space Vehicle Flight Mechanics 10 p (SEE N90-27741 22-18)   Jun. 1990
(AGARD-CP-489)   Copyright   Avail: NTIS HC A21/MF A03;
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AGARD/Scientific Publications Executive   CSCL 22/2
The current status and plans of the U.S. National Aero-Space Plane (NASP) program are reviewed. The goal of the program is to develop technology for single stage, hypersonic vehicles which use airbreathing propulsion to fly directly to orbit. The program features an X-30 flight research vehicle to explore altitude-speed regimes not amenable to ground testing. The decision to build the X-30 is now scheduled for 1993, with the first flight in the late 1990's. The flight mechanics, controls, flight management, and flight test considerations for the X-30 are discussed.   Author

N90-27760# Technische Univ., Munich (Germany, F.R.).
OPTIMAL TRAJECTORIES FOR SAENGER-TYPE VEHICLES
G. SACHS, R. BAYER, and J. DREXLER   *In* AGARD, Space Vehicle Flight Mechanics 12 p (SEE N90-27741 22-18)   Jun. 1990
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The ascent performance of winged space transportation systems is considered. The system investigated consists of two stages the first stage of which is equipped with an airbreathing propulsion system. For the second stage, two rocket-powered vehicles are considered of which one is equipped with wings and the other is a fuselage type body. It is shown which are key factors in regard to the ascent performance of the upper stage. This particularly concerns the performance enhancement due to its lifting capability. It is shown that an upper stage without wings also shows an ascent capability for small flight path angles at separation. Furthermore, the separation flight maneuver is considered. It is shown that constraints (dynamic pressure and load factor limits) have a significant effect on the ascent performance achievable in regard to a most favorable separation condition for the upper stage. The effects of thrust increase due to a fuel-air ratio more than stoichiometric are considered. It is shown which improvements can be achieved for the separation flight condition. Two optimization methods were used. One is an indirect technique applying the minimum principle and the method of shooting. The other represents a direct technique where the control vector function is parameterized.   Author

N90-27763*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE CHALLENGE OF ASSEMBLING A SPACE STATION IN ORBIT
VANCE D. BRAND   *In* AGARD, Space Vehicle Flight Mechanics 8 p (SEE N90-27741 22-18)   Jun. 1990
(AGARD-CP-489)   Copyright   Avail: NTIS HC A21/MF A03;
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Assembly of a space station in orbit is a challenging and complicated task. If mankind is to exploit the knowledge already gained from space flight and continue to advance the frontiers of space exploration, then space stations in orbit must be part of the overall space infrastructure. Space stations, like the Freedom, having relatively large mass which greatly exceeds the lifting capability of their transportation system, are candidates for on-orbit assembly. However, when a large wide-body booster is available, there are significant advantages to having a deployable space station assembled on Earth and transported into orbit intact or in a few large pieces. The United States will build the Space Station Freedom by the assembly method. Freedom's assembly is feasible, but a significant challenge, and it will absorb much of NASA's effort in the next 8 years. The Space Station Freedom is an international program which will be the centerpiece of the free world's space activities in the late 1990's. Scientific information and products from the Space Station Freedom and its use as a transportation depot will advance technology and facilitate the anticipated manned space exploration surge to the Moon and Mars early in the 21st century.   Author

N90-27764*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
IN-SPACE CONSTRUCTION AND DYNAMICS OF LARGE SPACE STRUCTURES
MARTIN M. MIKULAS, JR.   *In* AGARD, Space Vehicle Flight Mechanics 10 p (SEE N90-27741 22-18)   Jun. 1990
(AGARD-CP-489)   Copyright   Avail: NTIS HC A21/MF A03;
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AGARD/Scientific Publications Executive   CSCL 22/2
The types of equipment and structures that will be required to construct very large spacecraft in space are discussed. One of the basic issues that must be resolved is the appropriate mix of humans and machines in the construction process. While the use of robots offers the potential for reducing the number of extra-vehicular activity (EVA) hours required for particular construction operations, the availability of humans greatly increases the reliability of complex construction tasks. A hybrid system is described which makes the best use of man and machine to provide a highly reliable and versatile construction approach. Such a system will provide an efficient method for constructing large spacecraft until fully automated, robotic devices can be perfected. Details are given on an extensive ground test program which was designed to evaluate and demonstrate large spacecraft construction. A discussion is presented on the use of the Space Station Freedom, or an appropriate derivative, as a construction facility. Finally, a construction scenario and assembly timelines are presented for constructing a 20-meter-diameter high precision reflector.   Author

N90-27765# Aeritalia S.p.A., Turin (Italy).
A NEW METHOD FOR A TETHERED SYSTEM AIDED SPACE STATION ASSEMBLY
SALVATORE CIARDO and SILVIO BERGAMASCHI (Padua Univ., Italy)   *In* AGARD, Space Vehicle Flight Mechanics 15 p (SEE N90-27741 22-18) Jun. 1990
(AGARD-CP-489)   Copyright   Avail: NTIS HC A21/MF A03;
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During the Space Station Freedom building phase the major assembled item will be the main truss. Due to the gravity gradient torques, the stable equilibrium configuration is that with the minimum inertia aligned with the local vertical (yaw). Nevertheless, due to some user requirements, the planned building sequence imposes the same axis be pointed toward the pole of the orbit plane (pitch), in a configuration unstable at least in roll-yaw. Therefore, the Attitude Control System (ACS) has to be designed in such a way as to counteract the gravity gradient effects as well as the relatively small environment perturbing torques. The

dynamic behavior of a system whose moments of inertia are substantially altered by means of the displacement of a certain amount of additional mass connected to the S.S. Freedom by means of one or two tethers is investigated. The expected benefits and the potential disadvantages of the methods will be discussed. The configuration selection rationales will be analyzed, especially taking into account the operational aspects. A description of the relevant assumptions of the adopted dynamic model and an analytic deduction of the stability criteria is given. The results of an ad-hoc developed computer program will be shown. The dynamic response of the system during non-nominal operative conditions were analyzed in order to provide a complete assessment. The additional disturbance to the station attitude both due to the presence of the tethered system and to the probability that the tether is severed by micrometeoroids or man-made debris will be computed. During the building phase numerous substantial changes in the moments of inertia of the S.S. Freedom are planned. In these cases, the approach discussed permits a very versatile intervention strategy.
Author

N90-27766# Liege Univ. (Belgium). Dynamique des Constructions Mecaniques.
DEPLOYMENT OF LARGE FLEXIBLE SPACE STRUCTURES
M. GERADIN, A. CARDONA (Consejo Nacional de Investigaciones Cientificas y Tecnicas, Mar del Plata, Argentina), and D. GRANVILLE   In AGARD, Space Vehicle Flight Mechanics 11 p (SEE N90-27741 22-18)   Jun. 1990
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   A fairly general methodology developed to simulate the deployment of large flexible space structures using the finite element concept is described. Three simulations of structural deployment are presented to demonstrate the effectiveness of the method: an elementary cell of astromast, an elementary cell of the ERA structure and a 3-D antenna.   Author

N90-27768#   National   Aerospace   Lab.,   Amsterdam (Netherlands).
EFFECTS OF LOW BOND NUMBER LIQUID MOTIONS ON SPACECRAFT ATTITUDE
J. P. B. VREEBURG and R. F. VANDENDAM   In AGARD, Space Vehicle Flight Mechanics 13 p (SEE N90-27741 22-18)   Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03;
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   The introduction gives a short review of the effects that onboard liquid may have on the dynamics of the spacecraft. A distinction is made between arbitrarily moving craft and spin-stabilized vehicles. The modelling of rotating liquid behavior is very complicated and generally allows only to make predictions on the stability behavior of a spinning spacecraft. A flight experiment with a model satellite, with liquid in an annular tank, during parabolic aircraft flight is described. From a filmed record of the unconstrained motion, the attitude of the satellite is reconstructed. Details of the image processing scheme are given. The numerical simulation of the motion of the model satellite is explained. The liquid is inviscid and is assumed to move in the tank in two directions only, i.e., radial motion is neglected. Surface tension effects are important and are fully accounted for. The angular rates of the model following a short-duration torque, are presented. Plots of the liquid motion are included.   Author

N90-27769#   National   Aerospace   Lab.,   Emmeloord (Netherlands).
FLEXIBLE SPACE-BASED ROBOT MODELLING AND REAL-TIME SIMULATION
J. J. M. PRINS, P. DIELEMAN, and P. TH. L. M. VANWOERKOM In AGARD, Space Vehicle Flight Mechanics 10 p (SEE N90-27741 22-18)   Jun. 1990   Sponsored by Netherlands Agency for Aerospace Programs, Delft
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   The Hermes manipulation system (HERA) is a sophisticated space manipulator system, which has to perform tasks ranging from berthing to tool operation in various operational modes from

fully automatic to purely manual. Development and qualification of such a space-based manipulator must be supported by computer simulation facilities. The HERA system main contractor is Fokker Space and Systems B.V. (FSS). The National Aerospace Laboratory (NLR) in the Netherlands is responsible for the development of the so-called HERA Simulation Facilities (HSF). The focus is on the HSF-P: a first pilot real-time simulation facility. Design concept, simulation models and support tools are discussed in some detail.
Author

N90-27770*#   National Aeronautics and Space Administration, Washington, DC.
FLIGHT MECHANICS APPLICATIONS FOR TETHERS IN SPACE: COOPERATIVE ITALIAN-US PROGRAMS
FRANCO BEVILACQUA, PIETRO MERLINA (Aeritalia S.p.A., Turin, Italy), and JOHN L. ANDERSON In AGARD, Space Vehicle Flight Mechanics 12 p (SEE N90-27741 22-18) Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03;
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AGARD/Scientific Publications Executive   CSCL 22/2
   Since the 1974 proposal by Giuseppe Colombo to fly a tethered subsatellite from the Shuttle Orbiter, the creative thinking of many scientists and engineers from Italy and U.S. has generated a broad range of potential tether applications in space. Many of these applications have promise for enabling innovative research and operational activities relating to flight mechanics in earth orbit and at suborbital altitudes. From a flight mechanics standpoint the most interesting of the currently proposed flight demonstrations are: the second Tethered Satellite System experiment which offers both the potential for aerothermodynamics and hypersonics research and for atmospheric science research; the Tethered Initiated Space Recovery System which would enable orbital deboost and recovery of a re-entry vehicle and waste removal from a space station; and the Tether Elevator/Crawler System which would provide a variable microgravity environment and space station center of mass management. The outer atmospheric and orbital flight mechanics characteristics of these proposed tether flight demonstrations are described. The second Tethered Satellite System mission will deploy the tethered satellite earthward and will bring it as low as 130 km from ground and thus into the transition region between the atmosphere (non-ionized) and the partially ionized ionosphere. The atmospheric flight mechanics of the tethered satellite is discussed and simulation results are presented. The Tether Initiated Space Recovery System experiment will demonstrate the ability of a simple tether system to deboost and recover a reentry vehicle. The main feature of this demonstration is the utilization of a Small Expendable Deployment System (SEDS) and the low-tension deployment assumed to separate the reentry vehicle from the Shuttle. This low-tension deployment maneuver is discussed and its criticalities are outlined. The Tether Elevator/Crawler System is a new space element able to move in a controlled way between the ends of a deployed tethered system. A Shuttle test of an Elevator model is planned to demonstrate the unique capability of this element as a microgravity facility and to test the transfer motion control. The basic dynamical features of the Elevator system are presented and a preliminary assessment of the Elevator-induced tether vibrations is discussed.   Author

N90-27771# Institute for Defense Analyses, Alexandria, VA.
TESTING DOD SPACE SYSTEMS: THE CHALLENGE
W. ANDREW WISDOM and LOWELL C. KEEL (Air Force Systems Command, Bolling AFB, Washington, DC.) In AGARD, Space Vehicle Flight Mechanics 15 p (SEE N90-27741 22-18)   Jun. 1990
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   The advent of military space systems in the 1960's challenged the nation's test capabilities and demanded creation of new techniques and concepts to deal with the state-of-the-art complexities inherent in expensive, vital national assets. As the national dependence upon space systems increased over the past two decades, so too has the complexity of the hardware and software components needed to perform the assigned missions. This increasing complexity has required ever increasing sophistication and modernization of the Department of Defense test and evaluation capabilities, however, current concepts for new

military space systems outstrip the present test capabilities. New test and evaluation techniques, concepts and capabilities are required to meet these new challenges. The challenges of testing military space systems are reviewed and some of the new testing concepts and modernization initiatives being pursued are presented. Author

N91-19124# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
TECHNICAL EVALUATION REPORT ON THE FLIGHT MECHANICS PANEL SYMPOSIUM ON SPACE VEHICLE FLIGHT MECHANICS
N. X. VINH (Michigan Univ., Ann Arbor.) Nov. 1990 16 p
(AGARD-AR-294; ISBN-92-835-0570-0; AD-A230434) Copyright
Avail: NTIS HC/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
In recent years, manned flights into low earth orbits have been made both for scientific study and for the placement of unmanned satellites into geosynchronous orbits and also into interplanetary orbits. Efforts of many nations are currently under way to place man into orbit on a semipermanent basis through the use of a space station. At the same time, the aerospace industry worldwide is considering the extension from supersonic flight of advanced fighter aircraft to the hypersonic flight of a future aerospace plane. To meet the challenges of the many technical problems to be solved in this new area, the Flight MechaPanel has sponsored its first symposium on space vehicle flight mechanics, held in Luxembourg, from November 13 to 16, 1989. The purpose of the symposium was to examine the flight mechanics of vehicles in space and in the upper layer of the atmosphere and to identify the areas of technology relevant to the Flight Mechanics Panel. This technical evaluation report evaluates the presentations and discussions in each of the five sessions of the symposium, draws relevant conclusions, and makes recommendations for future symposia in space flight mechanics. Author

N92-12521# Aerospace Corp., Sunnyvale, CA.
ADVANCED SATELLITE WORKSTATION (ASW)
T. E. BLEIER, S. HOLLANDER, and S. SUTTON In AGARD, Machine Intelligence for Aerospace Electronic Systems 8 p (SEE N92-12517 03-63) Sep. 1991
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The ASW's goal was to evaluate the utility of expert systems in military satellite testing operations. It quickly became apparent, however, that the rule base was too limited. This project's goal was then modified to capture as much of the factory and flight experience as possible in an electronic, updateable medium. The resulting electronic library would then permit much deeper insight into the satellite's operation and more confidence in understanding and expanding the expert system rule base. Author

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SPACECRAFT INSTRUMENTATION

N90-27756# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Transport and Orbital Systems Div.
THE INSTRUMENT POINTING SYSTEM: PRECISION ATTITUDE CONTROL IN SPACE
RALF HARTMANN and ALBRECHT WOELKER In AGARD, Space Vehicle Flight Mechanics 11 p (SEE N90-27741 22-18) Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The Spacelab Instrument Pointing System (IPS) is a three axes gimbal system providing pointing and stabilization in the arcsec range to a variety of space experiments with a mass of up to 7000 kg. The IPS demonstrated its control performance during the maiden flight in July 1985, the Spacelab 2 mission on board the Space Shuttle Challenger. The most challenging problem for attitude control in space is the disturbance compensation in the presence of structural flexibilities. Kalman filtering based on optical sensor and gyro measurements as well as flexible mode attenuation and feedforward control were indispensable to achieve high precision. To further enhance the IPS pointing performance and versatility, a new, more autonomous computer and sensor concept has been conceived providing the capacity for a higher degree of automation as well as improved pointing and closed loop tracking control. The autonomy and control capacity of the enhanced IPS establish the basis to accommodate the IPS as long-term available tracking and pointing platform on the International Space Station Freedom (ISF). Author

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SPACECRAFT PROPULSION AND POWER

Includes main propulsion systems and components, e.g., rocket engines; and spacecraft auxiliary power sources.

N90-10196# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
EXPERIMENTAL STUDY ON THE STABILITY OF SMALL ROCKET ENGINES WITH STORABLE LIQUID PROPELLANTS [RECHERCHE EXPERIMENTALE SUR LA STABILITE DES PETITS MOTEURS FUSEES A ERGOLS STOCKABLES]
ROBERT FOUCAUD and RENAUD LECOURT In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 8 p (SEE N90-10191 01-25) Apr. 1989 In FRENCH; ENGLISH summary Previously announced in IAA as A89-31804
(AGARD-CP-450) Copyright Avail: NTIS HC A14/MF A02
The stability of small rocket engines with storable liquid propellants was quantified and the sensitivity of the injection zone to an acoustic disturbance measured. In the method, the rocket is periodically destabilized near its first longitudinal acoustic mode by means of an intermittent modulation of the nozzle neck. Results are presented for axial injectors, where the acoustic disturbance is mainly a pressure oscillation, and radial injectors, where the acoustic disturbance is mainly a velocity oscillation. IAA

N90-10197# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Kommunikationssysteme und Antriebe.
LOW FREQUENCY AND HIGH FREQUENCY COMBUSTION OSCILLATION PHENOMENA INSIDE A ROCKET COMBUSTION CHAMBER FED BY LIQUID OR GASEOUS PROPELLANTS
D. PRECLIK and P. SPAGNA In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 18 p (SEE N90-10191 01-25) Apr. 1989
(AGARD-CP-450) Copyright Avail: NTIS HC A14/MF A02
Combustion instability phenomena inside a rocket combustion chamber fed by liquid or gaseous propellants is investigated. The interpretation relies, among others, on the combustion time lag theory and the use of linear transfer functions for the different elements building the closed loop transfer function of the system. Author

N91-13488# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
HAZARD STUDIES FOR SOLID PROPELLANT ROCKET MOTORS
THOMAS L. BOGGS, ed. and RONALD L. DERR, ed. Sep. 1990 205 p
(AGARD-AG-316; ISBN-92-835-0581-6; AD-A229162) Copyright
Avail: NTIS HC/MF A10; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
This AGARDograph summarizes hazard studies for solid propellant rocket motors over the period 1984 to 1989. The AGARDograph presents concepts and methods for evaluating hazard risks associated with solid propellant rocket motors and the technology for minimizing potential damage due to these hazards. Author

20 SPACECRAFT PROPULSION AND POWER

N91-14285# Nielsen Engineering and Research, Inc., Mountain View, CA.
AERODYNAMIC DESIGN OF PEGASUS (TRADEMARK): CONCEPT TO FLIGHT WITH CFD
MICHAEL R. MENDENHALL, DANIEL J. LESIEUTRE, STEVEN C. CARUSO, MARNIX F. E. DILLENIUS, and GARY D. KUHN *In* AGARD, Missile Aerodynamics 11 p (SEE N91-14278 06-02) Oct. 1990 Sponsored in part by Orbital Sciences Corp., Vienna, VA (AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Pegasus (trademark), a three-stage, air-launched, winged space booster is currently under development to provide fast and efficient commercial launch services for small satellites. The aerodynamic design and analysis of the vehicle was conducted without benefit of wind tunnel and subscale model testing using only computational aerodynamic and fluid dynamic methods. All levels of codes, ranging in complexity from empirical database methods to three-dimensional Navier-Stokes codes, were used in the design. The design and analysis requirements, the unique and conservative design philosophy, and the analysis methods considered for the various technical areas of interest and concern are described. Author

N91-14296# Naval Weapons Center, China Lake, CA. Airbreathing Propulsion Branch.
OVERVIEW OF PROPULSION CONCEPTS FOR TACTICAL MISSILES
FREDERICK C. ZARLINGO *In* AGARD, Missile Aerodynamics 12 p (SEE N91-14278 06-02) Oct. 1990 (AGARD-CP-493) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Several propulsion concepts lend themselves to application in tactical missiles; many of them can improve missile system performance by means of longer range, high speed, or both. Tactical missile propulsion systems generally fall into one of two categories: rockets that carry all their fuel and oxidizer and airbreathing engines that have to carry only their fuel since their oxidizer is obtained from the surrounding air. Tactical missiles were typically propelled by conventional solid propellant powered rockets or, occasionally, liquid propellant powered rockets. However, newly emerging requirements and needs are placing more emphasis on sustained high speed and longer ranges, as well as reduced cost and improved reliability and safety. In addition, there is more emphasis on launcher (aircraft or ground based) survivability. Survivability can be enhanced by longer ranges or reduced visibility. These needs can be implemented either singly or in combination by using selected propulsion systems. Pulse rockets, ramjets (both liquid fueled and solid fueled), turbojets, and air-turborockets (or turboramjets) possess the potential of long range and high speeds. An overview is provided for the various propulsion concepts considered applicable to tactical missiles and describes and discusses the merits of each. Author

N91-23171# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
HIGHLY INTEGRATED DUCTED ROCKET PROPULSION MODULES FOR FUTURE HYPERSONIC TACTICAL MISSILES
HERMANN-L. WEINREICH *In* AGARD, Hypersonic Combined Cycle Propulsion 13 p (SEE N91-23147 15-07) Dec. 1990 (AGARD-CP-479) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Integrated airbreathing propulsion systems for future hypersonic tactical missiles were studied under funding of the German MOD. A 30 km range (Mach 5) antiradiation mission was selected for more detailed investigations. Main aspects for the missile/propulsion design are simple design with no or minimum geometrical variability, no ejecta during boost/sustain transition, and high average velocity (transition Mach number well above 3). To minimize the mass fraction of the required booster propellant an optimum, common (non-ejectable) boost/sustain nozzle must be adopted; the booster pressure should be optimized to use the strength potential of the ramcombustor structure, and the intake must be closed during boost to reudce drag and to avoid dangerous buzz. A special two position intake concept permits intake closure during boost, strating of the internal shock system, and cruise

flight with minimum external drag and high pressure recovery at transition Mach numbers. Based on promising test results of the DLR/Cologne obtained with a comparable intake model a new family of intakes with different internal compression ratio and lip-bluntness was designed. A boron loaded ducted rocket with subsonic self throttling gas generator flow was selected for cruise flight propulsion due to its simple design, excellent combustion stability, and the high level of existing experience. Even at combustor temperatures above the condensation temperature of boron-oxide, the volumetric impulse of boron loaded propellants remains attractive. The ducted rocket gas generator can be integrated within the missile freebody which also contains seeker, warhead, electric compartment, and missile controls. The missile flight control system is based on jet reaction using minirockets during boost and high pressure intake tap air during cruise. C/C material was adopted for the structural design. The superiority of the ducted rocket powered medium range antiradiation missile was demonstrated by comparison with a rocket powered missile having the same diameter and payload. For short range (6 to 12 km) low level missions the solid fuel ramjet with integral boost is an attractive propulsion concept. Author

N92-12523# Canadian Space Agency, Ottawa (Ontario). Computer and Intelligent Systems Group.
SPACECRAFT ELECTRICAL POWER SYSTEM FAULT DETECTION/DIAGNOSIS AND RESOURCE MANAGEMENT
PETER J. ADAMOVITS and ERIC JACKSON (International Submarine Engineering Ltd., Port Coquitlam, British Columbia) *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 11 p (SEE N92-12517 03-63) Sep. 1991 (AGARD-CP-499) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The domain of Electrical Power Systems (EPS) for Radar Spacecraft and its effects on the design of AI-based systems for health monitoring and resource management are discussed. Work on EPS Fault Handling and Resource Planning is presented. The Fault Handling System relies on model-based reasoning techniques, while the Resource Planning System relies on case-based reasoning techniques. The two systems perform their functions in a cooperative way and are distributed over both ground-based and space-based processing elements. Author

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CHEMISTRY AND MATERIALS (GENERAL)

N89-22654# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
APPLICATION OF ADVANCED MATERIAL FOR TURBOMACHINERY AND ROCKET PROPULSION
Mar. 1989 282 p In ENGLISH and FRENCH Meeting held in Bath, England, 3-5 Oct. 1988 (AGARD-CP-449; ISBN-92-835-0498-4; AD-A214462) Copyright Avail: NTIS HC A13/MF A02

The proceedings of the conference are presented. The specialists' meetings were arranged in the following sessions: Overview and Combined Applications; Gas Turbine Applications; Rocket Applications; and Special Applications. A Technical Evaluation report is included at the beginning of the proceedings. The aim of the specialists' meetings was to review the advances made in the field of materials applicable in the not parts of aerospace propulsion system during the last few years. The meetings offered a forum for the users of new materials in the fields of turbomachines and rockets to report on recent achievements and to discuss the various applications. For individual titles, see N89-22655 through N89-22680.

N89-22655# Air Force Materials Lab., Wright-Patterson AFB, OH. Metals and Ceramics Div.
TECHNICAL EVALUATION REPORT
NORMAN M. TALLAN   *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 11 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449)   Copyright   Avail: NTIS HC A13/MF A02
   A technical evaluation is presented of the materials presented at the 72nd Propulsion and Energetics Panel Specialists' Meeting. The objective of the meeting was to bring together the designers, developers and users of aerospace propulsion systems and the developers and producers of aerospace materials to provide a forum in which the material requirements of both current and future propulsion systems and the ability of emerging new materials to meet those requirements could be reviewed. The scope included the properties and potential applications of superalloys, refractory metals, advanced intermetallic alloys, and metal matrix composites based on them; carbon-carbon and ceramic matrix composites; coatings and the processes used to prepare them; bearing and insulation materials; braze and weld repair methods; innovative design approaches to the use of these new materials; and the damage tolerance and life prediction of these materials and their implications with regard to damage tolerant design and applications to real propulsion systems.   E.R.

N89-22656# Pratt and Whitney Aircraft, West Palm Beach, FL. Materials Engineering.
APPLICATION OF ADVANCED MATERIALS FOR TURBOMACHINERY AND ROCKET PROPULSION
JOSEPH B. MOORE   *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 5 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449)   Copyright   Avail: NTIS HC A13/MF A02
   Gas turbine engines of the 1980's and 1990's will require improved nickel and titanium alloys as well as certain intermetallic compounds and low temperature composites. Engines of the 2000's with significantly higher thrust to weight ratios will require lighter weight, higher temperature non-conventional materials including aluminum alloys, titanium metal matrix composites, intermetallic compounds, and ceramic matrix composites. Major concerns once these materials are developed will be the design, manufacture, inspection, and repair of required components at affordable cost. Current or near-term liquid rocket engines having technology levels equivalent to those being studied for the space transportation and advanced launch systems can benefit from improved materials for turbomachinery, high heat flux throat regions of the thrust chamber, high strength, hydrogen resistant materials for cases and ducts, and refractory materials for uncooled or partially cooled nozzle extensions. To meet the far term goals for advanced rocket engines required for single-stage-to-orbit (SSTO) vehicles materials requirements are not unlike those described above for 21st century gas turbine engines.   Author

N89-22661# Pratt and Whitney Aircraft, West Palm Beach, FL.
DAMAGE TOLERANCE CONCEPTS FOR ADVANCED MATERIALS AND ENGINES
T. E. FARMER and M. C. VANWANDERHAM   *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 7 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449)   Copyright   Avail: NTIS HC A13/MF A02
   Planned increases in thrust to weight for future gas turbine engines require dramatically higher operating temperatures and rotor speeds. This necessitates simpler design, improved materials and sophisticated fabrication techniques. Damage Tolerance Design (DTD) has been established as the basis for gas turbine engine design and maintenance in the U.S. Consideration of damage tolerance has significant influence on configurations and materials. The advanced configurations, bonded structures, composites, anisotropic alloys and less ductile materials required to meet the advanced engine goals challenge the current DTD philosophy. Fortunately, interim plans for incremental increases in performance and engine configuration to meet long-term goals afford the opportunities for developing transition technologies to meet these objectives.   Author

N89-22662# Rolls-Royce Ltd., Derby (England).
MATERIAL/MANUFACTURING PROCESS INTERACTION IN ADVANCED MATERIAL TECHNOLOGIES
G. W. MEETHAM   *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 7 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449)   Copyright   Avail: NTIS HC A13/MF A02
   Since the first flight of a gas turbine powered aircraft some forty years ago, tremendous advances in engine performance have been made in terms of thrust, thrust-weight ratio and specific fuel consumption. The performance and efficiency of gas turbine engines is a direct function of the maximum cycle temperature and, throughout the forty years in which the aero gas turbine has existed, this has provided the motivation for the continuous development of materials which are capable of operating at higher temperatures in the turbine section of the engine. Turbine entry temperatures have risen from around 700 C in the Whittle W1 engine in 1941 to around 1350 C in current advanced engines.   Author

N89-22678*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
CRYOGENIC TURBOPUMP BEARING MATERIALS
BILIYAR N. BHAT   *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 10 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449)   Copyright   Avail: NTIS HC A13/MF A02
CSCL 07/1
   Materials used for modern cryogenic turbopump bearings must withstand extreme conditions of loads and speeds under marginal lubrication. Naturally, these extreme conditions tend to limit the bearing life. It is possible to significantly improve the life of these bearings, however, by improving the fatigue and wear resistance of bearing alloys, and improving the strength, liquid oxygen compatibility and lubricating ability of the bearing cage materials. Improved cooling will also help to keep the bearing temperatures low and hence prolong the bearing life.   Author

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COMPOSITE MATERIALS

Includes physical, chemical, and mechanical properties of laminates and other composite materials.

N89-22666# United Technologies Research Center, East Hartford, CT. Materials Technology.
COMPOSITE MATERIAL SYSTEMS FOR HIGH TEMPERATURE APPLICATIONS
EARL R. THOMPSON   *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 13 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449)   Copyright   Avail: NTIS HC A13/MF A02
   One approach to the demands of high temperature, structural applications, being actively pursued, is through the development of composite materials. For applications up to approximately 1200 C, the materials research is primarily centered upon the fiber reinforcement of glass and glass-ceramic matrices. For applications above 1200 C, the development of coating systems for the protection of high-strength carbon-carbon composites is the prime focus. In terms of fabrication, the glass and glass-ceramic matrix composites reinforced by carbon and silicon carbide fiber yearns can be understood by considering the thermoplastic nature of the matrix constituent. Continuous, as well as chopped, fibers were successfully used to reinforce these brittle matrices. When optimally fabricated, the resultant composites have displayed a combination of high apparent toughness and high strength at room and elevated temperature. Carbon-carbon composites have extremely high temperature (greater than 2000 C) capability and excellent strength retention in inert environments. The major application limiting property of these composites is the lack of coatings which will provide the required long life, high-temperature oxidation resistance. Multilayer coating approaches which depend upon silicon nitride as the primary oxidation resistant barrier were developed. The

background leading to this choice and a consideration of the experience with this coating are considered. Author

N89-22667# Centre de Villaroche, Moissy (France).
UTILIZATION OF HIGH TEMPERATURE COMPOSITES IN TURBOJET ENGINES [UTILISATION DES COMPOSITES HAUTES TEMPERATURES DANS LES TURBOREACTEURS]
R. MESTRE *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 11 p (SEE N89-22654 16-23) Mar. 1989 In FRENCH
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02

The design of modern military turbojet engines yields a high performance thrust/weight nozzle of composite materials in the hot section of the engine. Within that context, SNECMA, developed ceramic composites for use as afterburning nozzles in the turbines, areas of the engine where the temperature of the gas goes above 2000 K, especially after prolonged use. The materials, CERASEP (SiC-SiC) and SEPCARB (C-SiC) provided by the European Societe of Propulsion is used for nozzle flaps and other pieces of the structure. Some tests were made on the prototype, in order to validate the fabrication procedures and the design concept. The engine parts were made and tested for endurance, while the engine was in operational use. Author

N89-22668# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
INITIAL RESULTS OF TESTS ON METAL-CERAMIC GUIDE VANES
W. HUETHER and W. KRUEGER *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 5 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02

Metal-ceramic guide vanes consist of an outer ceramic shell and an inner metallic core, which is cooled. The hot gas contacts only the uncooled ceramic shell, so that the total amount of cooling air is reduced to a low value compared with conventional guide vanes. A linear arrangement of four guide vanes in a size which would be suitable for the RB 199 was built and tested with hot gas at atmospheric pressure. It could be shown that material temperature of the ceramic shell higher than 1870 K (2900 F) are possible, under static as well as cyclic loading. Author

N89-22672# SIGRI Electrogradhit G.m.b.H., Meitingen (Germany, F.R.).
SILICON-CARBIDE COATED CARBON-CARBON: AN ADVANCED MATERIAL FOR ROCKET SYSTEMS
E. V.GELLHORN, U. GRUBER, and H. LEIS (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Germany, F.R.) *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 10 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02

To increase the resistance of rocket systems, materials have to be used which can withstand temperatures above 2000 C, as well as erosion and corrosion attack. Carbon fiber-reinforced carbon coated with silicon carbide seems to be the outstanding material suited to resist temperature as well as mechanical requirements. The manufacture of the nozzles is described. Carbon fibers are impregnated with resins, the resins are carbonized to form a closed carbon matrix and the shaped body is coated with silicon carbide. The nozzles were tested for up to 300 seconds in a semi-free jet and a connected pipe test rig for the ramrocket under regular operating conditions. The tests proved the excellent thermal shock resistance of the material, as well as its oxidation resistance. A better understanding of the material properties demanded was obtained. Author

N89-22675# Aerospatiale Aquitaine, Saint-Medard en Jalles (France), Etablissement d'Aquitaine.
HIGH-PERFORMANCE REFRACTORY COMPOSITE MATERIALS [LES MATERIAUX COMPOSITES REFRACTAIRES A HAUTE PERFORMANCE]
A. HORDONNEAU *In* AGARD, Application of Advanced Materials for Turomachinery and Rocket Propulsion 9 p (SEE N89-22654 16-23) Mar. 1989 In FRENCH
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02

Applications of carbon and ceramic composites to throats and inlet/outlet sections of solid rocket nozzles, combustion chamber elements, and rocket engine mechanical parts are discussed.

Application of these materials for hot structures of the Hermes hypersonic vehicle and the STS 2000 space transport vehicle is also discussed. In addition, various procedures associated with the fabrication of carbon and ceramic composites are discussed including the automatic weaving of fiber preforms, automatic densification, and surface treatment. E.R.

N89-22676# Societe Europeenne de Propulsion, Saint-Medard-en-Jalles (France).
HIGH TEMPERATURE COMPOSITE MATERIALS FOR ROCKET PROPULSION
PAUL DONGUY and JACQUES BROCA *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 11 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02

The promises of the composite materials with non degradable matrix like carbon or ceramics in rocket propulsion is shown by examples. From an historial point of view, carbon-carbon materials were first used in solid rocket motor nozzles. More recently, successful all composite hot gas valving systems have incorporated not only carbon-carbon materials, but also thermostable insulators and oxidation resistant materials with silicon carbide matrix. These oxidation resistant materials open the way now for liquid propellant rocket applications such as small thrusters and large nozzle exit-cone. The design philosopy to be followed to reach the best compromise between propulsion requirements and material properties is discussed. Author

N90-28070# German Air Force, Cologne (Germany, F.R.). Air Matierel Office.
NDI-CONCEPT FOR COMPOSITES IN FUTURE MILITARY AIRCRAFT
MATTHIAS STOERMER *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 8 p (SEE N90-28068 22-38) May 1990
(AGARD-CP-462) Copyright Avail: NTIS HC A11/MF A02;
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Helicopters and fixed wing aircraft entering service with the German Air Force, and the use of composites in these aircraft are reviewed. Past experiences with composites and with existing nondestructive inspection (NDI) techniques are used to identify some of the anticipated NDI requirements for the next generation aircraft. It is expected that if the level of effort devoted to inspection is to be kept within reasonable bounds, increased effort will be needed to develop improved NDI techniques and to provide training to Air Force craftsman to make them aware of the characteristics of composite materials and the types of flaws and defects that they are likely to contain. The use of artificial intelligence in NDI is also expected to increase, and a review of some of the German work in the area is provided. Author

N91-11908# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
METAL MATRIX COMPOSITE WITH LONG FIBERS [LES COMPOSITES A MATRICE METALLIQUE A FIBRES LONGUES]
J. F. STOHR *In* AGARD, New Light Alloys 39 p (SEE N91-11905 03-26) Sep. 1990 In FRENCH, ENGLISH summary
(AGARD-LS-174) Copyright Avail: NTIS HC/MF A11;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

The reinforcement of metal matrices by long ceramic fibers such as alumina, carbon, silicium carbide, leads to very high specific characteristics such as stiffness and strength at both room and high temperature. Progress achieved in the development of new fibers performance has revived the interest for metal matrix composites (MMC) development. After having briefly reviewed the basic laws of unidirectional composites linear mechanics and shed some light on the major role played by fiber-matrix interface in the micromechanics and behavior of these materials, their processing techniques and characteristics are examined. The improvement of the mechanical characteristics of the new generation of composites arises not only from the fiber surface treatment leading to a control of fiber matrix bond strength, but also to the processing techniques derived either from casting or rapid solidification rate techniques. Mechanical characteristics of the most relevant MMC are presented for both metallic and

intermetallic matrices. Attention is drawn to particular behavior such as thermal expansion, thermal cycling, and corrosion resistance.　　　　　　　　　　　　　　　　　　Author

N91-11909#　Nottingham Univ. (England). Dept. of Materials Engineering and Materials Design.
DEVELOPMENTS IN PARTICULATE AND SHORT FIBER COMPOSITES
S. J. HARRIS　*In* AGARD, New Light Alloys 21 p (SEE N91-11905 03-26)　Sep. 1990
(AGARD-LS-174)　Copyright　Avail: NTIS HC/MF A11;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

Major programs exist in the USA and Europe to produce lightweight, stiff, and strong metallic materials with the aid of discontinuous reinforcement. These efforts relate to light metal matrix alloys (aluminum, magnesium, and titanium) and the use of short fibers, whiskers, and particles of ceramics to provide the necessary reinforcement. Major interest was recently centered on the development of particulate reinforcement of aluminum alloys. The various methods of producing these metal matrix composites are reviewed. Then the influences of reinforcement size, shape and volume fraction, matrix alloy selection, processing route and heat-treatment on the mechanical properties, e.g. stiffness, strength, and toughness of the composites, are discussed. Microstructural evidence is used to interpret property data where possible. Elevated temperature and creep properties are described, as well as the ability of these composites to handle thermal cycling. Other properties, e.g. fatigue and corrosion, which influence the life of components fabricated from these materials also come under review.　　　　　　　　　　　　　　　　Author

N92-18577#　Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
FATIGUE LIFE BEHAVIOUR OF COMPOSITE STRUCTURES
W. BROECKER and K. WOITHE　*In* AGARD, Fatigue Management 10 p (SEE N92-18571 09-05)　Dec. 1991
(AGARD-CP-506)　Copyright　Avail: NTIS HC/MF A12;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

The general fatigue behavior of composite structures is presented. The verification and certification philosophy, depending on the special behavior of the material, is shown. On this basis a lot of structure tests were carried out, taking test parameters such as damages, environmental influence, and load conditions into consideration. The summary of these tests is presented.　Author

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INORGANIC AND PHYSICAL CHEMISTRY

Includes chemical analysis, e.g., chromatography; combustion theory; electrochemistry; and photochemistry.

N90-10191#　Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).　Propulsion and Energetics Panel.
COMBUSTION INSTABILITIES IN LIQUID-FUELLED PROPULSION SYSTEMS
Apr. 1989　306 p　In ENGLISH and FRENCH　Meeting held in Bath, England, 6-7 Oct. 1988
(AGARD-CP-450; ISBN-92-835-0503-4; AD-A211109)　Copyright
Avail: NTIS HC A14/MF A02

The Specialists' Meeting was arranged in the following sessions: Keynote/Overview; Turbine Engine Development Experience; Rocket and Ramjet Development Experience; and Theoretical Modeling and Experimental Methods and Results. The technical evaluation report is included at the beginning of the proceedings. Questions and answers of the discussions follow each paper. For individual titles, see N90-10192 through N90-10207.

N90-10192#　California Inst. of Tech., Pasadena.
COMBUSTION INSTABILITIES IN LIQUID-FUELED PROPULSION SYSTEMS: AN OVERVIEW
F. E. C. CULICK　*In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 73 p (SEE N90-10191 01-25)　Apr. 1989　Sponsored in part by California Inst. of Technology; Navy; AF; and Hersh Acoustical Engineering
(AGARD-CP-450)　Copyright　Avail: NTIS HC A14/MF A02

Combustion of reactants in a confined volume favors excitation of unsteady motions over a broad range of frequencies. A relatively small conversion of the energy released will produce both random fluctuations or noise, and, under many circumstances, organized oscillations generically called combustion instabilities. Owing to the high energy densities and low losses in combustion chambers designed for propulsion systems, the likelihood of combustion instabilities is high. The accompanying heat transfer to exposed surfaces, and structural vibrations are often unacceptable, causing failure in extreme cases. Combustion instabilities are briefly reviewed in liquid-fueled propulsion systems; rockets, ramjets, and thrust augmentors - with emphasis on work accomplished during the past decade. To provide a common framework for discussing the wide range of works, a theory of two-phase flow is reviewed as the basis for an approximate analysis of combustion instabilities. The analysis is directed primarily to treatment of linear stability; it is sufficiently general to accommodate all processes occurring in actual systems. A new result was obtained for an extended form of Rayleigh's criterion and its relation to the growth constant for unstable waves. The chief mechanisms for combustion instabilities in liquid-fueled systems are reviewed, followed by a summary of the common methods of analysis and applications to the three classes of propulsion systems. Control of instabilities by passive and active means is examined briefly.　　　　　　Author

N90-10193#　Pratt and Whitney Aircraft, West Palm Beach, FL. Government Engine Business.
COMBUSTOR INFLUENCE ON FIGHTER ENGINE OPERABILITY
THOMAS L. DUBELL and ANTHONY J. CIFONE (Naval Air Propulsion Test Center, Trenton, NJ.)　*In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 5 p (SEE N90-10191 01-25)　Apr. 1989
(AGARD-CP-450)　Copyright　Avail: NTIS HC A14/MF A02

An aspect of combustion instability that is generally unrecognized, but which has a critical influence on aircraft gas turbine engine operability is discussed. The basic lean combustion limit (static stability) of a combustor, when coupled with engine system dynamics, can result in the inability of an engine to recover from a compressor stall. This is a most serious event for a tactical fighter/attack aircraft engaged in air combat. The coupling of combustor static stability characteristics with engine system dynamics is reviewed, a hypothesis presented, solution approaches suggested and plans to address this challenge discussed.　　　　　　　　　　　　　　　　　　　　　　Author

N90-10194#　Rolls-Royce Ltd., Bristol (England).
CHARACTERISTICS OF COMBUSTION DRIVEN PRESSURE OSCILLATIONS IN ADVANCED TURBO-FAN ENGINES WITH AFTERBURNER
B. E. HENDERSON and J. S. LEWIS　*In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 8 p (SEE N90-10191 01-25)　Apr. 1989
(AGARD-CP-450)　Copyright　Avail: NTIS HC A14/MF A02

Development of a high thrust to weight ratio engine requires that the maximum afterburner thrust boost is achieved. The achievement of this thrust boost must be free of potentially damaging pressure oscillations. The characteristics of both low and high frequency combustion driven pressure oscillations associated with the afterburner of an advanced turbo-fan engine are described. These oscillations are related to the geometry and flow conditions of the afterburner and engine. Models of the characteristics have been developed based on experimental and theoretical techniques. It is shown how these were used to ensure unrestricted operation of the afterburner system throughout the required operating range.　　　　　　　　　　　Author

N90-10205# Imperial Coll. of Science and Technology, London (England).
OSCILLATIONS IN NON-AXISYMMETRIC DUMP COMBUSTORS
J. H. WHITELAW, S. SIVASEGARAM, K. C. SCHADOW, and E. GUTMARK (Naval Weapons Center, China Lake, CA.) *In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 12 p (SEE N90-10191 01-25) Apr. 1989
(AGARD-CP-450) Copyright Avail: NTIS HC A14/MF A02

Instabilities in dump combustors with triangular and round ducts were investigated with expansion ratio, eccentricity of the dump, equivalence ratio and method of injecting the gaseous fuel as variables, and with and without exit nozzles. The shear flow developing from the vertex of a triangular duct is free from large-scale coherent structures, and the injection of fuel close to the vertices of a triangular upstream duct made the flow less susceptible to periodic heat release and resulted in wider ranges of flammability and stability. This effect is quantified for different arrangements of injection. The effect of eccentricity on flammability and stability characteristics is shown to be unimportant for dump-plane area ratios greater than 2.5 and rough combustion in open-ended ducts gave rise to quarter-wave oscillations while the presence of an exit nozzle caused bulk-mode frequencies to dominate. Author

N90-10207# Ente Nazionale per l'Energia Elettrica, Pisa (Italy).
COMBUSTION-DRIVEN OSCILLATION IN LARGE COMBUSTION SYSTEMS FOR POWER GENERATION
G. BENELLI, V. COSSALTER (Padua Univ., Italy), and G. DEMICHELE *In* AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 11 p (SEE N90-10191 01-25) Apr. 1989
(AGARD-CP-450) Copyright Avail: NTIS HC A14/MF A02

Intense pressure oscillations reaching peak values of about 1200 Pa in the 50 divided by 100 Hz range occurred in the combustion chamber of a 480 t/h steam generator, fed with gas or oil and gas together. Through experimental analysis it was possible to identify the acoustic modes of the furnace of the burner. Furthermore, a finite-element mathematical model was devised for modal analysis of the combustion chamber; the numerical results were in close agreement with the experimental data. The analysis carried out showed what modifications needed to be made to the geometry of the burners in order to reduce the self-excited vibrations to acceptable limits. Author

N91-23165# Technische Univ., Munich (Germany, F.R.).
EXPERIMENTAL INVESTIGATIONS ON THE TRANSITION FROM STABLE TO UNSTABLE COMBUSTION BY MEANS OF ACTIVE INSTABILITY CONTROL
S. GLEIS, D. VORTMEYER, and W. RAU *In* AGARD, Hypersonic Combined Cycle Propulsion 7 p(SEE N91-23147 15-07) Dec. 1990
(AGARD-CP-479) Copyright Avail: NTIS HC/MF A20;
Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The interaction of numerous parameters affect excitation and development of combustion instabilities, and determine the excited acoustic modes. Therefore, to avoid combustion stabilities, it is essential to make out the sources of disturbances and to interrupt the feedback loop. The newly developed method of 'Active Instability Control' (AIC) opens experimental opportunities for this kind of diagnostics, because after having stabilized the oscillating system it starts to oscillate again if the AIC-system is switched off. It takes about 300 msec until the oscillation is again fully developed. During this transition period the combustion chamber pressure was registered, the intensity of chemical reaction and the flame contours time resolved by high-speed/-Schlieren-cinematography. Experiments with a laboratory combustor showed, that during the onset of instability various mechanisms of excitation can be observed. Further investigations pointed out that although vortex shedding is an important driving force for oscillations, it is not the origin for instability. Author

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METALLIC MATERIALS

Includes physical, chemical, and mechanical properties of metals, e.g., corrosion; and metallurgy.

N89-21873# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
THE FATIGUE IN AIRCRAFT CORROSION TESTING (FACT) PROGRAMME
R. J. H. WANHILL, J. J. DELUCCIA, and M. T. RUSSO (Naval Air Development Center, Warminster, PA.) Feb. 1989 214 p
(AGARD-R-713; ISBN-92-835-0495-X; AD-A208359) Copyright Avail: NTIS HC A10/MF A02

In the 1970s the Structures and Materials Panel decided to embark on collaborative research activities in the area of fatigue. One of the first activities was the Corrosion Fatigue Cooperative Testing Programme (CFCTP), the precursor to the Fatigue in Aircraft Corrosion Testing (FACT) program. Both programs are described. Failure by fatigue and degradation by corrosion continue to be major considerations in aircraft design. Environmental effects influence both initiation and propagation of fatigue cracks, and dynamic loading may cause more rapid deterioration of corrosion protection systems. Therefore the conjoint action of dynamic loading and environmental attack, i.e., corrosion fatigue, requires special attention. Many corrosion fatigue tests were done on aluminum alloys. However, few included critical structural details like joints, under realistic cyclic load histories and in service-like environments. Ever fewer used practical corrosion protection systems. These aspects are specifically addressed by the CFCTP and FACT programs. The results provide a significant contribution to the understanding of aircraft corrosion fatigue and should encourage further investigation. Author

N89-22660# Rolls-Royce Ltd., Derby (England). Materials Research.
NEW METALLIC MATERIALS FOR GAS TURBINES
M. A. HICKS *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 13 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02

The mix of properties required for high performance components in the gas turbine will continue to necessitate the use of metallic materials for the forseeable future. Examples are shown which indicate how a detailed understanding of material/component behavior and a better understanding and control of the manufacturing process are becoming increasingly important in meeting the anticipated design targets. Author

N89-22663# Fiat Aviazione S.p.A., Turin (Italy). Stress Dept.
DEVELOPMENT OF STRESS AND LIFING CRITERIA FOR SINGLE CRYSTAL TURBINE BLADES
S. SALVANO, M. STANISCI, and E. CAMPO *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 9 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02

The stress and lifing criteria applied to turbine blades are discussed, by focusing the relevant features which make single crystal materials different from conventional alloys. The discussion basis is provided by the material data and blade finite element analyses, collected for the application of single crystal alloys to advanced aircraft engines. Author

N89-22673*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FIBER REINFORCED SUPERALLOYS FOR ROCKET ENGINES
DONALD W. PETRASEK and JOSEPH R. STEPHENS *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 13 p (SEE N89-22654 16-23) Mar. 1989 Previously announced as N89-15990
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
CSCL 11/6

High pressure turbopumps for advanced reusable liquid propellant rocket engines such as that for the Space Shuttle Main

Engine (SSME) require turbine blade materials that operate under extreme conditions of temperature, hydrogen environment, high-cycle fatigue loading, thermal fatigue and thermal shock. Such requirements tax the capabilities of current blade materials. Based on projections of properties for tungsten fiber reinforced superalloy (FRS) composites, it was concluded that FRS turbine blades offer the potential of a several fold increase in life and over a 200 C increase in temperature capability over the current SSME blade material. FRS composites were evaluated with respect to mechanical property requirements for SSME blade applications. Compared to the current blade material, the thermal shock resistance of FRS materials is excellent, two to nine times better, and their thermal fatigue resistance is equal to or higher than the current blade material. FRS materials had excellent low and high-cycle fatigue strengths, and thermal shock-induced surface microcracks had no influence on their fatigue strength. The material also exhibited negligible embrittlement when exposed to a hydrogen environment. **Author**

N89-22674# Metallwerk Plansee, A.G., Reutte (Austria).
BEHAVIOR OF TUNGSTEN, MOLYBDENUM AND ALLOYS UNDER UNUSUAL HEATING CONDITIONS
R. ECK, H. BILDSTEIN, F. SIMADER, R. STICKLER (Technische Univ., Vienna, Austria), and J. TINZL *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 11 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
State of the art of fabricability of tungsten by powder metallurgy methods for relevant configurations in relation to final properties desired are summarized. Effects of unisotropy through metal forming and its relevance to design are discussed. For tungsten-thoria alloys, as an example of a refractory ODS alloy, mechanical properties such as DBTT for low temperature stresses and strength, ductility and microstructural data at temperatures up to 3000 K are presented and discussed in context with application considerations. As an alternative tungsten-rhenium alloys containing up to 26 percent Re are discussed in comparison with tungsten-thoria emphasizing advantages of ductility at low temperatures. A simple model of interference of heat dissipation and buildup of thermal stresses in a plate configuration of tungsten is shortly discussed. Relevant properties of the molybdenum alloys Mo5Re to Mo41Re, a selection of Ti, Zr, Hf carbide-oxide dispersion strengthened alloys and molybdenum tungsten alloys are discussed. Limitations of erosion and oxidation inhibiting coatings for refractory metals are explained for advanced chemical and physical methods. **Author**

N89-22680# Centre de Recherches Metallurgiques, Liege (Belgium).
METALLURGICAL STUDY OF SUPERALLOY BRAZING ALLOYS
CH. LECOMTE-MERTENS and W. BEX (FN Moteurs, Mimort, Belgium) *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 12 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
For a better understanding of the new superalloy repair or joining process, it is important to know the metallurgical behavior of more conventional brazing alloys more or less doped with melting point depressants such as aluminum boron and/or silicon especially during the diffusion-brazing treatment. Therefore, the brazing results on calibrated slots of different widths were metallographically compared after variable brazing and diffusion time-temperature cycles. The composition of the different phases present in the tested brazing alloys were also determined with the scanning electron microscope. Moreover, evaluation testings as fatigue and thermal shocks were performed to compare new and repaired parts. Finally, it was possible to evaluate the best time-temperature cycles bringing a satisfactory homogenization, while keeping them compatible with the eventual subsequent heat treatments and with the requirements of an economical industrial production. **Author**

N90-10231# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
CASTINGS AIRWORTHINESS
May 1989 137 p In ENGLISH and FRENCH Meeting held in Mierlo, Netherlands, 3-7 Oct. 1988
(AGARD-R-762; ISBN-92-835-0507-7; AD-A211111) Copyright Avail: NTIS HC A07/MF A01
The question of whether a casting factor, as such, need still be applied to premium quality castings given the improvements in casting technology obtained in recent years, was addressed. For individual titles, see N90-10232 through N90-10245.

N90-14325# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
SUPERPLASTICITY
Sep. 1989 248 p Lecture series held in Rome, Italy, 5-6 Oct. 1989, in Madrid, Spain, 9-10 Oct. 1989, and in Toulouse, France, 12-13 Oct. 1989 Revised version of AGARD lecture series 154
(AGARD-LS-168; AGARD-LS-154-REV; ISBN-92-835-0525-5; AD-A215877) Copyright Avail: NTIS HC A11/MF A02
Superplasticity was transformed from a metallurgical curiosity to an important production process, particularly for low-to-medium production runs of components for the aerospace industry. The whole spectrum of superplasticity was originally covered in Lecture Series 154 in the autumn of 1987, but such are the rapid advances in this technology, that the series is re-presented, with the same speakers updating their lectures to give the latest information on this most relevant technology and its impact upon the manufacture methods employed for components for aerospace applications. For individual titles, see N90-14326 through N90-14333.

N90-14326# Cranfield Inst. of Tech., Bedford (England). School of Industrial Science.
SUPERPLASTICITY: AN OVERVIEW
ROGER PEARCE *In* AGARD, Superplasticity 24 p (SEE N90-14325 06-26) Sep. 1989
(AGARD-LS-154-REV) Copyright Avail: NTIS HC A11/MF A02
Certain alloys, when deformed in tension at particular temperatures and strain rates, show very high elongations. This phenomenon is termed superplasticity. Importantly, the flow stresses at which this phenomenon occurs are extremely low. There are two types of superplasticity: isothermal superplasticity (ISP); and cycling superplasticity (CSP). For ISP, the alloy must possess an ultra-fine grain size which is relatively stable at greater than or equal to 0.5 T(sub m), where T(sub m) is the melting point of the lowest-melting constituent in the alloy, in absolute units, while for CSP the alloy must be capable of being cycled through a phase change. The mechanical properties, manufacturing, and surface properties are reviewed. **Author**

N90-14327# Washington State Univ., Pullman.
SUPERPLASTIC SHEET FORMING
C. H. HAMILTON *In* AGARD, Superplasticity 23 p (SEE N90-14325 06-26) Sep. 1989
(AGARD-LS-154-REV) Copyright Avail: NTIS HC A11/MF A02
The exceptional ductility of superplastic alloys can be utilized in the shaping and forming of parts, components, and structures which could not be easily or economically produced by materials of more limited ductility. A number of methods for forming these materials were studied on a laboratory scale, and several of these are being utilized to produce full scale parts on a production basis, with benefits being achieved in cost as well as in design efficiency. The forming of superplastic alloys, however, involves consideration of a number of factors which are interactive and lead to a relatively complex process, especially if maximum capability and minimum cost are to be achieved. These considerations include the superplastic properties of the alloy, effect of temperature, effect of strain rate, microstructural changes during forming and their effect on superplastic properties, effect of die configuration on forming capability, and forming parameters. The forming methods which were demonstrated for superplastic alloys include: blow forming, vacuum forming, thermo-forming, die-less drawing, deep drawing, forging, and superplastic forming with combined diffusion bonding (SPF/DB). With the exception of the forging, these processes utilize the high elongation capability and related resistance to localized necking. Therefore, the thinning gradients

which can develop during forming are of primary concern, and relate directly to the material characteristics and the mechanics of stretch forming into a given die configuration. The technology of SPF was found to benefit from modelling of the process, the results of which can guide the selection of pressurization parameters as well as predict the thinning characteristics and tendency to rupture. These concepts are reviewed. Many alloys tend to cavitate, or form internal voids. During SPF processing and mechanical design properties can suffer if this cavitation is severe. Concepts for minimizing or eliminating cavitation are discussed. Author

N90-14328# Stanford Univ., CA. Dept. of Materials Science and Engineering.
ADVANCES AND FUTURE DIRECTIONS IN SUPERPLASTIC MATERIALS
OLEG D. SHERBY and JEFFREY WADSWORTH (Lockheed Missiles and Space Co., Palo Alto, CA.) In AGARD, Superplasticity 24 p (SEE N90-14325 06-26) Sep. 1989 Sponsored by ONR, Washington, DC; ARO, Washington, DC and Lockheed Independent Research and Development Program
(AGARD-LS-154-REV) Copyright Avail: NTIS HC A11/MF A02
New events are reviewed in the development and modeling of superplastic materials. Over the last several years, superplasticity was developed in fine microstructures in microduplex stainless steels, aluminum-lithium alloys, mechanically alloyed aluminum, silicon carbide whisker-reinforced aluminum alloys, aluminum-magnesium alloys, and nickel alloys. In the latter three cases, the phenomenon is observed at high strain rates by comparison with most superplastic alloys. In a major breakthrough, a ceramic (yttria stabilized zirconia) and a ceramic composite (yttria stabilized zirconia containing alumina) were shown to be superplastic in tension tests. Superplastic behavior in iron carbide was also observed. Superplastic studies are also underway in intermetallics such as nickel silicides, nickel aluminides, and titanium aluminides. New insights are becoming apparent in the area of modeling superplastic behavior by the integration, into existing models, of new concepts based on grain boundary sliding accommodated by slip and the influence of threshold stresses associated with grain boundary sliding. Newtonian-viscous flow can be approached in fine-grained Class 1 solid solution alloys. Significant advances were also made in understanding internal stress superplasticity; recent examples include zinc, alpha-uranium, zinc-alumina composites and silicon carbide whisker reinforced aluminum alloys. A new model has been proposed for internal stress superplasticity. In other major developments, the mechanisms of superplasticity were successfully applied to consolidation of powders and superplastic behavior was developed in ferrous-based laminated composites. Finally, some neglected areas offering the potential for superplastic flow are reviewed. Author

N90-14329# Manchester Univ. (England). Dept. of Metallurgy and Materials Science.
CAVITATION AND SUPERPLASTICITY
NORMAN RIDLEY In AGARD, Superplasticity 14 p (SEE N90-14325 06-26) Sep. 1989
(AGARD-LS-154-REV) Copyright Avail: NTIS HC A11/MF A02
Cavitation occurs in many alloy systems during superplastic flow. Cavities either pre-exist or nucleate on grain boundaries and their subsequent growth, coalescence, and interlinkage leads to premature failure. The presence of cavities in superplastically formed components to be used for load bearing applications is clearly undesirable. It is apparent from studies on a wide range of materials that cavity growth is dominated by matrix plastic flow and that coalescence plays an important role in the development of large cavities. Hence, if cavitation damage is to be prevented, it is necessary to inhibit the nucleation event and to avoid the presence of pre-existing defects by careful control of the processing required to produce the superplastic microstructure. The influence that microstructural features and deformation conditions have on cavity nucleation is examined for a number of alloy systems, and it is clear that it is difficult to control these parameters so as to totally avoid cavitation. However, cavitation can be eliminated by the application of a hydrostatic pressure during forming. This reverses the sense of the driving force for cavity growth and the conditions for zero growth, which depend on the geometry of deformation, were identified. Cavitation damage can be prevented

by superimposed pressures of 0.5 to 0.75 of the uniaxial flow stress, although lower levels of pressure can substantially reduce the extent of cavitation. Author

N90-14330# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
DIFFUSION BONDING OF METALS
P. G. PARTRIDGE In AGARD, Superplasticity 29 p (SEE N90-14325 06-26) Sep. 1989
(AGARD-LS-154-REV) Copyright Avail: NTIS HC A11/MF A02
The need to reduce the cost and weight of aerospace metallic structures has led to increased interest in solid state and liquid phase diffusion bonding processes, especially in combination with superplastic forming. The bonding mechanisms and bonding techniques are reviewed and the process variables that affect metals. The importance of quality control and the limitations of current NDE techniques for diffusion bonding are emphasized. Finally some trends and priorities in diffusion bonding technology are indicated. Author

N90-14331# Royal Aircraft Establishment, Farnborough (England).
THE MECHANICAL PROPERTIES OF SUPERPLASTICALLY FORMED TITANIUM AND ALUMINIUM ALLOYS
P. G. PARTRIDGE, D. S. MCDARMAID, I. BOTTOMLEY, and D. COMMON (British Aerospace Public Ltd Co., Bristol, England) In AGARD, Superplasticity 33 p (SEE N90-14325 06-26) Sep. 1989
(AGARD-LS-154-REV) Copyright Avail: NTIS HC A11/MF A02
The behavior of aluminum and titanium alloys under superplastic forming conditions is well documented but there is much less published data on the effect of the superplastic forming process on the mechanical properties; these data are essential for the design of structures. The effect of superplastic forming parameters such as temperature, strain and post forming heat treatments upon the tensile, fatigue and fatigue crack growth performance of these alloys are reviewed and the property variation to change in the microstructure are related. During superplastic forming of aluminum alloys intergranular cavities are formed with increasing strain which degrade the material and reduce the mechanical properties. Ways to prevent cavitation both during and after superplastic forming were developed and the effect of these treatments on the mechanical properties will be discussed. Author

N90-14332# British Aerospace Public Ltd. Co., Bristol (England). Civil Aircraft Div.
DESIGNING FOR SUPERPLASTIC ALLOYS
D. STEPHEN In AGARD, Superplasticity 37 p (SEE N90-14325 06-26) Sep. 1989
(AGARD-LS-154-REV) Copyright Avail: NTIS HC A11/MF A02
Twelve years of development have brought the processes of superplastic forming and diffusion bonding to a state of maturity. These processes provide the opportunity to design components on new projects which are both cost and weight efficient. However, to achieve optimum performance, the designer needs to have an in-depth understanding of the freedoms and limitations provided by these processes. Substantial evidence exists to support the claim that titanium alloys, when processed by the superplastically formed (SPF) diffusion bonded (DB) route, can compete in weight and more particularly cost, with conventional aluminum fabrication. This is likely to be a major factor in the future exploitation of these processes and clearly requires a revision to the designers traditional views of the areas of application for titanium alloys. The more recent developments in the processing of high strength superplastic aluminum alloys will clearly add to the further use of the superplastic forming process on future aerospace products, but the development of a combined SPF/DB process for aluminum alloys, with the full range of capabilities provided currently by titanium alloys, remains to be established. Author

N90-14333# Alcan International Ltd., Banbury (England).
THE MANUFACTURE OF SUPERPLASTIC ALLOYS
R. GRIMES In AGARD, Superplasticity 16 p (SEE N90-14325 06-26) Sep. 1989
(AGARD-LS-154-REV) Copyright Avail: NTIS HC A11/MF A02
The requirements in a superplastic sheet material are either to possess a fine uniform grain size or to be capable of developing such a grain structure during the course of superplastic deformation

Alloys that are currently being commercially exploited fall into both categories and the manufacturing routes to produce material with good superplastic behavior using commercial scale processing are considered. Most of the paper is devoted to aluminum alloys since their manufacture in a superplastic form embodies most of the general principles. Since the aluminum alloys do not involve allotropic transformations limited consideration is also given to titanium alloys. Amongst aluminum alloys, the Al-6 percent Cu-0.4 percent Zr system that typifies the supral alloys, requires a specifically developed casting system in order to achieve a very high level of supersaturation with zirconium. Subsequent manufacturing is fairly conventional, the sheet product recrystallizing dynamically during superplastic forming. The higher strength aluminum alloys are conventionally cast but achieve a very fine grain size at the sheet stage by careful thermal mechanical-treatment during the latter stages of semi-fabrication. With titanium the standard production route for the Ti-6Al-4V alloy results in a product with superplastic capabilities perfectly adequate for most applications. Author

N90-15185# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
NEW LIGHT ALLOYS
Aug. 1989 364 p In ENGLISH and FRENCH Meeting held in Mierlo, Netherlands, 3-5 Oct. 1988
(AGARD-CP-444; ISBN-92-835-0519-0; AD-A215832) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The status of current developments in aluminum-lithium alloys, the characterization of commercially available products, and their likely applications in aircraft structures were reviewed. Also considered were developments in other lightweight metallic materials such as magnesium alloys, aluminum powder metallurgy alloys and aluminum metal matrix composites. For individual titles, see N90-15186 through N90-15209.

N90-15186# Cegedur Pechiney Centre de Recherche et Developpement, Voreppe (France).
AL-LI ALLOY DEVELOPED BY PECHINEY
M. DOUDEAU, P. MEYER, and D. CONSTANT In AGARD, New Light Alloys 17 p (SEE N90-15185 07-26) Aug. 1989
(AGARD-CP-444) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An up-to-date view of Al-Li development is presented in terms of both properties and production readiness. Successes achieved to date, mostly where damage tolerance and medium strength targets are concerned, will be outlined. Design allowables, properties, and product size capabilities will be presented for some alloy/product form combinations which are close to commercialization. As certification has started on some product forms, the introduction of Al-Li alloys on the aerospace market is under way. Author

N90-15187# Virginia Univ., Charlottesville. School of Engineering and Applied Science.
THE MICROSTRUCTURE AND PROPERTIES OF ALUMINUM-LITHIUM ALLOYS
EDGAR A. STARKE, JR. and WILLIAM E. QUIST (Boeing Commercial Airplane Co., Seattle, WA.) In AGARD, New Light Alloys 23 p (SEE N90-15185 07-26) Aug. 1989
(AGARD-CP-444) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The advantage to be gained by weight reduction of aerospace structures have encouraged the aluminum industry to develop a family of aluminum alloys which contain lithium as one of the alloying elements. When alloyed with aluminum, lithium can reduce the density by approximately three percent and increase the elastic modulus by six percent for every weight percent added. A new series of aluminum alloys, typified by 2090, 2091, 8090, and 8091, were developed and are currently being produced in commercial quantities. These alloys have densities between 7 and 10 percent lower than the conventional alloy 7075 with correspondingly higher stiffness. Although a combined set of specific properties of the Al-Li-X alloys often exceeds those of the conventional aluminum materials used in aerospace, these properties seem to be much more sensitive to processing parameters. The strong processing-property relationship is associated with sharp crystallographic textures that are developed during primary processing and very complex precipitate microstructures whose distributions are sensitive to quench rates and degree of deformation prior to aging. The processing-microstructure property relationships of the new Al-Li-X alloys are described and the focus is on strength, ductility, fracture toughness, fatigue and stress corrosion properties. Author

N90-15188# National Aerospace Lab., Emmeloord (Netherlands). Structures and Materials Div.
MECHANICAL PROPERTIES AND FRACTURE TOUGHNESS OF 8090-T651 PLATE AND 2091 AND 8090 SHEET
W. G. J. THART, L. SCHRA, D. S. MCDARMAID, and M. PETERS (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne, Germany, F.R.) In AGARD, New Light Alloys 17 p (SEE N90-15185 07-26) Aug. 1989
(AGARD-CP-444) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The strength and toughness properties of the medium strength Al-Li plate alloy 8090-T651 were determined and compared to those of damage tolerant 2000 series plate alloys. For the LT and TL orientations similar K_{Ic} values were obtained but 8090-T651 was inferior in terms of short transverse fracture toughness. Tensile tests through-the-thickness and with respect to rolling direction indicated considerable anisotropy. Residual strength tests were performed on center cracked sheet panels of the Al-Li alloys 2091 and 8090 in different tempers and 2024-T3 reference material. Fracture modes and characteristics were analyzed using fractography and resulted in a better understanding of the fracture behavior of the Al-Li alloys. Recrystallized Al-Li sheet in specific tempers achieved plane stress fracture toughness values similar to those of 2024-T3, but at somewhat lower yield strengths. Author

N90-15189# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Werkstoff-Forschung.
FATIGUE PROPERTIES OF AL-LI ALLOYS
M. PETERS, K. WELPMANN, D. S. MCDARMAID, and W. G. J. THART (National Aerospace Lab., Emmeloord, Netherlands) In AGARD, New Light Alloys 18 p (SEE N90-15185 07-26) Aug. 1989
(AGARD-CP-444) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Results are presented on fatigue properties of Al-Li 8090 plate material generated at DFVLR, NLR and RAE in the frame of a GARTEUR activity on Al-Li alloys. High cycle fatigue results are discussed as well as fatigue crack growth properties. Comparison is made to conventional high strength Al alloys. In most cases the Al-Li alloy showed at least equivalent high cycle fatigue properties and improved resistance to fatigue crack growth, primarily due to crack closure effects. Author

N90-15190# Royal Aerospace Establishment, Farnborough (England). Materials and Structures Dept.
CORROSION AND STRESS CORROSION OF ALUMINIUM-LITHIUM ALLOYS
C. J. E. SMITH, J. A. GRAY, L. SCHRA, J. A. M. BOOGERS, R. BRAUN, H. BUHL, and G. J. H. VAESSEN (Fokker B.V., Schipol-Oost, Netherlands) In AGARD, New Light Alloys 20 p (SEE N90-15185 07-26) Aug. 1989
(AGARD-CP-444) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A program of research to evaluate the corrosion and stress corrosion resistance of experimental, pre-production and production quality aluminum-lithium sheet and plate alloys is described. Accelerated laboratory tests and outdoor trials were used to compare the corrosion behavior of aluminum-lithium alloys with conventional aerospace alloys. Author

N90-15191# Laboratoire Central Aerospatiale, Suresnes Cedex (France). Section Metallurgie.
PROPERTIES OF AL-LI ALLOYS [PROPRIETES DES ALLIAGES AL-LI]
Y. BARBAUX *In* AGARD, New Light Alloys 18 p (SEE N90-15185 07-26) Aug. 1989 In FRENCH Sponsored by Service Technique des Programmes Aeronautiques, France
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Investigations of commercial aluminum lithium alloys conducted by Aerospatiale in the last five years are summarized. The characterization and application of thin metal sheets of 2091 CPH T8X and 8090C T81, medium-thickness sheets of 2091 T8x51, and structural sections of 8090 and 2091 T8511 are discussed. The eventual application of some of these materials in the A-340 Airbus is also discussed. Transl. by M.G.

N90-15192# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Transport Aircraft Group.
INVESTIGATION ON SHEET MATERIAL OF 8090 AND 2091 ALUMINIUM-LITHIUM ALLOY
W. ZINK, J. WEILKE, L. SCHWARMANN, and K. H. RENDIGS *In* AGARD, New Light Alloys 15 p (SEE N90-15185 07-26) Aug. 1989
(AGARD-CP-444) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The new aluminum-lithium alloys offer an attractive alternative of reducing structural weight for civil aircraft components. For fuselage application the damage tolerant version of aluminum-lithium as substitution of 2024 T3 material is of greatest interest. Due to the responsibility of MBB/UT for fuselage structures within the Airbus production sharing investigations on damage tolerant 8090 and 2091 sheet material was carried out a few years ago. The Al-Li alloys 2091 and 8090, developed by Pechiney, Alcoa, and Alcan for 2024 T3 substitution will be presented in view of mechanical properties and damage tolerant behavior with special emphasis placed on the comparison with conventional alloys. Fracture toughness data from R-Curves performed on CCT-specimens as well as crack propagation behavior and fatigue results will be discussed. Finally, a summary will be given on the different corrosion behaviors. Author

N90-15193# Naval Air Development Center, Warminster, PA.
ALUMINUM LITHIUM ALLOYS FOR NAVY AIRCRAFT
E. W. LEE and J. WALDMAN *In* AGARD, New Light Alloys 10 p (SEE N90-15185 07-26) Aug. 1989
(AGARD-CP-444) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Ingot metallurgy alloys of aluminum with lithium additions offer large gains in structural efficiency due to reduced density together with increased strength and elastic modulus. Several alloys are now commercially available. The Navy was sponsoring research and development activities in these alloys since the mid-seventies. Current efforts include ongoing multi-laboratory evaluations of aluminum alloys to replace 7075-T6 and 7075-T73. The Navy is also conducting research and development on thermal mechanical processing and superplastic forming on these alloys. Additional testing is being conducted to determine their corrosion resistance in an aircraft carrier environment. Author

N90-15194# Pisa Univ. (Italy). Dept. of Aerospace Engineering.
FATIGUE, FRACTURE MECHANICS AND CORROSION PROPERTIES OF SOME ALUMINIUM-LITHIUM ALLOYS
G. CAVALLINI, L. LAZZERI, M. SCOLARIS, F. BOSCHETTI, A. SOLINA, M. DESANCTIS, and G. ZENNARO (Divisione Aerea Studi Ricerche e Sperimentazioni, Pratica di Mare, Italy) *In* AGARD, New Light Alloys 18 p (SEE N90-15185 07-26) Aug. 1989 Sponsored in part by Italian National Research Council, Rome
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A research program for the evaluation of the main characteristics of the newly developed Al-Li alloys was undertaken under the sponsorship of the Italian National Research Council (CNR). Many Italian aeronautical industries and research institutes take part in this program which comprises a large variety of experimental activities: static tests, fatigue tests, crack propagation tests, fracture toughness, corrosion susceptibility, formability, workability, and other tests. Different producers provided the alloys tested in this program: 2091, 8090 and 2090 alloys were the objects of investigation. Some of the results obtained so far in the CNR program and some results obtained by Aeritalia in its own programs are described. The results are relevant to fatigue tests carried out both on notched and unnotched specimens, under constant amplitude loading (R=0.1). Fatigue tests, together with structural (TEM) and fractographic (SEM) studies, were performed also for assessing the influence of different ageing on both mechanical properties and failure modes of materials. Crack propagation tests were carried out under both C.A. loading and FALSTAFF sequence and are here presented, together with results from fracture toughness tests. Corrosion properties were assessed by measuring the free corrosion potential according to ASTM G 69 standard method and also in neutral salt solution of Na2SO4 (0.1M). Preliminary results obtained show that Li-containing materials exhibit an intermediate behavior between traditional 2024 and 7075 alloys and that the presence of Li does not influence appreciably the corrosion mechanism. Author

N90-15195# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
FATIGUE AND FRACTURE BEHAVIOUR OF A PM AL-LI ALLOY
RAINER SCHAEFER and BRIGITTE WEISS (Wien Univ., Austria) *In* AGARD, New Light Alloys 13 p (SEE N90-15185 07-26) Aug. 1989 Sponsored by BMFT, Fed. Republic of Germany and BMWF, Austria
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The fatigue life, fatigue crack growth behavior, and fracture toughness properties of the experimental mechanically alloyed Al-Mg-Li alloy Al 905 XL were investigated. This material was developed, above all, for being fabricated into structural components by forging. HCF as well as LCF data were determined at room temperature and elevated temperature (180 C). Crack growth rates were measured including near threshold behavior. The mean values of fatigue life at room temperature were found to be slightly better than the values of conventional high strength aluminum alloys. Internal defects, however, like inclusions or pores, may reduce fatigue life considerably. At 180 C fatigue strength decreased to approximately 60 percent of room temperature values. Crack propagation was noticeably faster in Al 905 XL than in conventional ingot alloy 7075, for example. Fracture toughness tests finally resulted in rather low K(sub Ic) values compared to conventional Al alloys. Author

N90-15196# Fokker B.V., Schipol-Oost (Netherlands). Material and Fabrication Technology.
FABRICATION OF TEST-ARTICLES FROM AL-LI 2091 FOR FOKKER 100
G. J. H. VAESSEN, C. VANTILBORGH, and H. W. VANROOIJEN *In* AGARD, New Light Alloys 12 p (SEE N90-15185 07-26) Aug. 1989
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The technical requirements for introduction of aluminum-lithium alloys in secondary structures of aircraft are formulated. The general corrosion behavior, stress-corrosion properties, and mechanical properties of the alloy 2091-T3 from Cegedur-Pechiney meet these requirements. The successful fabrication of access doors in the underwing fairing of the Fokker 100 is described. The same manufacturing techniques as for 2024 can be used for 2091, i.e., machining, blanking, bending, chemical milling, surface pretreatments, adhesive bonding, solution heat treatment and drop-hammer forming, stretch forming, painting and riveting. Operational in-service trial on Fokker 100 and F28 operated by major airlines as Swissair and Garuda has started. An estimate of the cost-effectiveness of the access doors out of 2091 is given. Author

N90-15197# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
PUTTING ALLOY 2091 TO WORK [MISE EN OEUVRE DE L'ALLIAGE 2091]
J. BEVALOT *In* AGARD, New Light Alloys 7 p (SEE N90-15185 07-26) Aug. 1989 In FRENCH
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Assessments leading to the replacement of alloy 2024 T3 with the aluminum-lithium alloy 2091 in aircraft applications are discussed. Formability, metallurgical characteristics, and fatigue properties of alloy 2091 are discussed and compared with those of alloy 2024. Alloy 2091 has very good deformation characteristics allowing the formation of panels in one pass with cold tempering instead of two passes for alloy 2024. The working time with cold tempering is very long with the 2091 alloy -- on the order of three days. In addition, alloy 2091 was found to have very good spot weld properties, good chemical machinability, and the same protection ranges as alloy 2024. Transl. by M.G.

N90-15198# British Aerospace Public Ltd. Co., Bristol (England). Production Development and Methods.
FABRICATION CHARACTERISTICS OF 8090 ALLOY
V. H. MOULD *In* AGARD, New Light Alloys 10 p (SEE N90-15185 07-26) Aug. 1989
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Some of the experience gained so far, by a user, during a production process evaluation of 8090 medium strength Al-Li alloy is collated. The four primary production processes, machining, forming, joining, and construction, in this sense finishing, treatments, painting, plating classed as secondary processes are examined. Sufficient work was completed to give confidence in the ability of this material to respond to these four basic processes, and produce a quality article. No fundamental changes will be required of machine tools, cutting tools, plant, or equipment. Some techniques will change from conventional alloy requirements, particularly with forming, where further work is required, as 8090 does not form well in the cold condition. It is concluded that 8090 medium strength Al-Li alloy is becoming available in sufficient quantity and quality to enable design engineers to specify the material for applications that can exploit the proven weight and strength advantages. The final responsibility resting with the manufacturing engineers is to ensure that Al-Li can be utilized as an economic proposition. Author

N90-15199# Superform Metals Ltd., Worcester (England).
SUPERPLASTIC PERFORMANCE AND PROPERTIES OF THE LITAL ALLOYS
R. G. BUTLER and B. J. DUNWOODY *In* AGARD, New Light Alloys 7 p (SEE N90-15185 07-26) Aug. 1989
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The requirements in a superplastic sheet material are either to possess a fine uniform grain size or to be capable of developing such a grain structure during the course of superplastic deformation. The lital alloys processed by the optimum route to produce superplastic grade sheet fall into the latter category. The evolution, superplastic performance, and properties of 8090 SPF produced by a commercial production route are described. The sheet produced by this processing route has good isotropic superplastic properties, the ability to be formed at the solution heat treatment temperature, and low quench sensitivity. Properties determined on components formed with hydrostatic confining pressure are presented. The low flow stress of the material enables cavitation to be controlled during forming by this process. Author

N90-15200# Airbus Industrie, Blagnac (France). Advanced Structures and Materials.
POINT OF VIEW OF A CIVIL AIRCRAFT MANUFACTURER ON AL-LI ALLOY
JOHANNES KOSHORST *In* AGARD, New Light Alloys 5 p (SEE N90-15185 07-26) Aug. 1989
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The process of evaluating a new material for use in a civil transport aircraft is rather complex and long. The introduction of Al-Li appears as being a particular difficult item. Initially developed for application in combat aircraft aiming for high strength properties, a civil transport airplane however requires Al-Li in a damage tolerant version. Equivalence to existing alloys is requested (equal or better) but Al-Li demands a compromise between major properties as strength, damage tolerance and corrosion resistance. Progress in achieving acceptable and harmonized material quality is very slow and time constraints have prevented introduction in a planned way in a number of programs. The question is raised whether a cost effective use of Al-Li can be envisaged over the next years. Author

N90-15201# Westland Helicopters Ltd., Yeovil (England).
USES AND PROPERTIES OF AL-LI ON THE NEW EH101 HELICOPTER
A. F. SMITH *In* AGARD, New Light Alloys 19 p (SEE N90-15185 07-26) Aug. 1989
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The EH101 is a long range, large capacity helicopter developed and built to meet the needs of civil, naval, and utility operations and in which many new aerodynamic, electronic and structural design concepts are successfully combined. In order to effect significant structural weight reductions, extensive use will be made of aluminum-lithium based alloys which are now becoming commercially available. The results of a weight-saving cost analysis favor the use of aluminum-lithium sheet, extruded profiles and forgings on the EH101, while corresponding plate and extruded bar will not be used due to the combined effects of low utilization rate and the inherently higher material cost of aluminum-lithium. Accordingly, greater emphasis is being placed upon the use of die forgings, particularly for the manufacture of components hitherto machined from non-lithium containing aluminum plate. Extensive evaluation programs are currently in progress covering AA 8090 and AA 2091 sheet, together with specific EH101 extruded profiles and forgings also in AA 8090 but with additional studies in alloy AA 8091; comparisons will be made with alloys AA 2014, 2024, 7075 and 7010 where appropriate. Notwithstanding the lower ductilities and anisotropic effects characteristic of aluminum-lithium, the results to date show that direct substitution of current aluminum alloys may be realistically pursued, particularly as superior fatigue properties are indicated in the new materials. The use of aluminum-lithium based alloys on the EH101 are reviewed and the findings of the current studies reported. Author

N90-15202# McDonnell Aircraft Co., Saint Louis, MO. Materials and Process Development Branch.
ALUMINUM-LITHIUM: APPLICATION OF PLATE AND SHEET TO FIGHTER AIRCRAFT
BYRON A. DAVIS *In* AGARD, New Light Alloys 11 p (SEE N90-15185 07-26) Aug. 1989
(Contract MCAIR PROJ. 7-220)
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The potential for weight savings resulting from the low density and high stiffness of aluminum-lithium (Al-Li) alloys led to the consideration of Al-Li alloys for use on both new and existing aircraft. The successful fabrication, and flight testing of several demonstration parts on both the F-15 and F/A-18 increased interest in these alloys. In support of these and other applications of Al-Li plate and sheet, the mechanical properties, conventional formability, and superplastic formability of 2090 and 8090 were evaluated. With a few notable exceptions, such as the anisotropy in sheet, these Al-Li alloys were comparable to conventional aluminum alloys. Chemical processing and corrosion resistance of

2090 and 8090 were also investigated and again were found comparable to conventional aluminum. Author

N90-15203# Royal Aerospace Establishment, Farnborough (England). Materials and Structures Dept.
CURRENT STATUS OF THE APPLICATION OF CONVENTIONAL ALUMINIUM-LITHIUM ALLOYS AND THE POTENTIAL FOR FUTURE DEVELOPMENTS
C. J. PEEL In AGARD, New Light Alloys 9 p (SEE N90-15185 07-26) Aug. 1989
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Commercial aluminum-lithium alloys are now entering service use and, while it cannot be claimed that they are yet fully achieving their maximum potential, it is now appropriate to consider the limitations to their further development and the possibilities for the development of other systems and composites based on light alloys, especially suited for aerospace structures. All the commercial aluminum-lithium alloys presently offered were designed to present a reduction in density and an increase in elastic modulus as their main benefits to the designers contemplating their application. The other important metallurgical properties of the alloys, such as strength and fracture toughness were matched to the performance of existing 2000 and 7000 series alloys. The possibilities for further density reductions and increases in mechanical properties, comparing the potential improvements with those offered by non-metallic composites are considered. Three types of structure are considered generically namely damage tolerant structure, typified by a pressurized fuselage skin, structure limited by inadequate material stiffness in either the case of aeroelastic performance or resistance to buckling and structure limited by currently obtainable strength levels at both ambient and elevated temperatures. It transpires from the following brief analysis that future developments may well have to be optimized against the special requirements of the three simple categories outlined and that the simple principle underlying the development of the conventional aluminum-lithium alloys cannot be extended greatly. Author

N90-15204# Drexel Univ., Philadelphia, PA. Dept. of Materials Engineering.
HIGH PERFORMANCE POWDER METALLURGY ALUMINUM ALLOYS: AN OVERVIEW
M. J. KOCZAK and M. K. PREMKUMAR In AGARD, New Light Alloys 18 p (SEE N90-15185 07-26) Aug. 1989 Sponsored by Naval Air Development Center, Warminster, PA and AFOSR, Washington, DC
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The historic development of aluminum powder metallurgy dates back to the early 1900s with initial flake powder production and has matured to the present day production of viable aerospace alloys. Primary powder production and processing techniques, such as atomization and mechanical alloying are reviewed. Processing-microstructure property relationships in four classes of high performance powder metallurgy (P/M) aluminum alloys are considered. These are high strength alloys (AlZnMgCuCo); high specific modulus alloys (AlLiCu); high temperature alloys (ALFeCo, AlFeNi); mechanically alloyed material (AlMg), and composite alloys. Direct property comparisons with counterpart ingot metallurgy alloys are presented where ever appropriate. Aluminum powder metallurgy alloy development is now at a mature stage of growth where commercial and aerospace application are being sought and developed in competition with traditional aluminum ingot metallurgy, titanium and composite structures. The future growth and development of these alloy systems is vested in reliable economic processing. Author

N90-15205# Calgary Univ. (Alberta). Dept. of Mechanical Engineering.
MICROSTRUCTURE/MECHANICAL PROPERTY RELATIONS IN A MECHANICALLY ALLOYED ALUMINUM
W. J. D. SHAW In AGARD, New Light Alloys 12 p (SEE N90-15185 07-26) Aug. 1989
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Mechanically alloyed aluminum has not lived up to its initial expectations and very little progress was made in understanding, controlling, and improving this material over the last decade. The complexities of the reactions that occur in this material are presented in terms of the present state of knowledge. This current understanding is linked to the mechanical properties of the material. It is necessary that an understanding of the mechanisms regarding the role of oxygen and carbon or hydrocarbon in the material be obtained before further development is undertaken. Once an understanding of the inherent reactions taking place in these materials is determined, then major advances in research and development will occur resulting in an unlimited potential of engineered materials. Author

N90-15206# Institut National des Sciences Appliquees de Lyon, Villeurbanne (France).
METAL MATRIX COMPOSITES WITH LONG INORGANIC FIBERS [COMPOSITES A MATRICE METALLIQUE ET A FIBRES LONGUES INORGANIQUES]
P. F. GOBIN In AGARD, New Light Alloys 17 p (SEE N90-15185 07-26) Aug. 1989 In FRENCH
(AGARD-CP-444) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The general characteristics and problems associated with inorganic-fiber metal-matrix composites are reviewed and recent French investigations related to these materials are summarized. The nature and properties of both metal matrices and reinforcing fibers are discussed along with compatibility factors and fiber-matrix interaction in general. Finally, production methods for this class of composite materials are addressed. Transl. by M.G.

N90-15207# Nottingham Univ. (England). Dept. of Metallurgy and Materials Science.
SHORT FIBRE AND PARTICULATE REINFORCED METAL MATRIX COMPOSITES
S. J. HARRIS In AGARD, New Light Alloys 13 p (SEE N90-15185 07-26) Aug. 1989
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Short fibers, whiskers, or particles of ceramic materials, e.g., silicon carbide and alumina, when dispersed in a more or less random manner in a metallic matrix can promote increases in stiffness and strength at ambient and elevated temperatures without imposing a weight penalty. The available routes for the fabrication of such composites, e.g., by squeeze casting, spray forming, powder technologies and hot working are considered. Influences of type and amount of reinforcement, matrix alloy selection, and processing route on strength, creep, and fatigue resistance are discussed. Comparisons are made with conventional metals and alloys, and polymers and metals reinforced with continuous fibers. Attention is drawn to the behavior of these materials under compressive loading as well as to their expansion and conductivity. The majority of the matrices considered are aluminum-based. Author

N90-15208# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. of Material Science.
METAL MATRIX COMPOSITES: A PROMISING ALTERNATIVE TO CONVENTIONAL ALLOYS
K. SCHULTE and W. BUNK In AGARD, New Light Alloys 10 p (SEE N90-15185 07-26) Aug. 1989
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Conventional metallic materials were tailored in the past close to their ultimate properties. New technological requirements ask for further improved materials. Metal-matrix composites (MMC)

promise to reach this goal. MMC can be described as materials whose microstructure comprise a continuous metallic phase (the matrix) into which a second phase is artificially introduced during processing, as reinforcement. Presently the interest in MMC is primarily focused on light alloys reinforced with fibrous or particulate phases to achieve major jumps in selected mechanical properties or thermal stability. This new interest is mainly related to the fact that ceramic based reinforcement constituents became recently available, which are comparatively inexpensive. Al2O3- or SiC-based fibers, whiskers, and particles, but also carbon fibers are used to reinforce aluminum, magnesium, or titanium matrix alloys.   Author

N90-15209#   Royal Aerospace Establishment, Farnborough (England). Materials and Structures Dept.
MAGNESIUM ALLOY TECHNOLOGY FOR AEROSPACE APPLICATIONS
D. J. BRAY   *In* AGARD, New Light Alloys 9 p (SEE N90-15185 07-26) Aug. 1989
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    Recent developments in magnesium alloy technology for aerospace applications are reviewed. Most of the current requirements are met by cast alloys and two new alloys were introduced; WE54 for high temperature applications up to 300 C, and high purity AZ91 with improved corrosion resistance. Improvements in casting technology permit the manufacture of more complex castings with wall thicknesses as low as 3.5 mm. A new polyimide coating was developed for gearbox casings which resists attack by lubricating oils at temperatures over 200 C. Rapidly solidified magnesium alloys are at an early stage of development, but their potential is illustrated by the improvements in mechanical properties and corrosion resistance which were obtained. The new rapidly solidified alloy EA55RS is reported to have a 0.2 percent proof stress of 435 MPa, a UTS of 472 MPa, 13 percent elongation, and a corrosion rate in salt spray of 8 mils/year.   Author

N90-18397# Rolls-Royce Ltd., Derby (England). Dept. of Materials and Mechanics Technology.
DEFECTS: THEIR BEHAVIOUR AND RELATED DESIGN ASSUMPTIONS
R. H. JEAL *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 2: Defects and Quantitative Materials Behaviour 7 p (SEE N90-18396 11-07) Aug. 1989
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    The design engineers traditional view of materials was enshrined in the assumptions he makes - namely, all materials are homogeneous elastic isotropic media free from defects. The metallurgical and manufacturing engineers job was to produce materials that met those assumptions as nearly as possible and design criteria were set to keep operating conditions within the limits of behavior described by those assumptions. Where the assumptions broke down, usually because of the presence of manufacturing aberrations or lack of understanding of operating conditions, the method of manufacture or component design was changed to make the assumption valid again. If the component could not be designed within the criteria of the current material then a new material was developed with a higher yield stress or better creep properties so the operating conditions again fell inside the assumed envelopes. As the designers of engines sought for greater efficiency and lower weight the stresses and temperature imposed on components gradually rose. Under these more arduous conditions the basic design assumptions started breakdown on three counts: defect free material cannot be produced in spite of cleaner, better control manufacturing routes; materials are not continuous isotropic media but do have a microstructure and directionally that changes their behavior. and materials are not elastic, they exhibit plasticity, fatigue and creep effects which are critical in determining their behavior. How far materials deviate from the traditional assumptions of their nature and behavior and the changes required in design. analysis and manufacture practices to maintain safe efficient engines with the required integrity, are discussed.   Author

N90-18398#   Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France). Lab. Materiaux et Procedes.
THE DAMAGE TOLERANCE OF DISC MATERIALS: METALLURGICAL FACTORS; RELATIONSHIP WITH PROCESSING PARAMETERS
E. J. BACHELET   *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 2: Defects and Quantitative Materials Behaviour 20 p (SEE N90-18396 11-07) Aug. 1989
(AGARD-R-769) Copyright Avail: NTIS HC A06/MF A01;
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    Until recently, the development of discs material were conducted within the framework of design and aging methods which essentially took into account the resistance to burst, fatigue crack initiation and creep, of these parts. Based on these criteria, alloy design and processing options, aiming at increased stresses or temperatures in operation, were often accompanied, for metallurgical reasons which shall be reviewed, by a decrease in the intrinsic damage tolerance of discs materials. In the early eighties such an evolution was the origin of difficulties which prompted basic research to understand and improve the damage tolerance of these materials, and more recently to develop more adapted materials. In parrallel, evolutions in regulations put explicit damands to insure an adequate damage tolerance of the newer engines, ENSIP for instance. The metallurgical factors which effect the damage tolerance of discs materials belonging to the classes of alloys presently used, Titanium-base and Nickel-base are reviewed. The main challenges facing the materials designers are presented.   Author

N90-18399#   Rolls-Royce Ltd., Derby (England).
REVIEW OF COMPONENT DEFECTS, THEIR RELATIONSHIP TO MANUFACTURING PROCESS, AND THEIR EFFECT ON MATERIALS BEHAVIOUR (FOR CRITICAL ROTATING PARTS)
A. C. PICKARD   *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 2: Defects and Quantitative Materials Behaviour 15 p (SEE N90-18396 11-07) Aug. 1989
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    All engineering materials contain defects. These may range from microstructural inhomogeneities through to gross abnormalities which are independent of the underlying microstructure. The key to understanding the importance of these defects is the determination of their effect on full scale component behavior. In general, the most dangerous defects are those which, when subjected to cyclic loading conditions, behave as propagating cracks, with little or no crack nucleation life. Danger is a relative concept here, however; for instance, where the density of such defects is high, and the size uniform, tests on specimens and components may automatically take into account the presence of the worst defect. If the equivalent initial crack size is small, use of the material will result in a component with a viable life. When the presence of a defect is an explicit occurrence, however, it is unlikely that specimen and component tests will cover the behavior of the defect. In these circumstances, it is necessary to assess the risk of failure from defects and to ensure that this is acceptably low for in-servive components.   Author

N90-18400#   Turbomeca S.A. - Brevets Szydlowski, Bizanos (France).
DEFECTS IN MONOBLOCK CAST TURBINE WHEELS [LES DEFAUTS DANS LES ROUES DE TURBINE COULEES MONOBLOC]
D. FOURNIER   *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 2: Defects and Quantitative Materials Behaviour 11 p (SEE N90-18396 11-07)   Aug. 1989
In FRENCH
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    Results of a study of cast alloy turbine wheels (blisks) are presented. The alloy used in the experiments was the nickel-based superalloy MAR M 004. The metallurgical structure, microstructure, and mechanical properties of the alloy are briefly described. Approximately 5000 specimens were evaluated using various destructive and non-destructive techniques. Data showing the

nature and frequency of defects are presented and discussed. Factors affecting the propagation of semi-elliptical cracks are also addressed.   Transl. by M.G.

N90-28698# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
HIGH TEMPERATURE SURFACE INTERACTIONS
Nov. 1989   239 p   The 68th meeting was held in Ottawa, Ontario, 23-28 Apr. 1989
(AGARD-CP-461; ISBN-92-835-0533-6; AD-A217461) Copyright
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In today's climate of life extension for military aircraft, the topic of corrosion control assumes a role of greater importance. Controlling the degradative effects of flight environments on aircraft engine materials was emphasized. The chemical and mechanical mechanisms involved in degradative processes were reviewed and some state-of-the-art solutions considered. Emphasis in discussions centered on hot-salt corrosion topics but wear and erosion problems were also considered. For individual titles, see N90-28699 through N90-28714.

N90-28699# Ohio State Univ., Columbus. Dept. of Materials Science and Engineering.
HIGH TEMPERATURE SURFACE INTERACTIONS: OVERVIEW
ROBERT A. RAPP   In AGARD, High Temperature Surface Interactions 13 p (SEE N90-28698 23-26)   Nov. 1989
(Contract N00014-87-K-0030; NSF DMR-86-20311; ORNL ORDER 19X-SB154C)
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A mechanistic model is presented to explain and interrelate the means for vacancy annihilation, stress generation, and scale adherence for cation/vacancy diffusion-limited scale growth on a pure metal. Specifically, the climb into the metal of a fraction of the intrinsic interfacial misfit edge dislocations accounts for vacancy annihilation, ultimately leading to cooperative dislocation glide in both the metal and the scale. The hot corrosion of metals by thin fused salt films is treated in terms of oxide solubilities, electrochemical experimentation, and corrosion mechanisms. The chemistry of mixed sodium sulfate/vanadate melts, and the influence of vanadate on the solubilities of oxides, are presented. Temperature limitations to the protection of carbon/carbon substrates by SiC conversion coatings are discussed. Specifically, the rate of vitreous silica film growth on SiC, the partial pressures of SiO and CO at the SiC/SiO2 interface, and the conditions for active/passive volatilization of SiC are considered. The vapor pressures for volatile iridium oxides as a function of temperature and oxygen pressure are calculated. Analyses and experimental verification of simultaneous chromizing/aluminizing coating of Ni-base alloys in a chloride-activated cementation pack are explained. These inwardly grown diffusion coatings promise improved resistance to thermal fatigue and to hot corrosion.
                                                    Author

N90-28700# National Physical Lab., Teddington (England). Div. of Materials Applications.
DEVELOPMENTS IN TEST PROCEDURES FOR HOT-SALT CORROSION OF SUPERALLOYS
S. R. J. SAUNDERS and T. B. GIBBONS   In AGARD, High Temperature Surface Interactions 8 p (SEE N90-28698 23-26) Nov. 1989
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It is important that the test procedures used to assess the resistance of superalloys to hot salt corrosion should reliably simulate conditions expected in service and the results should be capable of interpretation to provide a prediction of likely long-term behavior. Past experience has shown that the many test methods available have frequently given conflicting measures of alloy performance and intercomparability between test procedures was frequently poor. As a result of extensive research in Europe, much of which was carried out within the COST Project, there is now a better understanding of the critical factors that must be controlled to provide a reliable and reproducible procedure and which gives

corrosive attack similar to that encountered in service. In particular, contaminant flux rate was identified as a key parameter. These activities are briefly reviewed and progress towards the definition of a unified test procedure is outlined. Plans for a new international intercomparison, organized under the auspices of VAMAS, to probe the validity of the procedure are described.   Author

N90-28702# Naval Air Development Center, Warminster, PA. Aerospace Materials Div.
OXIDATION, SULFIDATION, AND HOT CORROSION: MECHANISMS AND INTERRELATIONSHIPS
T. A. KIRCHER   In AGARD, High Temperature Surface Interactions 8 p (SEE N90-28698 23-26)   Nov. 1989
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A discussion of the various types of oxide growth laws which describe oxidation of metals and alloys was given. The formation and maintenance of a dense, adherent oxide scale will result in diffusion-limited scale growth and a parabolic-type rate equation. These protective scales are formed by selectively oxidizing their respective metallic components from a complex base alloy or coating. Exposure of alloys to a sulfidizing or hot-corrosive type environment reduces the ability for protective scales to adhere or recover from scale damage and shortens the time for which an alloy can form a protective scale via selective oxidation.   Author

N90-28705# Royal Aerospace Establishment, Farnborough (England). Dept. of Materials and Structures.
HIGH TEMPERATURE OXIDATION OF AL-LI ALLOYS
P. G. PARTRIDGE   In AGARD, High Temperature Surface Interactions 22 p (SEE N90-28698 23-26)   Nov. 1989
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Lithium additions increase the oxidation rate of Al-alloys in the solid and liquid states. At elevated temperatures in the solid state lithium diffuses rapidly through the aluminum alloy and through oxidized surfaces to become oxidized preferentially at the oxide/air interface where it forms non-protective oxidation products. The consequent lithium depletion causes changes in the near surface microstructure and hardness to depths of up to 800 microns depending on the temperature and exposure times. Depleted surface layers can lead to substantial reductions in the strength of thin sections. Procedures for minimizing lithium depletion during processing of Al-Li alloys are discussed. Oxidation in the liquid state is important in casting, in fusion welding and in rapid solidification processing and the behavior of Al-Li alloys under these conditions is described.   Author

N90-28706# Nottingham Univ. (England). Dept. of Metallurgy and Materials Science.
FRETTING WEAR AND FRETTING FATIGUE AT TEMPERATURES UP TO 600 C
R. B. WATERHOUSE   In AGARD, High Temperature Surface Interactions 12 p (SEE N90-28698 23-26)   Nov. 1989
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Raising the temperature increases the oxidation rate of most alloys. The thicker oxide film prevents metal-to-metal contact and reduces the coefficient of friction. On ferrous materials a type of oxide layer develops which was first observed in high temperature unidirectional sliding and, because of its smoothness, was given the name glaze oxide. Both high temperature and sliding are necessary for its formation. The result is that the wear is much reduced and also fatigue strengths are increased. It is only stable at the high temperature. If the temperature falls to room temperature it is soon completely disrupted. The evidence is that the alloys which are capable of forming the glaze oxide are those on which an oxide with a spinel structure can develop. The appearance of the oxide is a smooth, grooved outer surface, with a granular structure underneath. If the oxide is damaged it is soon repaired. Titanium alloys do not develop this type of oxide. Surface modification by implantation of Ba and Bi ions has produced significant improvements in the tribological behavior of these alloys in high temperature fretting.   Author

N90-28707# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Dept. of Materials Science.
EFFECT OF PROTECTIVE COATINGS ON MECHANICAL PROPERTIES OF SUPERALLOYS
REMY MEVREL and JEAN-MARIE VEYS (Service Technique des Programmes Aeronautiques, Paris, France) In AGARD. High Temperature Surface Interactions 13 p (SEE N90-28698 23-2.) Nov. 1989 Previously announced in IAA as A90-11126
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The influence of protective coatings on the mechanical properties of superalloys employed in hot sections of gas turbine engines is investigated. The most used coatings are aluminide-based such as MCrAlY overlays and zirconia-based thermal barrier coatings, which may affect the mechanical properties of the superalloy substrates in several ways. Interdiffusion phenomena taking place between coating and substrate at high temperature during service may decrease the load bearing section of the superalloy and, as a consequence, may degrade its creep lifetime. Examples of possible effects of coating/substrate interdiffusion on the creep life of single crystal CMSX2 (no effect) and in the case of a directionally solidified eutectics superalloy (significant degradation) are considered. In the long run, the presence of a coating can enhance the creep life of a substrate due to its protective effect against high temperature corrosion. After considering different factors which can affect the mechanical behavior of the coated systems, a review of recent experimental results is presented. Author

N90-28709# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
FRETTING FATIGUE STRENGTH OF TI-6AL-4V AT ROOM AND ELEVATED TEMPERATURES AND WAYS OF IMPROVING IT
RAINER SCHAEFER and WALTER SCHUETZ In AGARD, High Temperature Surface Interactions 15 p (SEE N90-28698 23-26) Nov. 1989 Sponsored by BMFT, Fed. Republic of Germany
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The high sensitivity of titanium alloys to fretting fatigue has to be taken into account when oscillatory relative motion occurs in joints of fatigue loaded components, e.g., in the connection of the disc with the blades in compressors of aircraft engines. Against this background fretting fatigue behavior of Ti-6Al-4V was investigated at room temperature and service temperature (350 C) as well by testing flat specimens under fatigue loading and simultaneous fretting applied by a special fretting apparatus. The results show a complex system of parameters affecting fretting fatigue resistance: Fretting fatigue resistance decreases with increasing contact pressure and increasing amplitude of slip, down to a certain limit value for each. Other parameters investigated here are surface finish and stress ratios. The lowest value of fretting fatigue limit found was about 20 percent of the original fatigue limit of the unfretted material. Elevated temperature (350 C), however, had little additional detrimental effect. Among several methods to improve fretting fatigue resistance, shot peening and coating are also employed in compressor components. By shot peening the fretting fatigue limit could be increased by more than a factor of two, by coating with PVD systems by nearly a factor of two. Author

N90-28713# Hawker Siddeley Canada Ltd., Toronto (Ontario). Research and Technology Development Group.
SURFACE PROPERTY IMPROVEMENT IN TITANIUM ALLOY GAS TURBINE COMPONENTS THROUGH ION IMPLANTATION
J. E. ELDER, M. R. PISHVA, N. C. BELLINGER, P. C. PATNAIK, and R. THAMBURAJ In AGARD, High Temperature Surface Interactions 11 p (SEE N90-28698 23-26) Nov. 1989 Sponsored by Department of National Defence, Ottawa, Ontario
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The feasibility of applying ion implantation to produce substantial improvement in the wear/fretting fatigue resistance of titanium alloys used as gas turbine fan and compressor blade material was studied. Detailed/microscopy and mechanical test results were used to analyze the various mechanisms contributing to wear and fretting fatigue damage in titanium alloys at room and elevated temperatures. The manner in which ion implantation might modify the normal wear/fretting fatigue response of these alloys is discussed in detail, along with the factors to be considered in choosing optimum ion implantation parameters. Author

N90-28714# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. for Materials Research.
OVERVIEW ON HOT GAS TESTS AND MOLTEN SALT CORROSION EXPERIMENTS AT THE DLR
H.-J. RAETZER-SCHEIBE In AGARD, High Temperature Surface Interactions 14 p (SEE N90-28698 23-26) Nov. 1989
(AGARD-CP-461) Copyright Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The use of more corrosive low-grade fuels in combination with increasing combustion gas temperatures are major challenges in the present and future operation of heat engines. Improved thermal efficiency under practical operating conditions can only be accomplished by improved materials and/or coatings. This development motivated in 1982, the procurement of a high-velocity burner rig for simulation of the operation of gas turbines under service conditions. As an aircraft research and development establishment, corrosion and oxidation of aircraft gas turbines were the main interest. Working in this new field of research yielded a review on hot corrosion in aircraft engines. For an overview of the work, to date, in the field of hot corrosion and high temperature oxidation some topics are selected. Burner rig tests were started with investigations on the hot corrosion resistance of protective coating systems to evaluate coating alloys for use in highly contaminated combustion gases. Thermocyclic oxidation tests of coated aircraft turbine glade materials in hot gases of JP4 up to temperatures of 1100 C, followed later. Since hot corrosion is induced by molten salts or low-melting oxides deposited from the hot gas on the material surface the necessity is seen for fundamental investigations of molten salt corrosion. Therefore a device was developed for electrochemical experiments in molten salts. Another motivation for developing molten salt experimentation was to have an alternative test procedure to the high-cost burner rig tests. Author

N91-11251# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
TEXTURE ANALYSIS OF 2090-T8E41 ALUMINUM-LITHIUM ALLOY SHEET: ANNEX
A. W. BOWEN In AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 5 p (SEE N91-11240 02-39) Aug. 1990
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This annex describes the texture analysis that was made on the 2090-T8E41 aluminum-lithium alloy sheet used in the AGARD Supplemental Test Program. The information obtained in this analysis was supplied to all participants who tested the aluminum-lithium alloy. Author

N91-11905# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
NEW LIGHT ALLOYS
Sep. 1990 245 p In ENGLISH and FRENCH Lectures held in Madrid, Spain, 15-16 Oct. 1990; in Toulouse, France, 18-19 Oct. 1990; and in Monterey, CA, 29-30 Oct. 1990
(AGARD-LS-174; ISBN-92-835-0588-3; AD-A228899) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Developments in research, manufacture, and exploitation of new light alloys (based on aluminum and magnesium) are reviewed for structural applications in aeronautics and space. These new alloys exhibit significant potential for reducing structural weight and are gaining recognition as competitive materials within the aerospace industries. Topics addressed in the lectures include: metal physics and processing aspects, properties of existing materials, and prospects for future development and exploitation. For individual titles, see N91-11906 through N91-11912.

N91-11906# Royal Aerospace Establishment, Farnborough (England). Dept. of Materials and Structures.
THE DEVELOPMENT OF ALUMINUM LITHIUM ALLOYS: AN OVERVIEW
C. J. PEEL *In* AGARD, New Light Alloys 55 p (SEE N91-11905 03-26) Sep. 1990
(AGARD-LS-174) Copyright Avail: NTIS HC/MF A11;
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AGARD/Scientific Publications Executive
For the last decade the aluminium industry has been redeveloping aluminium-lithium alloys for aerospace use. While not new in concept or in technology, these alloys would appear to offer the aircraft designer as much weight saving as non-metallic composite materials with the added advantage of the continued employment of well developed manufacturing routes supported by existing expensive equipment. It is clear that, were it not for significant technical and production difficulties, many of the airframes produced today would already be manufactured in aluminum-lithium alloy. Not only the property advantages that enable very significant weight savings to be achieved, but those difficulties that are being slowly overcome by intensive effort are highlighted. The scale of this effort can be judged by the fact that the last of the five International Conferences, held exclusively on aluminum -lithium alloys, produced over 1700 pages of print. It is far beyond the scope of this paper to comprehensively review this aggregated volume of work but an attempt is made to precis those aspects thought to be most relevant to the successful outcome of the development. Author

N91-11907# Virginia Univ., Charlottesville. School of Engineering and Applied Science.
THE MICROSTRUCTURE AND PROPERTIES OF ALUMINUM-LITHIUM ALLOYS
EDGAR A. STARKE, JR. and WILLIAM E. QUIST (Boeing Commercial Airplane Co., Seattle, WA.) *In* AGARD, New Light Alloys 21 p (SEE N91-11905 03-26) Sep. 1990 Previously announced as N90-15187
(Contract DAAL03-86-K-0128; N00014-85-0526; AF-AFOSR-0082-87)
(AGARD-LS-174) Copyright Avail: NTIS HC/MF A11;
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The advantage to be gained by weight reduction of aerospace structures have encouraged the aluminum industry to develop a family of aluminum alloys which contain lithium as one of the alloying elements. When alloyed with aluminum, lithium can reduce the density by approximately three percent and increase the elastic modulus by six percent for every weight percent added. A new series of aluminum alloys, typified by 2090, 2091, 8090, and 8091, were developed and are currently being produced in commercial quantities. These alloys have densities between 7 and 10 percent lower than the conventional alloy 7075 with correspondingly higher stiffness. Although a combined set of specific properties of the Al-Li-X alloys often exceeds those of the conventional aluminum materials used in aerospace, these properties seem to be much more sensitive to processing parameters. The strong processing-property relationship is associated with sharp crystallographic textures that are developed during primary processing and very complex precipitate microstructures whose distributions are sensitive to quench rates and degree of deformation prior to aging. The processing-microstructure property relationships of the new Al-Li-X alloys are described and the focus is on strength, ductility, fracture toughness, fatigue and stress corrosion properties. Author

N91-11910# Aluminum Co. of America, Alcoa Center, PA.
ALUMINUM POWDER ALLOYS: AN OVERVIEW
GREGORY J. HILDENMAN and MICHAEL J. KOCZAK (Drexel Univ., Philadelphia, PA.) *In* AGARD, New Light Alloys 25 p (SEE N91-11905 03-26) Sep. 1990
(AGARD-LS-174) Copyright Avail: NTIS HC/MF A11;
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AGARD/Scientific Publications Executive
The historic development of aluminum powder metallurgy dates back to the early 1900s with initial flake powder production and has matured to the present day production of viable aerospace alloys. Primary powder production and processing techniques, such as atomization and mechanical alloying are reviewed.

Processing-microstructure-property relationships in four classes of high performance powder metallurgy (PM) aluminum alloys are considered. These are high strength alloys (Al-Zn-Mg-Cu-Co); high specific modulus alloys (Al-Li-Cu); high temperature alloys (Al-Fe-Co, Al-Fe-Ni); mechanically alloyed material (Al-Mg) and composite alloys. Direct property comparisons with counterpart ingot metallurgy alloys are presented wherever appropriate. Aluminum powder metallurgy alloy development is now at a mature stage of growth where commercial and aerospace application are being sought and developed in competition with traditional aluminum ingot metallurgy, titanium, and composite structures. The future growth and development of these alloy systems is vested in reliable economic processing and design reliability. Author

N91-11911# Ecole des Mines, Nancy (France).
PHYSICAL METALLURGY OF ALUMINUM POWDER ALLOYS
GEORGES CHAMPIER *In* AGARD, New Light Alloys 21 p (SEE N91-11905 03-26) Sep. 1990
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The discovery of new alloy compositions and new processes increases the application field of aluminum alloys. In particular the powder metallurgy route allows alloying with transition and rare earth metals, oxygen and carbon usually forbidden by the classical ingot metallurgy route. Further improvements can be obtained by rapid solidification and/or mechanical alloying by modifying the microstructures. The relation between microstructure and mechanical properties of high strength alloys for room temperature applications (7090, 7091, CW67 and Al-C-O), and alloys for high temperature applications (Al-Fe-Ce, Al-Fe-V-Si, Al-Cr-Zr, Al-Zr-V, Al-Cr-Y, and some other under studies) are examined. Author

N91-11912# Royal Aerospace Establishment, Farnborough (England). Dept. of Materials and Structures.
CAST AND RAPIDLY SOLIDIFIED MAGNESIUM ALLOYS
D. J. BRAY *In* AGARD, New Light Alloys 29 p (SEE N91-11905 03-26) Sep. 1990
(AGARD-LS-174) Copyright Avail: NTIS HC/MF A11;
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AGARD/Scientific Publications Executive
Recent developments in magnesium alloy technology will be described. The majority of applications for magnesium alloys in the aerospace industry are in castings. A range of yttrium containing alloys was introduced for high temperature applications, and the corrosion resistance of Mg-Al-Zn cast alloys was improved by increasing the alloy purity. Fluxless melting, to reduce the number of inclusions, is now common, and low pressure casting permits more complex, thin walled components to be made. For gearbox casings, a polyimide coating was developed which resists attack by lubricating oils up to 225 C. Further development of magnesium alloys by ingot metallurgy is limited by the structure of the phase diagram of many magnesium alloy systems. To overcome these restrictions, attention is now turning to the rapid solidification of magnesium alloys and progress in this field is reviewed. Author

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NONMETALLIC MATERIALS

Includes physical, chemical, and mechanical properties of plastics, elastomers, lubricants, polymers, textiles, adhesives, and ceramic materials.

N89-22657# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.). Inst. for Structures and Design.
MONOLITHIC AND FIBER CERAMIC COMPONENTS FOR TURBOENGINES AND ROCKETS
R. KOCHENDOERFER *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 10 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
From the design point of view, whether or not the existing experience gained during the automotive ceramic turbine

development can be transferred to aero jet engines is reviewed. It is well known that design considerations strongly influence the failure tolerance of ceramic structures. Following material adequate design concepts will increase component reliability. Focussing these topics, the future application of ceramics for thermally and/or mechanically high-loaded structures within the propulsion system are discussed. Actual available data of emerging materials as C/C, C/SiC, SiC/Sic are presented. The material's behavior, their potential for structural applications as well as design consequences are evaluated.   Author

N89-22658# Royal Aircraft Establishment, Farnborough (England). Space Dept.
CVD AND DIFFUSION COATINGS FOR HIGH TEMPERATURE APPLICATIONS IN TURBOMACHINERY AND ROCKET MOTORS
S. P. FIELD, J. E. RESTALL, C. D. CHALK, and C. HAYMAN (Fulmer Research Inst. Ltd., Stoke Poges, England) *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 12 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
    A brief but critical review is presented of recent developments in Chemical Vapor Deposition (CVD) metal and ceramic coatings for aerospace applications, covering in addition to standard CVD, activated CVD, diffusion CVD, pressure pulsed CVD and the more recently explored chemical vapor infiltration (CVI) processing. Fused slurry diffusion coatings are also covered. Important applications of such coatings and free-standing shapes are outlined and illustrated, particularly CVD diffusion aluminizing, chromizing and siliconizing of turbine blades, refractory metal coatings and free-standing components of rocket motors. Future trends in materials technology are also discussed with particular reference to the CVD coating of fibers, including modified carbon-carbon and other ceramic composites for high temperature operation in oxidizing environments.   Author

N89-22664# Cranfield Inst. of Tech., Bedford (England). School of Industrial Science.
ADVANCED MATERIALS TO COMBAT THE HIGH TEMPERATURE DEGRADATION PROCESSES IN TURBOMACHINERY
P. HANCOCK and J. F. RESTALL (Royal Aircraft Establishment, Farnborough, England) *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 11 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
    The reasons for the necessity of protective surface coatings on conventional superalloy components are examined. Diffusion coatings, together with newer overlay coatings based on MCrAlY compositions produced by electron beam plasma vapor, are examined and their mechanisms of surface breakdown identified. It is suggested that further developments could be made with compositions that are outside the current commercially available coatings. The limitations of the upper operating temperature of conventional coating systems suggest the need for thermal barrier coatings and the conflict between dense coatings for surface protection and porous coatings for essential mechanical stability is examined. Finally, the advantages of fiber reinforced ceramic components are considered, together with potential mechanisms of surface breakdown.   Author

N89-22665# Garrett Turbine Engine Co., Phoenix, AZ.
THE DEMONSTRATION OF MONOLITHIC AND COMPOSITE CERAMICS IN AIRCRAFT GAS TURBINE COMBUSTORS
FRANK G. DAVIS and DALE A. HUDSON *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 10 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
    Since the mid seventies, the Air Force Wright Aeronautical Laboratories Aero Propulsion Laboratory has been on a course to evaluate and demonstrate the application of advanced non-metallic materials in experimental gas turbine engines. Potential increases of several hundred degrees or more in operating temperature represents a quantum leap in engine capability. Since the seventies, combustion rig tests have been successfully performed at near-stoichiometric conditions on two ceramic combustor configurations. These combustors were annular, through-flow designs similar to the metallic burners used in present-day military

propulsion gas turbines. The first configuration used monolithic ceramic segments as a portion of the inner and outer combustor liners. The segments were supported by an external metal structure. These segments were fabricated from silicon carbide material. In the most recent program ceramic composite rings were used to form the inner and outer liners. The rings were composed of silicon carbide fibers and a silicon carbide matrix. The ceramic composite rings required no external support structure. Testing consisted of both steady-state and transient operations. During transient testing, the combustors were subjected to rapid thermal cycling. Testing of silicon carbide and silicon nitride ceramic materials has just begun.   Author

N89-22669# Brown, Boveri und Cie A.G., Mannheim (Germany, F.R.). Materials Technology Lab.
INTERACTION OF COATINGS WITH BASE METALS AT HIGH TEMPERATURE
HERMANN W. GRUENLING, K. SCHNEIDER, and L. SINGHEISER *In* AGARD, Application of Advanced Materials for Turbomachinery and Rocket Propulsion 23 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
    The interaction of aluminide, CoCrAlY- and NiCrAlY-based coatings on the nickel-based alloy IN 738 LC was investigated in the temperature range 850 to 1000 C. Due to intensive interdiffusion behavior of CoCrAlY-coatings with Ni-based alloys the coating composition changes to CoNiCrAlY at high temperature. The degradation of the coating occurs primarily by Al-diffusion into the alloy. NiCrAlY-coatings show less interdiffusion with Ni-based alloys. Coating degradation occurs by oxidation. A similar behavior was observed for aluminide coatings. Interdiffusion effects between coatings and alloys increase N sub v - numbers in the interdiffusion zone resulting in the precipitation of brittle phases.   Author

N89-22670*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
VACUUM PLASMA SPRAY COATING
RICHARD R. HOLMES and TIMOTHY N. MCKECHNIE (Rockwell International Corp., Huntsville, AL.) *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 5 p (SEE N89-22654 16-23) Mar. 1989
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
CSCL 11/3
    Currently, protective plasma spray coatings are applied to space shuttle main engine turbine blades of high-performance nickel alloys by an air plasma spray process. Originally, a ceramic coating of yttria-stabilized zirconia ($ZrO2.12Y2O3$) was applied for thermal protection, but was removed because of severe spalling. In vacuum plasma spray coating, plasma coatings of nickel-chromium-aluminum-yttrium (NiCrAlY) are applied in a reduced atmosphere of argon/helium. These enhanced coatings showed no spalling after 40 MSFC burner rig thermal shock cycles between 927 C (1700 F) and -253 C (-423 F), while current coatings spalled during 5 to 25 test cycles. Subsequently, a process was developed for applying a durable thermal barrier coating of $ZrO2.8Y2O3$ to the turbine blades of first-stage high-pressure fuel turbopumps utilizing the enhanced NiCrAlY bond-coating process. NiCrAlY bond coating is applied first, with $ZrO2.8Y2O3$ added sequentially in increasing amounts until a thermal barrier coating is obtained. The enchanced thermal barrier coating has successfully passed 40 burner rig thermal shock cycles.   Author

N89-22671*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THRUST CHAMBER THERMAL BARRIER COATING TECHNIQUES
RICHARD J. QUENTMEYER *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 10 p (SEE N89-22654 16-23) Mar. 1989 Previously announced as N88-24690
(AGARD-CP-449) Copyright Avail: NTIS HC A13/MF A02
CSCL 11/3
    Methods for applying thermal barrier coatings to the hot-gas side wall of rocket thrust chambers in order to significantly reduce the heat transfer in high heat flux regions has been the focus of technology efforts for many years. A successful technique developed by NASA-Lewis that starts with the coating on a mandrel and then builds the thrust chamber around it by electroforming

appropriate materials is described. This results in a smooth coating with exceptional adherence, as was demonstrated in hot fire rig tests. The low cycle fatigue life of chambers with coatings applied in this manner was increased dramatically compared to uncoated chambers.   Author

N89-22677#   Office National d'Etudes et de Recherches Aerospatiales, Palaiseau (France).
CERAMIC HEAT EXCHANGERS AND TURBINE BLADES: THEORY AND EXPERIMENTAL RESULTS [ECHANGEURS DE CHALEUR ET AUBES DE TURBINE EN CERAMIQUE THEORIE ET RESULTATS EXPERIMENTAUX]
P. AVRAN and S. BOUDIGUES   *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 11 p (SEE N89-22654 16-23)   Mar. 1989   In FRENCH; ENGLISH summary
(AGARD-CP-449)   Copyright   Avail: NTIS HC A13/MF A02
     Theoretical and experimental research on the use of ceramics in gas turbines developed at O.N.E.R.A (the French Aerospace Research Institute) during the last five years is reviewed and discussed. The two main lines of this research are ceramic heat exchangers for high efficiency, low specific fuel consumption gas turbine cycles, and use of ceramics for fixed or moving turbine blades.   Author

N89-22679#   Defence Research Establishment Valcartier (Quebec).
DEVELOPMENT OF AN ASBESTOS-FREE INSULANT FOR ROCKET MOTORS
D. SANSCHAGRIN and G. COUTURE   *In* AGARD, Application of Advanced Material for Turbomachinery and Rocket Propulsion 10 p (SEE N89-22654 16-23)   Mar. 1989
(AGARD-CP-449)   Copyright   Avail: NTIS HC A13/MF A02
     As a result of concerns about restrictions on the industrial use of asbestos, DREV initiated a research project aimed at replacing asbestos in the rocket motor insulant designated RF/B. RF/B is a polymer composite consisting of a carboxyl terminated polybutadiene filled with asbestos. While retaining the same polymeric resin, a combination of fibers (Kevlar, Refrasil and Pyron) and fillers (kaolin and Mg(OH)2) was used to obtain formulations compatible with the processing of RF/B, which is based on the use of a sigma-blade mixer and two roll mills. The mechanical properties of the new material and its suitability in CRV7 rocket motors were assessed.   Author

N90-15909#   Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
THE EFFECT OF PRIMER AGE ON ADHESION OF POLYSULPHIDE SEALANT
S. P. WILFORD and J. DAY   *In* AGARD, Fuel Tank Technology 7 p (SEE N90-15904 08-05)   Nov. 1989
(AGARD-R-771)   Copyright   Avail: NTIS HC A08/MF A01;
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     Sealants used in aircraft integral fuel tanks must adhere well to primed substrate surfaces. The adhesion of polysulphide sealant (PR1422) to primed aluminum alloy surfaces of different primer age was studied with respect to the effect on lap-shear strength of ageing in fuel at 100 C. Freshly primed surfaces, 1 day old, were compared with a range of older primed surfaces. With a standard epoxy chromate primer, primer age has a very marked effect on lap-shear strength, the value after 10 days in fuel (Avtur) at 100 C being a factor of 2 less for 2 to 20 week old primed specimens as compared to a freshly primed one. In contrast, similar studies using three tolerant epoxy chromate primers indicate that primer age has much less effect on the adhesion of PR1422 sealant to these primers, lap shear strengths after ageing in fuel at 100 C showing much less dependence on primer age. These results would appear to be very relevant to both repair and manufacture of integral fuel tanks.   Author

N90-15910#   Products Research and Chemical Corp., Glendale, CA. Aerospace Div.
IMPROVED PERFORMANCE POLYSULFIDE BASED SEALANT
AHMED SHARABY   *In* AGARD, Fuel Tank Technology 9 p (SEE N90-15904 08-05)   Nov. 1989
(AGARD-R-771)   Copyright   Avail: NTIS HC A08/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
     It was recently discovered that low viscosity mercaptan terminated polymers which exhibit application and performance properties superior to their precursor materials can be obtained by chemical modification of Thiokol LP polymers. For example, these chemically modified Thiokol LP polymers, known as Permapol P-5 polymers, can be formulated and cured using similar methods as LP polymers to give elastomeric materials which, compared to the same LP polymer based materials, exhibit: superior ozone and UV radiation resistance; higher physical properties; better fuel resistance; higher temperature resistance; greater compatibility with traditional plasticizers; better adhesion to many substrates after exposure to liquids such as aromatic hydrocarbon containing fuels; and better resistance to permeability of inert gases and fuel vapors. The properties and uses, of this new class of polymers, in some sealant formulations are described as compared to their precursor materials, the Thiokol LP polymer.   Author

N90-15911#   Products Research and Chemical Corp., Glendale, CA.
FUEL RESISTANT COATINGS FOR METAL AND COMPOSITE FUEL TANKS
SANTO RANDAZZO   *In* AGARD, Fuel Tank Technology 20 p (SEE N90-15904 08-05)   Nov. 1989
(AGARD-R-771)   Copyright   Avail: NTIS HC A08/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
     Coating systems based on fuel resistant polythioether polyurethane polymers were developed. These systems are formulated to provide a secondary seal and thereby protect the interior of composite fuel tanks. In addition to fuel resistance the systems have excellent physical properties, low specific gravity and prevent fuel leakage even after severe impact damage to the composite tank. Reduction of mechanical damage, prevention of water penetration into the composite, and prevention of leakage through composite imperfections are other desirable properties of these coatings. Data are presented showing the fuel resistance and hydrolytic stability of these new materials. The retention of physical properties is tabulated after prolonged environmental exposure to fuel and water. Impact damage data on coated composites and metal is presented using different energy levels of impact and various thicknesses of coating. The effectiveness of these coatings in sealing composite tanks, both before and after impact damage, is demonstrated. Fuel and water permeability data are presented. Rapid cure characteristics are also illustrated making these coatings of particular value for production lines. Coating procedures for sealing disposable or integral fuel tanks without use of faying surface sealants are discussed. Results on adhesion to metals, composites and conventional aerospace sealants are presented. Ease of repair, surface preparation and product application are also discussed when sealing simple or complex fuel tanks. The chemistry of polythioether polyurethane polymers is also discussed and compared to conventional polyurethane materials, illustrating how these new coatings provide a new dimension in aircraft sealing technology.   Author

N90-28074#   National Aeronautical Establishment, Ottawa (Ontario). Structures and Materials Lab.
NONDESTRUCTIVE EVALUATION OF ADHESIVELY-BONDED JOINTS
A. FAHR and S. TANARY (Ottawa Univ., Ontario)   *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 10 p (SEE N90-28068 22-38)   May 1990
(AGARD-CP-462)   Copyright   Avail: NTIS HC A11/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
     The structural use of adhesively bonded joints, particularly in aerospace applications, requires nondestructive evaluation techniques for the characterization and qualification of bond integrity. The types of defects encountered in bonded joints and

the nondestructive evaluation (NDE) methods available to detect them are reviewed. In particular, techniques which have shown potential for nondestructive characterization of bond strength are described. Finally, experimental results from acousto-ultrasonic (AU) measurements followed by destructive shear tests on single-lap joint specimens made from either metallic or carbon fiber composite adherends and FM 300 film adhesive with different types of bond line defects are presented.   Author

N90-28701#   National Research Council of Canada, Ottawa (Ontario).
THE EFFECTS OF A COMPRESSOR REBUILD ON GAS TURBINE ENGINE PERFORMANCE: FINAL RESULTS
J. D. MACLEOD and J. C. G. LAFLAMME (Canadian Forces Base, Baden-Soellingen, Germany, F.R.)   *In* AGARD, High Temperature Surface Interactions 13 p (SEE N90-28698 23-26)   Nov. 1989
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   The Canadian Department of National Defence, in conjunction with the Engine Laboratory of the National Research Council Canada (NRCC), initiated a project for the evaluation of gas path coatings on the Allison T56 engine. The objective was to evaluate blade coatings in terms of engine performance effects and material durability. The project included a study of the influence of rebuilding the compressor on performance, since dismantling and rebuilding was required for the coating process. The compressor rebuild study, including the overall objectives, the test set-up, the performance effects, and the uncertainty of the measured results are described. The impact of this work on the coatings project is also documented.   Author

N90-28703#   United Technologies Research Center, East Hartford, CT.
SCALE ADHERENCE EFFECTS IN OXIDATION AND SULFIDATION
M. A. DECRESCENTE and N. S. BORNSTEIN   *In* AGARD, High Temperature Surface Interactions 10 p (SEE N90-28698 23-26) Nov. 1989
(AGARD-CP-461)   Copyright   Avail: NTIS HC A11/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   The most oxidation-resistant gas turbine alloys and coatings form adherent Al_2O_3 oxide scales which slowly thicken and resist spallation when thermally stressed. Work performed in the period 1966 to 1972 demonstrated that the onset of sulfidation was also affected by the adhesion of the Al_2O_3 scale. The relationship between sulfidation corrosion, and oxide scale adherence as it relates to oxidation resistance is reviewed. The sulfidation mechanism research is summarized to illustrate the role of Al_2O_3 scale in the sulfidation process; whereas more recent oxidation results of in-house and ONR and NADC-sponsored programs is presented which demonstrates that sulfur present in gas turbine materials, even at very low concentrations, degrades Al_2O_3 scale adhesion. Finally, results are disclosed which indicate that the very low sulfur-containing materials are extremely oxidation resistant and delay the onset of sulfidation.   Author

N90-28704#   Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Dept. of Materials Science.
MOLTEN SALT INDUCED HIGH TEMPERATURE DEGRADATION OF THERMAL BARRIER COATINGS
SERGE ALPERINE   *In* AGARD, High Temperature Surface Interactions 18 p (SEE N90-28698 23-26)   Nov. 1989   Previously announced in IAA as A89-48745
(AGARD-CP-461)   Copyright   Avail: NTIS HC A11/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   Thermal barriers are now fairly well known as a new generation of protective coatings for components of the hot sections of conventional, diesel and turbine engines. The more performing system is a duplex coating consisting of a stabilized zirconia top coat generally air plasma sprayed on a approximately 100 micron thick MCrAlY bond coat. The service degradation modes of such coatings have been extensively studied during the past ten years. Their failure mechanisms are generally thought of in terms of thermomechanical stress, thermal expansion coefficient mismatch and bond coat high temperature oxidation. Efforts are thus made

to design ceramic and bond coat composition, microstructure and processing parameters, according to these requirements. However, degradation of thermal barrier coatings by hot corrosion processes and, more generally, by fused salt thin films related phenomena, should also be taken into account. A review is given of the degradation modes that can be encountered when partially stabilized zirconia coatings are exposed to intermediate temperature range and sulphur and/or vanadium containing atmosphere. The interaction of the salt film with the coating is threefold: a chemical acidic or alkaline dissolution of the zirconia stabilizing oxide may occur, provoking zirconia tetragonal to monoclinic phase transformation and subsequent coating spallation on cooling. Fused salt may diffuse inside the ceramic microcracks network and solidify on cooling with a generation of extra stress inside the coating. Fused salt diffused throughout the microcracks network down to the ceramic/bond coat interface may also affect the MCrAlY bond coat. Careful distinction should be made between the working conditions encountered in diesel engines and marine turbines and those involved in aircraft turboengines. An illustration of the hot corrosion resistance of a ZrO_2-8wt percent Y_2O_3/NiCrAlY thermal barrier coating, plasma sprayed on a single crystal superalloy substrate, in a typical aircraft turbine environment is given.   Author

N90-28708#   Naval Air Development Center, Warminster, PA.
MICRODAMAGE TO CERAMIC SURFACES UNDER SLIDING CONDITIONS
P. J. KENNEDY and A. CONTE   *In* AGARD, High Temperature Surface Interactions 7 p (SEE N90-28698 23-26)   Nov 1989
(AGARD-CP-461)   Copyright   Avail: NTIS HC A11/MF A02;
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   Fretting studies were performed on silicon nitride in order to ascertain the effect of small amplitude slip (0.1 to 10 micrometers) on ceramic wear. The results indicate that the small amplitude fretting of silicon nitride on silicon nitride is primarily controlled by tribochemical reaction forming a soft silicon oxide layer. This reaction was not observed to any measurable extent at slip amplitudes of less than 3 micrometers. The tribochemical reaction was initially observed at the edge of the contact region and then progressed toward the center of the contact zone. The reacted material in the contact zone tended to flow out of the high pressure region to form a debris pile-up outside of the contact area. The wear ratio was found to be $4 \times 10^{(exp-16)}$ sq m/Nm.   Author

N90-28710#   Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Dept. of Materials Science.
HIGH TEMPERATURE PROTECTIVE COATINGS: RECENT TRENDS
REMY MEVREL   *In* AGARD, High Temperature Surface Interactions 10 p (SEE N90-28698 23-26)   Nov. 1989   Previously announced in IAA as A90-21039
(AGARD-CP-461)   Copyright   Avail: NTIS HC A11/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   Major types of currently used high-temperature protective coatings, including modified aluminides, MCrAlY overlays, and ceramic thermal barrier coatings are described, and recent trends in the coating field research reviewed. These research trends include studies of high-temperature corrosion degradation mechanisms, the mechanical properties of coated components, and the diffusional stability of coating/substrate systems. Particular attention is given to the development of high-performance ceramic coatings and to alternative coating processes, such as the deposition of MCrAlY alloys by electrophoresis and coelectrodeposition, cladding, or replacing Pt by Pd in modified aluminide coatings.   Author

N90-28711# National Aerospace Lab., Emmeloord (Netherlands).
THERMAL SHOCK AND OXIDATION RESISTANCE OF CERAMIC COATINGS
J. A. M. BOOGERS, R. J. H. WANHILL, and H. J. C. HERSBACH *In* AGARD, High Temperature Surface Interactions 16 p (SEE N90-28698 23-26) Nov. 1989 Sponsored by Royal Netherlands Air Force
(AGARD-CP-461) Copyright Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Thermal shock and long term oxidation tests on ceramic thermal barrier coatings were done under flight simulation conditions in a burner rig. Three coating combinations were investigated: magnesium stabilized zirconia topcoat with Ni-5 percent Al bondcoat; magnesium stabilized zirconia topcoat with NiCoCrAlY bondcoat; and yttrium stabilized zirconia topcoat with NiCoCrAlY bondcoat. The ZrO2/Y2O3 + NiCoCrAlY combination showed superior resistance to thermal shock and long term oxidation as compared to the ZrO2/MgO + Ni-5 percent Al coating. The long term oxidation resistance of the ZrO2/MgO + NiCoCrAlY combination was intermediate to that of the other two coatings. Degradation of the coatings was examined in detail, and the practical significance of the results is assessed. Author

N90-28712# National Aeronautical Establishment, Ottawa (Ontario).
EVALUATION OF HIGH TEMPERATURE PROTECTIVE COATINGS FOR GAS TURBINE ENGINES UNDER SIMULATED SERVICE CONDITIONS
A. K. GUPTA, T. TERADA, P. C. PATNAIK (Hawker Siddeley Canada Ltd., Toronto, Ontario), and J.-P. IMMARIGEON *In* AGARD, High Temperature Surface Interactions 31 p (SEE N90-28698 23-26) Nov. 1989 Sponsored by Department of National Defence, Ottawa, Ontario
(AGARD-CP-461) Copyright Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The surface degradation of turbine hot section components, due to oxidation, hot corrosion, erosion, and thermal fatigue, is discussed. The mechanisms of each mode of attack are summarized and the state-of-the-art in protective coatings for gas path components is reviewed. Durability evaluations of coatings under simulated service conditions are discussed, including evaluations conducted in high velocity burner rigs. Inconsistencies in the ranking of coatings in rigs is attributed to laboratory-to-laboratory variations in test procedures and/or test conditions. Finally, the important parameters for durability testing in rigs are discussed in terms of the environmental and operational factors that control hot gas chemistry and the extent of surface damage of hot parts. A description of commonly used burner rigs and test procedures employed is also provided to complete the paper. Author

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PROPELLANTS AND FUELS

Includes rocket propellants, igniters, and oxidizers; their storage and handling procedures; and aircraft fuels.

N91-18079# Department of National Defence, Ottawa (Ontario). Operational Research and Analysis Establishment.
EVALUATION OF A NEW FUEL WITH HIGHER ENERGY DENSITY
P. E. DESMIER and R. R. HASTINGS *In* AGARD, Progress in Military Airlift 17 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

In order to increase the range and endurance of fighters operating in the far northern regions of Canada, and to extend maritime surveillance capability with existing aircraft assets, the Department of National Defence of Canada has pursued the development of an aviation fuel with a high energy density. The fuel selection criteria included: an energy increase of at least 10 percent by volume over current NATO F40/JP-4; acceptable performance and durability impact on aircraft systems; and large scale availability at reasonable cost. A description of the analysis is provided which was used to determine the potential benefits to be derived from the use of a high energy density fuel. Mission analyses included discussions which cover fighter (CF-18), maritime surveillance (CP-140 Aurora), and tankers (CC-137 and KC-130), aircraft. The fuel characteristics which were perceived to have a potential impact on aircraft or engine military performance are discussed. The results of engine component rig tests are then briefly discussed to demonstrate how critical fuel blend factors were evaluated to ensure that an optimal energy/performance blend was determined. Finally, a description is provided on testing objectives for the subsequent full scale engine performance and durability testing as well as an outline of the final flight certification program for the High Density Fuel (HDF). The test results to date are most encouraging. There appears to be considerable potential for the introduction of HDF to military service. Author

N92-10106# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
COMBUSTION OF SOLID PROPELLANTS
Jul. 1991 172 p In ENGLISH and FRENCH Lecture series held in Quebec City, Quebec, 4-5 Sep. 1991, in Saint-Medard-en-Jalles, France, 16-17 Sep. 1991, and in Ankara, Turkey, 19-20 Sep. 1991 Original contains color illustrations
(AGARD-LS-180; ISBN-92-835-0630-8; AD-A244246) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The theoretical and experimental analysis of the complex combustion phenomena is presented. The following subject areas are covered: overview on solid propellant combustion within a rocket motor; solid propellant steady combustion; erosive burning; special effects in solid propellant combustion; combustion instabilities; ignition and unsteady combustion; and combustion and safety of solid propellant rocket motors. For individual titles, see N92-10107 through N92-10110.

N92-10107# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Energetics Dept.
SOLID PROPELLANT STEADY COMBUSTION: PHYSICAL ASPECTS
GUY LENGELLE, JEAN-ROBERT DUTERQUE, JEAN-CLAUDE GODON, and JEAN-FRANCOIS TRUBERT *In* AGARD, Combustion of Solid Propellants 25 p (SEE N92-10106 01-28) Jul. 1991 Sponsored in part by Societe Nationale des Poudres et Explosifs and Ecole Nationale Superieure des Techniques Avancees
(AGARD-LS-180) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A review of the understanding of the combustion mechanisms of solid propellants is presented. Such an understanding is an important part of the process carried out to master the behavior of solid propellants and to obtain desired characteristics (with respect to energetic level, burning rate level, sensitivity to pressure and initial temperature, nature of emitted combustion products, vulnerability to various aggressions, etc.). Author

N92-10108# National Science Foundation, Washington, DC. Chemical and Thermal Systems Div.
EROSIVE BURNING OF SOLID PROPELLANTS
MERRILL K. KING *In* AGARD, Combustion of Solid Propellants 26 p (SEE N92-10106 01-28) Jul. 1991
(AGARD-LS-180) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Presented here is a review of the experimental and modeling work concerning erosive burning of solid propellants (augmentation of burning rate by flow of product gases across a burning surface). A brief introduction describes the motor design problems caused by this phenomenon, particularly for low port/throat area ratio motors and nozzleless motors. Various experimental techniques for measuring crossflow sensitivity of solid propellant burning rates are described, with the conclusion that accurate simulation of the flow, including upstream flow development, in actual motors is

important since the degree of erosive burning depends not only on local mean crossflow velocity and propellant nature, but also upon this upstream development. In the modeling area, a brief review of simplified models and correlating equations is presented, followed by a description of more complex numerical analysis models. Both composite and double-base propellant models are reviewed. A second generation composite model is shown to give good agreement with data obtained in a series of tests in which composite propellant composition and heterogeneity (particle size distribution) were systematically varied. Finally, the use of numerical models for the development of erosive burning correlations is described, and a brief discussion of scaling is presented.   Author

N92-10109#   National Science Foundation, Washington, DC. Chemical and Thermal Systems Div.
EFFECTS OF WIRES ON SOLID PROPELLANT BALLISTICS
MERRILL K. KING   In AGARD, Combustion of Solid Propellants 13 p (SEE N92-10106 01-28)   Jul. 1991
(AGARD-LS-180) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Metallic wires have been employed in numerous end-burning solid propellant rocket motors over the last thirty years to provide desired burning rate amplifications needed for certain applications. These wires provide such amplification by serving as a thermal short-circuit between the hot final products of the propellant combustion and the unburned solid material, with resultant development of cones penetrating into the propellant adjacent to the wires (creating an increase in burning surface area) which lead the propellant regression. A brief review of models developed by others and of a systematic data base with regard to burning of wired strands is presented. The major emphasis is on modeling. A model of the processes by which wires amplify the burning of strands (at fixed pressure) was developed and applied to analysis of the systematic data base referred to above. This model is capable of treating unsteady-state phenomena and the effects of local (sporadic) gaps between wire and propellant. Accordingly, the strand model was subsequently coupled with a chamber ballistic analysis and a geometrical analysis of cone shaped evolution to permit prediction of pressure-time histories along the wired motors with various distributions along the wire of gaps between the wire and the propellant.   Author

N92-10110#   Naval Weapons Center, China Lake, CA. Research Dept.
COMBUSTION AND SAFETY OF SOLID PROPELLANT ROCKET MOTORS
T. L. BOGGS   In AGARD, Combustion of Solid Propellants 14 p (SEE N92-10106 01-28)   Jul. 1991
(AGARD-LS-180) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The subject of munition safety is one of continuing importance, with recent emphasis in various insensitive munition requirements, because of the potential damage that can be caused by any device highly loaded with energetic materials. It is a difficult task to prevent inadvertent initiation and to mitigate the effects of reactions once initiation has occurred. This difficulty is compounded by several considerations such as: (1) the initiation can occur via many mechanisms; and (2) solid propellants have evolved to meet increased performance requirements. The need for high burn rates have led to some propellants that are extremely easy to ignite, especially as they age. Similarly, the need for increased range and decreased signature has led to propellants having high specific impulse with little or no metal ingredients. Herein, the ignition and combustion aspects are presented of solid propellant rocket motors. An overview is presented of the subject. The reader is referred to AGARDograph no. 316 for more detailed data.   Author

Includes vacuum technology; control engineering; display engineering; cryogenics; and fire prevention.

N90-15912#   Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
SPRAY SEALING: A BREAKTHROUGH IN INTEGRAL FUEL TANK SEALING TECHNOLOGY
MARTIN D. RICHARDSON and J. H. ZADARNOWSKI (McDonnell Aircraft Co., Saint Louis, MO.)   In AGARD, Fuel Tank Technology 12 p (SEE N90-15904 08-05)   Nov. 1989
(AGARD-R-771) Copyright Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
In a continuing effort to increase readiness, a new approach to sealing integral fuel tanks is being developed. The technique seals potential leak sources by spraying elastomeric materials inside the tank cavity. Laboratory evaluations project an increase in aircraft supportability and reliability, an improved maintainability, decreasing acquisition and life cycle costs. Increased usable fuel volume and lower weight than conventional bladders improve performance. Concept feasibility was demonstrated on sub-scale aircraft fuel tanks. Materials were selected by testing sprayable elastomers in a fuel tank environment. Chemical stability, mechanical properties, and dynamic durability of the elastomer are being evaluated at the laboratory level and in sub-scale and full scale aircraft component fatigue tests. The self sealing capability of sprayable materials is also under development. Ballistic tests show an improved aircraft survivability, due in part to the elastomer's mechanical properties and its ability to damp vibrations. New application equipment, system removal, and repair methods are being investigated.   Author

N91-14035#   Rutherford Appleton Lab., Chilton (England).
MINIATURE CLOSED CYCLE REFRIGERATORS
T. W. BRADSHAW and A. H. ORLOWSKA   In AGARD, Applications of Superconductivity to Avionics 7 p (SEE N91-14030 05-76)   Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A closed cycle cooler suitable for long-life space applications is described. The development heritage and the mechanical design are described and the inherently long life-time characteristics of the cooler are explained. Many types of cooler were developed from the original concept; those developed at the Rutherford Appleton Laboratory (RAL) are the main focus.   Author

N91-25302#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AGARD HANDBOOK ON ADVANCED CASTING
DIETMAR MIETRACH, ed. (Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen, Germany, F.R.)   Mar. 1991   192 p
(AGARD-AG-299; ISBN-92-835-0455-0; AD-A235914) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The need to improve aircraft performance and, simultaneously, to reduce costs has led to a re-examination of the use of casting processes in aircraft manufacture. The Structures and Materials Panel of AGARD has provided practical information about design, mechanical values, applications, quality assurance and damage tolerance. By providing the data in this form it is hoped that the designer will be encouraged to exploit the many recent advances in casting to optimum effect.   Author

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COMMUNICATIONS AND RADAR

Includes radar; land and global communications; communications theory; and optical communications.

N90-10881# Identification Friend, Foe, or Neutral Joint Test Force, Kirtland AFB, NM.
IDENTIFICATION FRIEND, FOE OR NEUTRAL JOINT TEST
JAMES E. HAILE *In* AGARD, Flight Test Techniques 12 p (SEE N90-10860 02-05) Jul. 1989
(AGARD-CP-452) Copyright Avail: NTIS HC A18/MF A03
The Identification Friend, Foe, or Neutral (IFFN) Joint Test Force (JTF) located at Kirtland AFB, NM, has developed a testbed that is composed of high fidelity, real time man-in-the-loop simulators designed to replicate the NATO Central Region Integrated Air Defense System. The purpose of the test is to assess the ability of this air defense system to correctly identify and engage enemy aircraft. The testbed represents the largest real time command and control (C2) simulation which consists of 57 medium and high fidelity tactical consoles and over a million lines of code. The OSD-sponsored testbed development and test is scheduled to run through July 1989. After this the testbed will beome the Theater Air Command and Control Simulation Facility (TACCSF) operated by the USAF Tactical Air Warfare Center (TAWC). The facility will be used by both Army and Air Force commands to resolve joint operational issues and support test and evaluation of the NATO Air Command and Control System (ACCS). Author

N90-11400# Centre National d'Etudes des Telecommunications, Lannion (France).
RADIO PROPAGATION CONDITIONS FORECAST ABOVE A LOW LATITUDE REGION
H. SIZUN and M. LISSILLOUR *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 17 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
The purpose is to present for the Tahiti region, a low latitude station, a method for determining monthly, weekly and daily forecasts of radio propagation conditions. The monthly forecasts are necessary to establish radio links in good conditions (antennas, frequencies, power and working hours determination) and are based on the forecast of the solar activity. The weekly and daily forecasts take into account the fine evolution of both solar and magnetic activities and also the influence of ionospheric storms. Author

N9C-11401# Millman (George H.), DeWitt, NY.
AN IONOSPHERIC MODEL FOR HF SKY-WAVE BACKSCATTER RADAR
GEORGE H. MILLMAN, CARL A. BOWSER, and ROGER W. SWANSON (General Electric Co., Syracuse, NY.) *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 16 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
The determination of target location by an HF over-the-horizon backscatter radar is accomplished by the use of an ionospheric model in conjunction with ionogram transmission curves. An ionospheric model is described in terms of the temporal and spatial characteristics of the various ionospheric layers. The model includes the high-latitude region and is used with the transmission curve overlay process for HF backscatter radar-target coordinate registration. Author

N90-11403# Andrews Antennas, Adelaide (Australia).
IONOSPHERIC LIMITATIONS TO THE ACCURACY OF SSL ESTIMATES OF HF TRANSMITTER LOCATIONS
L. F. MCNAMARA *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 15 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
Procedures for determining the location of an HF transmitter using observations from a single DF site have improved greatly in recent years. The ability to measure angles of arrival of the incoming skywave has now progressed to the point where the accuracy of the postion estimation is set by the ionosphere and its variability, and by imperfect knowledge of these variations, rather than by errors in the measured angles of arrival. After discussing the levels of accuracy currently obtainable, some of the limits set by the inability to specify the ionosphere accurately enough are discussed and methods suggested by which some of these limitations can be overcome. Author

N90-14405# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
OPERATIONAL DECISION AIDS FOR EXPLOITING OR MITIGATING ELECTROMAGNETIC PROPAGATION EFFECTS
Sep. 1989 475 p In ENGLISH and FRENCH Symposium held in San Diego, CA, 15-19 May 1989
(AGARD-CP-453; ISBN-92-835-0524-7; AD-A215917) Copyright Avail: NTIS HC A20/MF A03
Exploitation of mitigation of environmental effects rank equal in importance with weapons systems. The rapidly changing propagation environment throughout NATO's area of concern requires a rapid operational assessment capability. Since operational decision aids require appropriate propagation models and accurate environmental inputs, attention must be paid to propagation modelling, direct and remote sensing techniques and environmental forecasting. To this end, the following topics were covered: General aspects; propagation modeling and validation; decision aids for tropospheric radio progation; decision aids for electro-optical propagation; remote and direct sensing techniques; and forecasting of environmental parameters and operational systems impact. For individual titles, see N90-14406 through N90-14448.

N90-14407# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
PROPAGATION ASSESSMENT AND TACTICAL DECISION AIDS
JUERGEN H. RICHTER *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 8 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
The evolution of real time electromagnetic/electro optic propagation assessment systems for the U.S. Navy is reviewed and applications of such systems to the development of Tacitcal Decision Aids (TDAs) are described. Author

N90-14410# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
PROPAGATION-BASED DECISION AIDS IN THE U.S. NAVY
RICHARD A. PAULUS *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 9 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
The U.S. Navy was using a shipboard radar propagation assessment system for the past decade. This system was conceived as the Integrated Refractive Effects Prediction System (IREPS) in 1973; tested at sea in 1976; and installed on most capital ships beginning in 1978. IREPS provided two types of products: displays of refractivity data and sensor performance displays. The workhorse display was the radar coverage diagram used by the air wing to determine penetration or jamming altitudes against hostile radars. This initial capability to exploit propagation effects was received so enthusiastically and proved so successful that the development of Tactical Decision Aids (TDAs) became part of an ongoing program to enhance this capability in the fleet. These TDAs structure the propagation information for the decision maker and perform functions that would otherwise overwhelm him. The decision maker is not directed to a specific course of action but rather is provided a framework within which tradeoff decisions can be made with respect to propagation in conjunction with ther essential factors of the mission. This approach to the development of an aircraft stationing aid is discussed along with an overview of several TDAs applicable to various warfare areas. Efforts to incorporate these tactical decisions aids into Navy sea-based command and control systems are explored. Author

N90-14411# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
ENGINEER'S REFRACTIVE EFFECTS PREDICTION SYSTEM (EREPS)
HERBERT V. HITNEY *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 10 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03

In recent years, electromagnetic tactical decision aids were developed to assess environmental effects on the performance of operational systems such as shipboard radars. In general, these systems have performed well and are now routinely used by operational forces to optimize their use of sensors and deployment of forces. In many cases, the existing tactical decision aid software was taken and used to assess the performance of proposed new sensors. Since the original software was not designed for this purpose, many deficiencies in such a use were soon identified. For example, most engineers prefer to graphically compare performance results as a single design parameter, such as radar pulse length, is varied over a range of possible values. Also, in designing a new system, one is usually more interested in the long-term statistical performance than in single-event performance that the tactical decision aids are normally designed to assess. The Engineer's Refractive Effects Prediction System (EREPS) is a recent development effort tailored to engineering uses and based on the propagation models of the Integrated Refractive Effects Prediction System (IREPS). EREPS is hosted on IBM PC computers for maximum availability to the engineering community, and was developed using interactive graphics displays for optimum comparison studies. The models are designed in such a way as to give results within a few seconds to allow multiple design trade-off studies to be easily performed. EREPS Revision 1.00 was distributed to interested users in the summer of 1988 and is currently being revised for a summer 1989 distribution. Existing and planned capabilities will be presented along with some examples of applications. Author

N90-14412# Naval Ocean Systems Center, San Diego, CA. Signals Warfare Div.
PROPHET AND FUTURE SIGNAL WARFARE DECISION AIDS
ROBERT B. ROSE *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 4 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03

Decision aids, even well designed ones, have demonstrated a wide range of utility and effectiveness when employed in the operational environment. The development and employment of the PROPHET HF propagation assessment system was observed for over a decade. Recent studies indicate that some of the early assumptions on how the module was to be employed were invalid. Although it uniquely fills a real need and its models and products were extensively tested in operational environments by its users, which include most military and civilian branches of the U.S. Department of Defense, PROPHET faces an uncertain future as a stand-alone system. Its main strength is to provide mission oriented and scenario products to perform HF signal coverage, signal vulnerability and radio circuit connectivity in near real time. While technically sound in meeting these objectives, PROPHET's effectiveness is limited by variations in user training, experience, motivation and the lack of operationally convenient access. These problems appear to apply in some degree to the employment of most decision aids. Based on the PROPHET experience, the fallacies that are common in decision aid development and employment, how they affect the decision aid effectiveness, a recommendation for the next generation propagation assessment decision aid results from an initial demonstration prototyping effort to check out some of the new concepts are described. Author

N90-14413# Naval Research Lab., Washington, DC.
DECISION-AID DESIGN FACTORS IN CONNECTION WITH HF COMMUNICATION AND EMITTER LOCATION DISCIPLINES
JOHN M. GOODMAN *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 9 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03

The advance of microcomputer technology, the growing sophistication of specified propagation models, and the expanding ability to sense the medium and apply that knowledge in real time is leading to an improvement in the prediction of system performance for tactical users. The maturation of artificial intelligence disciplines should provide the user of advanced C3I decision aids an ability to manage the plethora of information more effectively. Critical aspects of the process of developing useful and cost-effective decision aids are identified with emphasis upon the HF medium which is strongly propagation-limited and controlled by variable and often unpredictable phenomena. A major factor in this field of activity is the evolution of self-adaptive system architecture incorporating imbedded Real Time Channel Evaluation (RTCE). In this context, the decision aid is a process which is operationally transparent to the the user but could be user-defined. A key to the development of an adaptive resource management capability is the integration of a set of tools or decision aids which direct the system to compensate for pathological effects by adjustment of system parameters. The approach is ultimately limited by the accuracy with which the ionosphere or the HF channel may be specified. The accepted specification accuracy will determine the design approaches to be followed. Author

N90-14414# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
LONG WAVE PROPAGATION ASSESSMENT
JERRY A. FERGUSON and F. PERRY SNYDER *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 8 p (SEE N90-14405 06-32) Sep. 1989
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The long wavelength propagation capability of the Naval Ocean Systems Center is described. This capability applies the concept of the earth-ionosphere waveguide to very low frequency (vlf: 10 kHz to 30 kHz) and low frequency (lf: 30 kHz to 100 kHz) radio propagation. It is used to perform assessment of communications coverage at long wavelengths via graphical displays of signal strength and signal to noise over individual propagation paths and over large geographical areas. The propagation assessment capability is a collection of computer programs which are exercised separately or in sequence depending on the application. The execution of these individual programs for purposes of obtaining coverage maps can be set up by a driver program which automates the process. At the present time, this driver program implements the sequencing of the programs via Digital Equipment's VAX VMS control language. The automation of the calculations depends on accurate specification of the parameters of the earth-ionosphere waveguide. The driver program contains models for these parameters which were developed over a number of years. The model of the ionsphere is an approximate one which characterizes the conductivity as an exponentially increasing function of height. Some allowance for the nighttime differences between temperate and polar latitudes is made. The lower boundary of the waveguide is defined by a detailed ground conductivity map based on geological formations. Author

N90-14415# Hull Univ. (England). Dept. of Electronic Engineering.
A COMMUNICATIONS SYSTEM WITH AN ADAPTIVE MULTI-FUNCTIONAL ARCHITECTURE
A. H. KEMP *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 10 p (SEE N90-14405 06-32) Sep. 1989 Sponsored by British Science and Engineering Research Council
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Within NATO's area of operations, high frequency (HF) channels exhibit an inherently variable capacity. Furthermore there is also a wide geographical variety of noise sources; in North America atmospheric noise is significant while, in Western Europe, a dominant noise source is co-channel interference. A communications system which can operate across this whole region needs to be both highly adaptive and have a real-time channel evaluation (RTCE) capability. To allow a system to manage multiple adaptive components in an optimum manner while the system configuration and RTCE data vary, a multi-functional regime is proposed. The design and implementation of such an adaptive, multi-functional communications system are described. Author

N90-14418# Johns Hopkins Univ., Laurel, MD. Applied Physics Lab.

THE PARABOLIC EQUATION APPROACH TO PREDICTING TROPOSPHERIC PROPAGATION EFFECTS IN OPERATIONAL ENVIRONMENTS

G. DANIEL DOCKERY and ERIC R. THEWS   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 9 p (SEE N90-14405 06-32) Sep. 1989   Sponsored by Naval Sea Systems Command
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The Electromagnetic Parabolic Equation (EMPE) propagation program was demonstrated to predict accurately the propagation of electromagnetic energy in environments with complicated refractivity characteristics. The validation and application of EMPE have also necessitated the development of new atmospheric measurement techniques as well as methods for representing realistically the range variations of refractivity structures. A brief description of the parabolic equation approach and solution technique is first presented; comparisons with other propagation models are included. The measurement techniques that were used to obtain accurate, high-resolution refractivity data are then discussed. Examples of how such refractivity data, in conjunction with a refractivity range-interpolation algorithm, were used in EMPE to obtain good agreement with measured signal levels are also presented. The problem of developing a useful decision aid for operational systems based on the EMPE program is then addressed. The issues that are discussed include vertical and horizontal resolution of atmospheric data, timeliness of measurements, speed of propagation calculations, use of refractivity models, and automation of the environmental assessment process. An approach that is being pursued at APL for AEGIS shipboard applications, involving the use of expendable rocketborne radiosondes, is described.   Author

N90-14419# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.

RPE: A PARABOLIC EQUATION RADIO ASSESSMENT MODEL

F. J RYAN   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 10 p (SEE N90-14405 06-32)   Sep. 1989   Sponsored in part by Office of Naval Technology
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The use of parabolic wave equation codes to model tropospheric radio propagation is rapidly gaining popularity. To properly implement these powerful techniques into radar performance assessment models, requires a detailed understanding of the inherent errors in the parabolic approximation. Three major sources of errors in split-step parabolic equation solvers are examined: approximation of the elliptic wave operator by a parabolic operator, truncation error in the formal parabolic solution and truncation error in the split-step operator. These errors are discussed in the context of operational codes.   Author

N90-14420# Science Research Council, Chilton (England). Radio Communications Research Unit.

A FORECASTING SYSTEM USING THE PARABOLIC EQUATION: APPLICATION TO SURFACE-TO-AIR PROPAGATION IN THE PRESENCE OF ELEVATED LAYERS

K. H. CRAIG and M. F. LEVY   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 13 p (SEE N90-14405 06-32)   Sep. 1989   Sponsored in part by Procurement Executive, Ministry of Defence
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The parabolic equation approach to clear-air propagation modeling overcomes many of the difficulties associated with ray and mode theory methods. A parabolic equation model was implemented on a PC based system using a transputer to carry out the computationally intensive numerical integrations. The model was used from VHF to millimetric frequencies and applied to evaporation duct and elevated duct problems. The latter are important for surface-to-air propagation and were difficult to solve because of the complicated structure of the layers. A case study of an elevated duct caused by anticyclonic subsidence shows the importance of up-to-date meteorological data from a wide geographical area. A full-wave calculation of the wideband properties of the propagation channel illustrates the possibilities opened up by the new model. The frequency selective effects

can be large, and are sensitive to the small-scale structure of the ducting layers.   Author

N90-14421# Thomson-CSF, Velizy (France). Centre d'Applications Radars.

ANALYSIS OF PROPAGATION IN AN INHOMOGENEOUS ATMOSPHERE IN THE HORIZONTAL AND VERTICAL DIRECTION USING THE PARABOLIC EQUATION METHOD

MICHEL FOURNIER   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 13 p (SEE N90-14405 06-32)   Sep. 1989   In FRENCH; ENGLISH summary
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Operational programs calculating radar coverage are now available on ships having a meteorological capability. A fundamental assumption of these programs is that only vertical variations of refraction index are known and consequently that the atmosphere is homogeneous along the propagation path in the horizontal direction. Measurements made by the French Meteorological Office and by other countries established that this hypothesis may be inconsistent during significal laps of time. Consequently it seems necessary to develop a tool to compare of existing operational programs and those given by more sophisticated programs which are able to take into account variations of refractive index in vertical and horizontal directions. A resolution method of this problem, using the parabolic equation is described. This tool was used for exploitation of index of refraction map from in situ measurements obtained during tests made over the Atlantic Ocean and the Mediterranean Sea. Exploitation of these data allows a study of the effect of horizontal index inhomogeneities of the atmosphere in horizontal direction.   Author

N90-14422# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.

PROPAGATION MODELING FOR SOME HORIZONTALLY VARYING TROPOSPHERIC DUCTS

RICHARD A. PAPPERT   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 15 p (SEE N90-14405 06-32)   Sep 1989
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For propagation assessment in a maritime environment, the assumption of horizontal homogeneity (i.e., invariance of the refractivity structure along the path of propagation) is generally adequate (Hitney et al., 1985). Nevertheless, theoretical methods are available to handle special cases when the assumption fails. For example, horizontal inhomogeneity can in principle be treated by mode conversion methods or by parabolic equation solvers. The theory for a slab mode conversion model is discussed within the context of modified refractive index formalism and applied to several hypothetical laterally inhomogeneous problems including elevated layers as well as shallow evaporative layers. Results of the mode conversion calculations are compared with parabolic equation results generated concurrently by Ko and Burkom (1987). Most of the comparisons, along with the ease of implementation and speed of the parabolic equation calculations relative to the mode conversion analysis, strongly supports the superiority of the parabolic equation method for systems studies involving laterally inhomogeneous tropospheric layering.   Author

N90-14423# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.). Management Consulting.

PROPAGATION PREDICTION FOR THE NORTH SEA ENVIRONMENT

R. VIETH   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 7 p (SEE N90-14405 06-32)   Sep. 1989
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Evaporation ducting can have an important influence on the propagation of electromagnetic waves. The dependence of those ducting conditions on geographic location requires an estimate of occurrence and effects of ducting in various areas. Duct height statistics using long term statistical meteorological data in combination with propagation models are used for this purpose. Jeske's propagation measurements during 1961 at the German coast of the North Sea were taken and compared with the calculated results from the combination of the statistical weather data base and the propagation models, as well as another measurement program performed in Greece. A brief description

of the models is followed by an example of the results of the Greek measurements. The German experimental data and duct height distributions for that region are described. Finally the results of measurements and calculations are discussed. A good agreement was found between measured propagation data and predictions based on climatological averages. Author

N90-14424# Science Research Council, Chilton (England). Radio Communications Research Unit.
ASSESSMENT OF ANOMALOUS PROPAGATION PREDICTIONS USING MINISONDE REFRACTIVITY DATA AND THE PARABOLIC EQUATION METHOD
M. F. LEVY and K. H. CRAIG *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 12 p (SEE N90-14405 06-32) Sep. 1989 Sponsored in part by Procurement Executive, Ministry of Defence
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Accurate and easy-to-use systems are now available to measure the refractive index structure in the troposphere. Combined with an efficient package for solving Maxwell's equations for radiowave propagation based on the Parabolic Equation Method, they provide a powerful tool for real time forecasts of anomalous propagation. Quantitative field-strength predictions can be obtained in a few minutes from measured meteorological profiles, on a desk-top computer. However, measurement errors inevitably lead to variability in the predictions, which should be seen in a stochastic light. Some examples based on experimental data are presented, at X-band and in the millimetre wave part of the spectrum, as well as a sensitivity analysis using statistical simulations. The Parabolic Equation Method copes well with noisy refractivity data, and the predictions are fairly insensitive to radiosonde errors.
Author

N90-14425# Mitre Corp., Eatontown, NJ.
FORWARD SCATTER PROPAGATION PATH LOSS TESTING USING SURROGATE TERRAIN IN THE 100 TO 1500 MHZ REGION
LOUIS L. TAYLOR *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 12 p (SEE N90-14405 06-32) Sep. 1989
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Numerous path loss calculation models were developed for links employing forward scatter propagation. Variances in propagation loss prediction between these models and the loss experienced when a link is actually established arise because of the manner in which the models represent the large variety of absorbers and reflectors present in the actual terrain. A method to enrich a model with actual measurements that produce a more accurate method of predicting propagation loss is described. The method is based upon selecting a surrogate section of terrain for the actual terrain over which a propagation loss determination is desired, then measuring the forward scatter loss variation through this surrogate terrain. The loss value is then used as a factor in the simplified mathematical model used for the desired prediction. Examples are given of the use of this technique to assist in the design and implementation of a wide area VHF/UHF radio network serving a large fleet of mobile units. Through use of this method, one learns to judge when existing models may be used and when measurements are indicated, how to estimate the effects of different types of terrain and foliage upon propagation, and how these effects change in different seasons of the year. Author

N90-14426# Institut National des Sciences Appliquees, Rennes (France). Laboratoire Composants et Systemes pour Telecommunications.
IMPROVING THE QUALITY OF A SPREAD-SPECTRUM RADIOMOBILE LINK
A. DANIEL, G. ELZEIN, M. SALEHUDIN, and J. CITERNE *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 9 p (SEE N90-14405 06-32) Sep. 1989 In FRENCH
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A means for improving the quality of a digital spread-spectrum mobile radio link with the aid of a multipath diversity system is described. The novelty of the system lies in the use of a transverse filter designed using a surface acoustic wave (SAW) multiconnector delay line and adapted to the pulse response of the channel (obtained through a convoluter). The adaptation of the receiver to

the channel transmission parameters is accomplished with an instantaneous coefficient of balance. The multipaths are then combined in order to eliminate, as well as possible, the selective fading occurring with a mobile radio link. Transl. by M.G.

N90-14427# Centre National d'Etudes des Telecommunications, Lannion (France).
NEW PERSPECTIVES FOR THE INVERSION OF BACKSCATTER IONOGRAMS
N. RUELLE, J. Y. LESAOUT, and L. BERTEL (Rennes Univ., France) *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 9 p (SEE N90-14405 06-32) Sep. 1989
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High frequency (HF) backscatter sounders offer the perspective of real-time sensing of ionospheric radio propagation conditions in an extended area. However, to this date, difficulties are experienced with the interpretation of sounding data, which places a severe limit on the operational use of these sounders. The French National Telecommunications Research Centre is constructing a sounder of original design. The new possibilities for data interpretation offered by this system are evaluated and possible operational implications discussed. Author

N90-14428# Illinois Univ., Urbana-Champaign.
DESIGN OF A COMPENSATION FILTER FOR A QUADRATIC PHASE COMMUNICATION CHANNEL
K. C. YEH and R. L. MICKELSON *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 14 p (SEE N90-14405 06-32) Sep. 1989
(Contract DAAB07-87-K-A0006)
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There was always great interest in understanding and describing the dispersive effects that occur in many types of communication channels. An analysis of a general dispersive channel is performed by a set of weighted delay lines. This model clearly illustrates that mitigation of dispersive effects can be achieved via an inverse filtering procedure. Specifically, a compensation filter is designed using a conjugate delay line. Ideally, complete compensation can be achieved and a replica of the transmitted signal can be restored. In practical implementation and application, these idealized conditions can never be met. Nevertheless, this channel simulator and compensation filter are implemented for a quadratic phase transfer function. The system is tested for three basic signals: Gaussian pulse, rectangular pulse, and sudden phase-switched signal. In addition, the case of transmitting multiple pulses is considered. The simulation yields good results for moderate dispersion. As dispersiveness increases, the number of taps in the compensation filter must be increased in order to restore the received signal to a reasonable approximation of its original shape. Author

N90-14429# Signatron, Inc., Lexington, MA.
IMPROVED RELIABILITY PREDICTION FOR HF DIGITAL VOICE TRANSMISSION
ALFONSO MALAGA *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 10 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
A method for predicting the performance of High Frequency (HF) digital voice transmission is described. The method takes into account the effects of multipath propagation and signal processing techniques which exploit the multipath to achieve improved performance. A propagation prediction model which provides the necessary multipath and signal-to-noise ratio statistics is also described. Author

N90-14430# Air Force Systems Command, Hanscom AFB, MA. Ionospheric Physics Lab.
A MODERN TRANS-IONOSPHERIC PROPAGATION SENSING SYSTEM
G. J. BISHOP, J. A. KLOBUCHAR, A. E. RONN, and M. G. BEDARD (Air Weather Service, Scott AFB, IL.) *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 11 p (SEE N90-14405 06-32) Sep. 1989
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One of the most important potential problems with modern military systems which utilize spacecraft is the effect of the

ionosphere on the radio signals which pass to and from the spacecraft. Such systems include active communications and navigation satellites as well as both ground-based and potential space-based ranging systems. The major effects the ionosphere can have on such systems are the additional time delay the electrons in the earth's ionosphere add to the free space path delay, the short term rate of change of this additional delay, amplitude scintillation or fading effects the signal encounters due to irregularities in the ionosphere, and Faraday rotation of linearly polarized radio waves transmitted through the ionosphere. While some of these effects were studied adequate models of these effects on military systems still do not exist. A modern trans-ionospheric sensing system, called TISS, is being procured which will consist of a number of stations located throughout the world, making real time measurements of the time delay of the ionosphere, and its rate of change, as well as amplitude scintillation, along several different viewing directions from each station. These trans-ionospheric measurements will be used to allow models, which currently provide only monthly propagation parameters. The real-time specifications of these parameters can then be used as decision aids in both the tactical and the strategic military environments. The TISS will include first order artificial intelligence design to aid in gathering the most appropriate sets of available real-time trans-ionospheric propagation data, and will communicate these data sets to the Air Weather Service Forecasting Center where they will be tailored to specific military customers.　　Author

N90-14431#　　Lowell Univ., MA.　Center for Atmospheric Research.
A PORTABLE IONOSONDE IN SUPPORT OF RELIABLE COMMUNICATIONS
D. MARK HAINES, D. F. KITROSSER, B. W. REINISCH, and F. J. GORMAN (Army Communications-Electronics Command, Fort Monmouth, NJ.)　In AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 8 p (SEE N90-14405 06-32)　Sep. 1989
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The temporal and spatial variations in ionospheric structure have frustrated the efforts of communications and radar system operators who base their frequency management decisions on monthly mean predictions or computer based models. A low power miniature version of the Digisonde sounders capable of making real-time on-site measurements to support communications or surveillance operations was produced. The system compensates for a low power transmitter by employing intrapulse phase coding, digital pulse compression and Doppler integration. The data acquisition, control, signal processing, display, storage and automatic data analysis functions were all condensed into a single multi-tasking, multiple processor computer system while the analog circuitry was condensed and simplified by use of reduced transmitter power, wide bandwidth devices, and commercially available PC expansion boards. Noteworthy new technology involved in this system includes: an electronically switched active crossed dipole receiving antenna; a TMS 320C25 digital signal processor; compact DC-DC converters allowing full operation on a single 24 VDC battery; a high speed data acquisition board interfaced via an IBM-AT expansion bus; a proprietary multi-tasking operating system; reprogrammable PROM based coherent oscillators; use of complementary codes which virtually eliminate the time domain pulse compression sidelobes typical of pulse compression systems; and automatic mode identification and parameter scaling by an embedded expert system.　　Author

N90-14433#　　Hull Univ. (England). Communications Research Group.
THE USE OF BROADCAST SIGNALS FOR PASSIVE SENSING IN AUTOMATED HF COMMUNICATION SYSTEMS
N. G. RILEY　In AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 8 p (SEE N90-14405 06-32)　Sep. 1989
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The use of passive sensing for derivation of HF system control data has advantages over active techniques from both tactical and spectrum conservation points of view. Methods are described by which ionospheric data may be derived from passive sensing of the HF spectrum. Data derived using these techniques may be used in the operational decision process to control automated HF communication systems. The techniques described are facilitated

by the availability of powerful, low-cost signal processors and fast tuning receivers allowing a high level of signal processing to be performed in real time.　　Author

N90-14434#　　Paris-Sud Univ., Cachan (France).
THE USE OF BACKSCATTER FOR MODELLING IONOSPHERE AND JAMMING IN VERY SHORT TERM FORECASTS
J. CARATORI and C. GOUTELARD　In AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 16 p (SEE N90-14405 06-32)　Sep. 1989
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High frequency (HF) radio links involving reflection from the ionosphere are mainly long-range communications. The setting up of an optimum link, requires the knowledge of the real propagation and interference data. Several types of ionospheric predictions, based on different ionospheric soundings, are necessary in order to take account of the medium variability. A centralized backscatter sounding station is well adapted to provide short-term predictions. However, the interpretation of the data, and the inversion of the icnogram are difficult. A method of inversion, taking account of horizontal gradients is proposed. Experiments carried out at the station studio of the Letti showed its validity. Interferences are very important in the HF band, and represent the second factor to deal with. The spatial decorrelation of interferences is highlighted, and the derivation of predictions for the Western Europe zone is discussed. These predictions are then used to compute the signal to noise ratio of a link.　　Author

N90-14435#　　Massachusetts Technological Lab., Inc., Bethesda, MD.
COMMUNICATION OVERVIEW PROGRAM (COP)
D. J. FANG, I. BENOLIEL, and H. SOICHER (Army Communications-Electronics Command, Fort Monmouth, NJ.)　In AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 8 p (SEE N90-14405 06-32)　Sep. 1989
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In establishing a communications system for fulfilling a given mission requirement, multiple levels of decision-making processes are encountered. The decision making process at the lowest level, such as subsystem design and component specification can be accomplished by known routines and procedures, or even by computer packages known as CAD. The middle level of decision-making involves professional articulation as the processes generally involve trade-off's and optimization. As such, engineering prejudice, preference and experience play a significant role. The highest level of decision making, because of its nature, generally is more policy oriented rather than technically oriented. In this level, a broad view including the background, the finance, priority and other administrative concerns are included for decision. The unfortunate part of this is that the decision makers often do not have the necessary insight in making a proper technical decision which has a profound and unequivocal impact on the implementation at lower levels. The Communication Overview Program (COP) is being developed for applications at the highest level of decision-making. The program is not a design tool but is intended to provide the necessary scenarios and technical insights to assure a correct decision can be made for the establishment of a communications system to carry out a given mission.

Author

N90-14436#　　Naval Postgraduate School, Monterey, CA. Dept. of Meteorology.
PHYSICAL MODELS FOR AEROSOL IN THE MARINE MIXED-LAYER
GERRIT DELEEUW, KENNETH L. DAVIDSON, STUART G. GATHMAN, and R. V. NOONKESTER (Naval Ocean Systems Center, San Diego, CA.)　In AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 8 p (SEE N90-14405 06-32)　Sep. 1989
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A model is presented to calculate the vertical variation of aerosol extinction coefficients throughout the marine atmospheric boundary layer. It is referred to as the Naval Oceanic Vertical Aerosol Model (NOVAM). NOVAM is a combination of empirical and physical models, formulated to describe the often observed non-uniform, but also non-logarithmic, profiles. The physical model is based on

the dynamical processes affecting the production, mixing, deposition and size of the aerosol within the marine atmosphere. A status report is presented including a critical evaluation.

Author

N90-14439# Forschungsinstitut fuer Hochfrequenzphysik, Werthhoven (Germany, F.R.).
LOW LEVEL RANGE COVERAGE PERFORMANCE PREDICTION FOR VHF RADAR
H. KUSCHEL *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 13 p (SEE N90-14405 06-32) Sep. 1989
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A VHF radar frequencies the range coverage is not strictly limited by the quasi-optical horizon like at microwave radar frequencies but is extended due to diffraction propagation. This effect, here called beyond-the-horizon (BTH) detection capability is strongly dependent on the propagation path and thus on the terrain structure. The availability of digital terrain maps gives way to the use of computerized methods for the prediction of radar range coverage in real environment. In combination with wave propagation models suitable for diffraction at terrain structures, digital terrain data can even be used for the prediction of BTH target detectability at VHF radar. Here the digital landmass system (DLSS) terrain database was used in combination with a multiple-knife-edge diffraction model to predict the diffraction attenuation between the radar and the potential target positions, especially beyond the optical horizon. The propagation paths extracted from the database are modeled as a sequence of diffraction screens suited for the application of a Fresnel-Kirchhoff algorithm yielding the knife-edge-diffraction attenuation. This terrain related propagation model was verified by a large number of measurements at different frequencies. Implemented in a fast computer system, this prediction model can be used for mission planning of air operations. Considering hostile VHF radar coverage and terrain condition for flight path optimization or, on the other hand it can assist in siting mobile radars for gap filling according to the actual threat situation. Calculations of the diffraction propagation using the prediction model, yield range coverage patterns in real terrain situations, allowing to quantify the BTH detection advantage of VHF radar compared to microwave radar. An experimental large wavelength radar LARA (VHF) built flying targets beyond the close horizon. Here, especially the detection of hiding helicopters by exploiting diffractive wave propagation was examined. Measurements at different VHF frequencies were carried out, to validate the results obtained by simulation. Author

N90-14440# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, The Hague (Netherlands). Physics and Electronics Lab.
THE EFFECT OF OBLATE SPHEROIDAL DROPS ON RAIN ATTENUATION AT 94 GHZ: COMPARISON BETWEEN THEORY AND EXPERIMENT
W. P. M. N. KEIZER *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 10 p (SEE N90-14405 06-32) Sep. 1989
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Rain induced attenuations for horizontally and vertically polarized waves at 94 GHz were measured on a 935 m link and compared with theoretical predictions. During the experiment which covered a period of two years the raindrop size distribution along the propagation was also recorded. The theoretical predictions were based on the actually measured raindrop size distributions and assumed both spherical and spheroidal shapes for the raindrops. The calculations for oblate spheroidal raindrops showed that horizontally polarized waves are more attenuated by rain than vertically polarized waves. It was also found that the Mie scattering theory for spherical raindrops underestimates the rain attenuation for both polarizations. The comparison of the measured rain attenuation results with the predictions confirmed completely the outcome of the theoretical calculations. A remarkable improvement in the accuracy of rain attenuation modeling for horizontal and vertical polarization was noted when a spheroidal drop shape was taken into account instead of the spherical shape. Author

N90-14441# Hava Ikmal Bakim Merkezi Komutanligi, Ankara (Turkey).
MITIGATING DOPPLER SHIFT EFFECT IN HF MULTITONE DATA MODEM
YASAR SONLU *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 8 p (SEE N90-14405 06-32) Sep. 1989
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Digital communications over High Frequency (HF) radio channels are getting important in recent years. Current HF requirements are for data transmission at rates 2.4 kbps or more to accommodate computer data links and digital secure voice. HF modems which were produced to meet these speeds are, serial modems and parallel modems. On the other hand, the HF sky-wave communication medium, the ionosphere, has some propagation problems such as multipath and Doppler shift. The effect of Doppler shift in a parallel modem which employs Differential Quadrature Phase Shift Keying (DQPSK) modulation is considered and a correction method to mitigate the Doppler Shift effect is introduced. Author

N90-14442# Naval Environmental Prediction Research Facility, Monterey, CA.
A ONE-DIMENSIONAL SHIPBOARD MODEL FOR FORECASTING REFRACTIVE EFFECTS IN THE PLANETARY BOUNDARY LAYER
PAUL M. TAG *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 4 p (SEE N90-14405 06-32) Sep. 1989
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In order to forecast the refractivity structure in the atmosphere, the accompanying temperature and moisture structures must be forecast. As a means of providing shipboard-generated forecasts of low-level temperature and moisture structures in the planetary boundary layer, the Navy has converted a sophisticated, turbulence model to a micro-computer. This model, called the Navy Over-Water Local Atmospheric Prediction System (NOWLAPS), is part of the Tactical Environmental Support System (TESS), a shipboard, automated, environmental diagnosis/prediction system. NOWLAPS is a one-dimensional, second order closure model that can provide forecasts over water for temperature, moisture, and winds up to heights of 2 km, and out to 24 hrs. From these temperature and moisture distributions, the refractivity profile can be generated. Author

N90-14443# Pacific Missile Test Center, Point Mugu, CA. Geophysics Div.
WEATHER SATELLITE AND COMPUTER MODELING APPROACHES TO ASSESSING PROPAGATION OVER MARINE ENVIRONMENTS
JAY S. ROSENTHAL, ROGER A. HELVEY, STEVEN W. LYONS (Texas A&M Univ., College Station.), ALAN D. FOX, RICHARD SZYMBER, and LEE EDDINGTON *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 15 p (SEE N90-14405 06-32) Sep. 1989
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Exploiting electromagnetic propagation in the Navy's marine environment requires an ability to assess and predict atmospheric refractive structure over the ocean. Efforts are underway to develop such capabilities by correlating duct existence, height and intensity to synoptic and mesoscale weather features. In addition to the latter conventional parameters, meteorological satellite data, through pattern recognition was valuable in inferring important aspects of ducting conditions. More recently, a technique was developed to derive duct height information directly from computer-processed infrared (IR) satellite data over ocean regions capped by stratified low clouds. This approach, still in development, also provides a means of measuring the horizontal variability of duct height which is crucial to determining the appropriateness and useability of various propagation models for predicting systems performance. Inferring the impact of horizontal variability over the ocean was facilitated by use of range-dependent raytrace techniques which allow inputs from such diverse sources as local radiosonde observations; predicted marine layer depth (from a mixed-layer mesoscale model); and duct heights derived from the satellite-IR duct technique. Author

N90-14444# Signatron, Inc., Lexington, MA.
TROPO: A TECHNIQUE FOR PREDICTING PROPAGATION AND MODEM PERFORMANCE OF DIGITAL TROPOSCATTER SYSTEMS
STEEN A. PARL   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 9 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
The capabilities of a PC-based decision aid for digital troposcatter link engineering are presented. The program includes propagation effects such as multipath and spatial diversity, as well as adaptive modem performance, transmitter emission control filtering. The model uses the existing NBS method for predicting long term effects and for short-term effect below 1 GHz. Above 1 GHz it uses a turbulent volume scattering model. It uses numerical integration whenever possible to avoid coarse analytical approximations. A key function is its ability to evaluate advanced diversity receiver and modem techniques. A predecessor of this program was used by the USAF to evaluate and engineer current and planned digital troposcatter links.   Author

N90-14445# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, The Hague (Netherlands). Physics and Electronics Lab.
MODELLING UHF PROPAGATION FOR FREQUENCY ASSIGNMENT IN RADIO RELAY NETWORKS
JEAN-PAUL M. G. LINNARTZ (Technische Hogeschool, Delft, Netherlands) *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 10 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP 453) Copyright Avail: NTIS HC A20/MF A03
An account is given of experiences in developing UHF-propagation models for the terrain of the North German plain which is characterized by woods and farmland. A few empirical results on the relevance of modeling the interaction between diffraction and groundwave propagation are discussed. However, the focus is mainly on (statistical) methods used to select appropriate models, rather than going into the (physical) details of propagation mechanisms. Since local variability of the field strength prohibits prediction of the feasibility of radio relay links with absolute reliability, (static) diversity tests are recommended to avoid antenna positioning in local multipath nulls. It is shown that such antenna position tests are only worthwhile if the propagation model forecasts local mean signal powers with sufficient reliability.   Author

N90-14446# National Telecommunications and Information Administration, Boulder, CO. Inst. for Telecommunications Sciences.
PATTERN RECOGNITION TECHNIQUES APPLIED TO THE NASA-ACTS ORDER-WIRE PROBLEM
KENNETH C. ALLEN   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 11 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
The National Aeronautics and Space Administration (NASA) is planning to launch an Advanced Communication Technology Satellite (ACTS). This satellite will use several methods to adaptively mitigate the effects of fading due to rain in its 20- and 30-GHz links. A decision algorithm is needed to control the implementation of these mitigating techniques. The use of a learning pattern recognition algorithm as the solution to this problem is explored. The algorithm is applied to data simulating fading on a slant path through the atmosphere at 20 and 28.8 GHz. The data were scaled from data measured on a 1-km path at 28.8 GHz in Hilo, Hawaii. The sole cause of fading in the data was attenuation due to rainfall on the path. The results indicate, at least for the test data, that the use of the most recently measured value of the received signal level (RSL) is adequate for predicting the future RSL and can be used to decide when the mitigating techniques should be used. More complicated algorithms based on linear combinations of previous RSL samples do not perform significantly better than the simple previous value approach.
Author

N90-14447# Forschungsinstitut der Deutschen Bundespost, Darmstadt (Germany, F.R.).
THE FTZ HF PROPAGATION MODEL FOR USE ON SMALL COMPUTERS AND ITS ACCURACY
TH. DAMBOLDT and P. SUESSMANN   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 10 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
A self-contained method of estimating the critical frequency and the height of the ionosphere is described. This method was implemented in the computer program FTZMUF2. The accuracy of the method tested against the CCIR-Atlas (Report 340) yielded an average difference of less than 0.1 MHz and a standard deviation of 2.3 MHz. The FTZ HF field-strength prediction method is described which is based on the systematics found in previously measured field-strength data and implemented in a field-strength formula based thereon. The accuracy of the method -when compared with about 16,000 measured monthly medians contained in CCIR data bank D- equals that of main-frame computer predictions. The average difference is about 0 dB and the standard deviation is about 11 dB.   Author

N90-14448# Allgemeine Elektrizitaets-Gesellschaft, Ulm (Germany, F.R.). Radio and Radar Systems Group.
THE CHARACTERISTICS OF THE HF RADIO CHANNEL AND ITS INFLUENCE ON MODERN HF DATA COMMUNICATION SYSTEM DESIGN
DETLEV BORGMANN and JUEGEN LINDNER   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 12 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
A basic requirement for the design and realization of modern HF data communication systems is the detailed analysis and modeling of the transmission medium. How this analysis and modeling of the HF radio channel influences the design of such data communication systems are described. The characteristics of the HF radio channel by parameters like multipath and Doppler spread and its variation with time, short and long term statistics, variation of useful frequencies with time are described and a short introduction into modeling is given. A modern system design coping with the unwanted characteristics of the transmission medium is examined. As an example a system is presented, which is realized according to the open systems interconnection architecture proposed by ISO and in which the protocols of layers 1 to 3 are adapted to the medium HF radio. Details are described of an adaptive frequency management system with its operational requirements, the basic functions and the position within the communications system. The frequency management system is implemented as a functional module or a radio link processor, which is a part of the data communication system. The frequency management system comprises the following features: long term prediction and analysis; short term analysis with link statistics; and channel monitoring with measurement of noise and interference. Some results of field test with this frequency management system are presented.   Author

N90-17932# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
MODERN ANTENNA DESIGN USING COMPUTERS AND MEASUREMENT: APPLICATION TO ANTENNA PROBLEMS OF MILITARY INTEREST
Sep. 1989 224 p Lectures held in Ankara, Turkey, 19-20 Oct. 1989, in Lisbon, Portugal, 23-24 Oct. 1989, and in London, England, 26-27 Oct. 1989
(AGARD-LS-165; ISBN-92-835-0526-3) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The working environment in which an antenna is installed may substantially modify such antenna parameters as radiation efficiency, impedance, bandwidth, power handling capacity or pattern. The need for more accurate antenna design, combined with the continuing growth of computational techniques, are complementing the more traditional approaches of measurement and analysis to vastly broaden the breadth and depth of problems that are now quantifiable. Computers are being used not only for numerical modeling/simulation, but also for measurement, data

acquisition, and subsequent transformation of data. The newly available computational techniques is changing the way one thinks about, formulates, solves, and interprets problems. For individual titles, see N90-17933 through N90-17941.

N90-17933# General Research Corp., Santa Barbara, CA.
A SELECTIVE SURVEY OF COMPUTATIONAL ELECTROMAGNETICS FOR ANTENNA APPLICATIONS
E. K. MILLER *In* AGARD, Modern Antenna Design Using Computers and Measurement: Application to Antenna Problems of Military Interest 29 p (SEE N90-17932 10-32) Sep. 1989
(AGARD-LS-165) Copyright Avail: NTIS HC A10/MF A02;
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The continuing growth of computing resources is changing how one thinks about, formulates, solves, and interprets problems. In electromagnetics as elsewhere, computational techniques are complementing the more traditional approaches of measurement and analysis to vastly broaden the breadth and depth of problems that are now quantifiable. An attempt is made to place into perspective some of the tools used in computational electromagnetics with respect to the different kinds of approaches that may be used and their computer-resource requirements, paying particular attention to numerical models based on integral and differential equations. After a brief background discussion, some of the analytical and numerical issues involved in developing a computer model are reviewed. Some practical considerations are included from the viewpoint of computer-resource requirements, followed by a discussion of some ways by which computer time might be reduced. Validation and error checking are briefly examined. Emphasis throughout is on review and summarization rather than detailed exposition. Author

N90-17934# Lawrence Livermore National Lab., CA.
RECENT ADVANCES TO NEC: APPLICATIONS AND VALIDATION
G. J. BURKE *In* AGARD, Modern Antenna Design Using Computers and Measurement: Application to Antenna Problems of Military Interest 25 p (SEE N90-17932 10-32) Sep. 1989
Previously announced as N90-11917
(Contract W-7405-ENG-48)
(AGARD-LS-165) Copyright Avail: NTIS HC A10/MF A02;
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Capabilities of the antenna modeling code Numerical Electromagnetics Code (NEC) are reviewed and results are presented to illustrate typical applications. Recent developments are discussed that will improve accuracy in modeling electrically small antennas, stepped-radius wires and junctions of tightly coupled wires, and also a new capability for modeling insulated wires in air or earth is described. These advances will be included in a future release of NEC, while for now the results serve to illustrate limitations of the present code. NEC results are compared with independent analytical and numerical solutions and measurements to validate the model for wires near ground and for insulated wires. Author

N90-17935# General Research Corp., Santa Barbara, CA.
SOME APPLICATIONS OF MODEL-BASED PARAMETER ESTIMATION IN COMPUTATIONAL ELECTROMAGNETICS
E. K. MILLER and G. J. BURKE (Lawrence Livermore National Lab., CA.) *In* AGARD, Modern Antenna Design Using Computers and Measurement: Application to Antenna Problems of Military Interest 26 p (SEE N90-17932 10-32) Sep. 1989
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All of electromagnetics, whether measurement analysis, or computation, may be regarded as activities of information acquisition, processing, and presentation. It is relevant to mention the information-intensive nature of electromagnetics because this property can provide a useful, unifying perspective from which might be developed efficiency improvements in these various areas. If, for example, redundant information can be reduced or avoided in numerical calculations, the result should be a possibly substantial decrease in the amount of computer time that is needed for computer modeling. The use of a generalized signal-processing approach called model-based parameter estimation (MBPE) for

making various improvements in either the efficiency of electromagnetic computer modeling or the efficiency of representing electromagnetic observables is considered. One is to increase the efficiency of the basic model computation itself, a typical example being that of replacing the rigorous Green's function for the antenna-interface problem by a simpler, more easily computable, approximation. Another is to make more efficient use of the results that are computed, for example, by reducing the number of samples needed to construct a transfer function over some frequency band. A third arises because the electromagnetic fields/sources in various transformed-pair domains, such as exhibited by the far fields and locations of a linear-source array, are described by exponential and pole series from which physically relevant parameters can be extracted, which are useful for such purposes as data compression and physical interpretation. The discussion deals primarily with MBPE based on exponential- and poles-series models which yield generalized waveform- and spectral-domain response functions of various transform-pair variables. It is demonstrated how sampling such observables in terms of the appropriate variable or derivatives thereof leads to a data matrix from which the model parameters can be computed. Various kinds of data and models are used to illustrate the breadth of potential applications, with an emphasis on estimating frequency responses from frequency-sampled data. Some concluding remarks are addressed to use of MBPE for the Green's-function application. Author

N90-17936# Concordia Univ., Montreal (Quebec). EMC Lab.
MEASUREMENT AND COMPUTER SIMULATION OF ANTENNAS ON SHIPS AND AIRCRAFT FOR RESULTS OF OPERATIONAL RELIABILITY
STANLEY J. KUBINA *In* AGARD, Modern Antenna Design Using Computers and Measurement: Application to Antenna Problems of Military Interest 28 p (SEE N90-17932 10-32) Sep. 1989
Sponsored in part by Defence Research Establishment, Ottawa, and by National Sciences and Engineering Research Council
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The review of the status of computational electromagnetics by Miller and the exposition by Burke of the developments in one of the more important computer codes in the application of the electric field integral equation method, the Numerical Electromagnetic Code (NEC), coupled with Molinet's summary of progress in techniques based on the Geometrical Theory of Diffraction (GTD), provide a clear perspective on the maturity of the modern discipline of computational electromagnetics and its potential. Audone's exposition of the application to the computation of Radar Scattering Cross-section (RCS) is an indication of the breadth of practical applications and his exploitation of modern near-field measurement techniques reminds one of progress in the measurement discipline which is essential to the validation or calibration of computational modeling methodology when applied to complex structures such as aircraft and ships. The latter monograph also presents some comparison results with computational models. Some of the results presented for scale model and flight measurements show some serious disagreements in the lobe structure which would require some detailed examination. This also applies to the radiation patterns obtained by flight measurement compared with those obtained using wire-grid models and integral equation modeling methods. In the examples which follow, an attempt is made to match measurements results completely over the entire 2 to 30 MHz HF range for antennas on a large patrol aircraft. The problem of validating computer models of HF antennas on a helicopter and using computer models to generate radiation pattern information which cannot be obtained by measurements are discussed. The use of NEC computer models to analyze top-side ship configurations where measurement results are not available and only self-validation measures are available or at best comparisons with an alternate GTD computer modeling technique is also discussed. Author

N90-17937# Communications Research Centre, Ottawa (Ontario).
HF WIRE ANTENNAS OVER REAL GROUND: COMPUTER SIMULATION AND MEASUREMENT
JOHN S. BELROSE, G. M. ROYER, and L. E. PETRIE (Petrie Telecommunications, Ottawa, Ontario) *In* AGARD, Modern Antenna Design Using Computers and Measurements: Application to Antenna Problems of Military Interest 30 p (SEE N90-17932 10-32) Sep. 1989
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The considerable combined experience with numerical and experimental modeling, with fabricating, with measuring performance of and with using practical HF antennas for the low HF band (2 to 8 MHz) is examined. The antenna poses a particularly difficult problem for this frequency band, particularly if a broad-band antenna is wanted for frequency agile systems, because of the four-to-one change in wavelength over the band. A further complication is that as the frequency is reduced so is the electrical height of the antenna above the ground, and since the ground is an imperfect conductor, the finite conductivity of the ground introduces loss of gain, and detuning. There is great concern with antennas at low (electrical) heights, even with antennas very near to or actually lying on the ground. Antennas lying on or near the ground are of particular interest for military tactical communicators, since low profile antenna systems that require no support mast or masts are operationally and logistically an advantage for use in a tactical environment. HF radio operators in the Canadian north have frequently reported success with using HF dipoles lying on the ground. The reason that antennas perform at all under the circumstances is because of the very low ground conductivities found in the Canadian north. It is shown what gain to expect under such circumstances. The comparison between computer simulation with measurement is emphasized, and with the application of computers for both numerical modeling, measurement, and data analysis and presentation. Author

N90-17938# Hochschule der Bundeswehr, Munich (Germany, F.R.).
ANTENNAS ON LAND VEHICLES FOR IMPROVED COMMUNICATIONS
H. K. LINDENMEIER *In* AGARD, Modern Antenna Design Using Computers and Measurement: Application to Antenna Problems of Military Interest 19 p (SEE N90-17932 10-32) Sep. 1989
(AGARD-LS-165) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

In the meter wave region the time and space dependent superposition of a multitude of waves with great time delay leads to receiving distortions at the location of reception especially in a driven car. This multipath reception, which reduces the quality of FM-reception by noise or by AF-distortions, was investigated in theory and computer-aided measurements were made by means of test transmissions from a broadcasting station to evaluate the statistical distribution of the sets of superimposed time delayed waves causing multipath distortion in the receiver. These results are discussed. By means of a specially developed measuring device receiving distortions were evaluated statistically for several different types of car antennas under various measuring conditions. For application in an antenna-diversity system a distortion detector was developed which by means of signal processing indicates not only multipath distortions as a result of great time delays between superimposed waves but also indicates noise interference as well as co-channel interference and nonlinear distortions as a result of large signal interference. Main feature of this detector is its extremely short detection time of 25 microseconds which is limited to the group delay time of the if-filters of the receiver. On the basis of this distortion detector in combination with a logic processor the performance of antenna-diversity is investigated as a function of the number of implemented antennas. The results show that the improvement factor increases considerably by the number of antennas applied. Author

N90-17939# Societe Mothesim, Le Plessis-Robinson (France).
GTD/UTD: BRIEF HISTORY OF SUCCESSIVE DEVELOPMENT OF THEORY AND RECENT ADVANCES. APPLICATIONS TO ANTENNAS ON SHIPS AND AIRCRAFT
F. A. MOLINET *In* AGARD, Modern Antenna Design Using Computers and Measurement: Application to Antenna Problems of Military Interest 22 p (SEE N90-17932 10-32) Sep. 1989
(AGARD-LS-165) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The basic concepts of Geometrical Theory of Diffraction (GTD) and its relation to the wave equation are reviewed in the frame-work of asymptotic expansions which historically formed the basis for further developments and improvements of the theory. Uniform solutions and especially the Uniform Theory of Diffraction (UTD) are introduced and a brief synthesis of successive development of GTD/UTD is presented. Among the subjects which were recently advanced, those which either lead to fundamental improvements of the theory or which have an important impact on its applications to current radiation and scattering problems have been selected and analyzed in more details. A great emphasis is given to the extension of GTD/UTD to metallic bodies with coatings. Finally some general ideas for conceiving a computer program founded on GTD/UTD are presented together with some software packages which were recently developed in France. A few selected applications of these computer programs to predict the EM radiation from antennas on an aircraft or a spacecraft and on a ship are described and illustrated by graphical displays. Author

N90-17940# Aeritalia S.p.A., Caselle Torinese (Italy). Gruppo Sistemi e Teleguidati.
COMPACT RANGES IN ANTENNA AND RCS MEASUREMENTS
B. AUDONE *In* AGARD, Modern Antenna Design Using Computers and Measurement: Application to Antenna Problems of Military Interest 16 p (SEE N90-17932 10-32) Sep. 1989
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With the increased complexity and extended frequency range of operation model measurements and far field test ranges are no longer suitable to satisfy the demand of accurate testing. Moreover plane wave test conditions are required for Radar Cross Section (RCS) measurements which represent a key point in stealth technology. Compact ranges represent the best test facilities available presently since they allow for indoor measurements under far field conditions in real time without any calculation effort. Several types of compact ranges are described and compared discussing their relevant advantages with regard to RCS and antenna measurements. In parallel to measuring systems sophisticated computer models were developed with such a high level of accuracy that it is questionable whether experiments give better results than theory. Tests performed on simple structures show the correlation between experimental results and theoretical ones derived on the basis of GTD computer codes. Author

N90-17941# British Aerospace Dynamics Group, Bristol (England). Microwave Antennas.
ANTENNA INSTALLATION ON AIRCRAFT: THEORY AND PRACTICE
T. J. MURPHY *In* AGARD, Modern Antenna Design Using Computers and Measurement: Application to Antenna Problems of Military Interest 8 p (SEE N90-17932 10-32) Sep. 1989
(AGARD-LS-165) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The problems to be faced in the integration of an antenna system onto an aircraft are reviewed. The techniques, both mathematical and empirical, used to assess radiation pattern performance are placed in the context of the requirement on the airframe as a system. A systematic approach to the integration task is described which experience has shown to be suited to the overall task. Author

N90-21223#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
HIGH RESOLUTION AIR- AND SPACEBORNE RADAR
Oct. 1989   224 p   In ENGLISH and FRENCH   Symposium held in The Hague, Netherlands, 8-12 May 1989
(AGARD-CP-459; ISBN-92-835-0530-1; AD-A218658)   Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Imaging techniques are important sources of information in military operations. They may serve for purposes such as target detection and location, reconnaissance, classification and identification of fixed or moving objects as well as for orientation over unknown terrain. Despite considerable advances in electro-optical imaging systems the radar sensor has become an attractive alternative for several reasons: large range performance, penetration of weather, smoke, dust and foilage, day and night operation. On the other hand high resolution radar techniques such as synthetic aperture radar (SAR) and inverse synthetic aperture radar (ISAR) promise geometrical resolution of about 1 m and less. For individual titles, see N90-21224 through N90-21246.

N90-21224#   Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.).
CONCEPTS FOR HIGH RESOLUTION SPACE BASED SAR/ISAR SYSTEMS: PRELIMINARY DESIGN CONSIDERATIONS
C. BOESSWETTER, A. P. WOLFRAMM, T. K. PIKE, and J. M. HERMER (Thomson-CSF, Montrouge, France)   In AGARD, High Resolution Air- and Spaceborne Radar 9 p (SEE N90-21223 14-32)   Oct. 1989
(AGARD-CP-459)   Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Some results are presented of preliminary feasibility considerations for a next generation space based multimode Synthetic Aperature Radar (SAR) and/or Inverse SAR system. A key element of next generation SAR systems, as currently designed for future remote sensing applications, is the active phased array antenna. Based on this antenna technology, some new operational modes are discussed, which currently are not available. Different beam pointing techniques (mono beam or multibeam in azimuth elevation) for strip mapping SAR modes as well as for Moving Target Indicator (MTI) ISAR modes are addressed. Basic requirements for selection of orbits are also discussed. The MTI/ISAR mode intended to detect and possibly classify from space, clusters of fast moving small targets against the clutter background of the earth surface, probably constitutes the highest risk in terms of requirements for onboard real time processing capabilities, pointing accuracies and coverage.   Author

N90-21225#   Marconi Space Systems Ltd., Portsmouth (England).
TRADE-OFFS IN A SPACE BASED SURVEILLANCE RADAR
IAN MCMILLAN   In AGARD, High Resolution Air- and Spaceborne Radar 9 p (SEE N90-21223 14-32)   Oct. 1989   Sponsored in part by ESA and Ministry of Defence Procurement Executive, England
(AGARD-CP-459)   Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The design of a dual polarization high resolution synthetic aperature space based radar is discussed along with features which allow an adaptable operation mode to be utilized for ocean or land observation. The requirements for wide coverage for ocean observation at lower spatial resolution and smaller area coverage at high resolution of specific target areas in one instrument presents the designer with a significant challenge. The instrument incorporates dual polarization receiver features with selectable polarization transmit. Wide coverage transmit beams are utilized with a narrow steerable receive beam which follows the time dependent return signals in angle. The transmission of raw measurements to ground based facilities is impractical for high resolution and the instrument must perform on board much of the necessary data analysis. The technology tradeoffs applicable to such an instrument design for deployment and use in space are examined and the choices made in recent work are presented. A concept design incorporating a phased array with distributed

transmit/receive modules with local intelligence and an all radio frequency and control optical distribution system and control system is examined.   Author

N90-21226#   Allgemeine Elektrizitaets-Gesellschaft, Ulm (Germany, F.R.).
A FREQUENCY AGILE 94 GHZ PULSE-DOPPLER RADAR WITH DUAL POLARISATION CAPABILITY
HELMUT BARTH, WOLFGANG MANZEL, ALFRED PLATTNER, and JOERG SCHROTH   In AGARD, High Resolution Air- and Spaceborne Radar 6 p (SEE N90-21223 14-32)   Oct. 1989
(AGARD-CP-459)   Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The design of a coherent, frequency agile 94 GHz radar frontend is reported. This radar includes features like pulse frequency agility in steps of 10 MHz within a bandwidth of 400 MHz and fixed or staggered pulse repetition frequency in a wide range between 1 and 50 kHz. The output power of 16 Watts and the antenna gain of 45 dB result in an effective radiated power of 89 dBm. The polarization of the transmitted wave is switchable from pulse to pulse either from RHC to LHC or from horizontal to vertical. This depends on the primary feed horn used for the 300 mm cassegrain antenna. Co- and cross-polarized echo signals are received and processed by two separate but identical receiver channels. Line scanning with a rate of 20 scans per sec is done by a flat rotating mirror.   Author

N90-21227#   Forschungsinstitut fuer Funk und Mathematik, Werthoven (Germany, F.R.). Dept. of Electronics.
APPLICATION OF SUPERRESOLUTION METHODS FOR AIRBORNE RADAR
U. NICKEL   In AGARD, High Resolution Air- and Spaceborne Radar 6 p (SEE N90-21223 14-32)   Oct. 1989
(AGARD-CP-459)   Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The usefulness of superresolution methods for airborne radar is examined. Angular resolution of closely flying targets is an interesting application. For SAR images, superresolution methods do not seem to be very helpful. A survey is given of the possible methods and problems and constraints are pointed out.   Author

N90-21228#   Physics and Electronics Lab. TNO, The Hague (Netherlands).
THE PHARUS PROJECT: DESIGN OF A POLARIMETRIC C-BAND SAR IN THE NETHERLANDS
P. HOOGEBOOM and P. J. KOOMEN   In AGARD, High Resolution Air- and Spaceborne Radar 7 p (SEE N90-21223 14-32)   Oct. 1989   Sponsored in part by Ministry of Defense and National Remote Sensing Board Prepared in cooperation with National Aerospace Lab., Amsterdam, Netherlands and Technische Hogeschool, Delft, Netherlands
(AGARD-CP-459)   Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

In the Netherlands, a digital side looking aperture radar system (X band) was used for many years in radar remote sensing research. Examples of results and the system's key features are given. Calibration and high geometric and radiometric accuracy were the keywords to success in remote sensing for this system. Based on this experience, a polarimetric C band aircraft SAR is designed. In its final version, it will make use of a phased array antenna with solid state amplifiers. Before this system can be developed, a number of problems must be solved. In a preparatory study, a SAR testbed will be constructed to test parts of the technology that will be used in the final system and to gain experience with airborne SAR in general. This testbed is described. The data processing for the PHARUS (PHased ARray Universal SAR) requires the development of software tools, that take geometric and radiometric corrections into account, as well as the calibration. This in turn requires accurate measurements of the aircraft position and attitude.   Author

N90-21229# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.).
ROSAR (HELICOPTER-ROTOR BASED SYNTHETIC APERTURE RADAR)
HELMUT KLAUSING, HORST KALTSCHMIDT, and WOLFGANG KEYDEL (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Wesseling, Germany, F.R.) In AGARD, High Resolution Air- and Spaceborne Radar 12 p (SEE N90-21223 14-32) Oct. 1989
(AGARD-CP-459) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

ROSAR is a synthetic aperture radar concept based on rotating antennas of a helicopter for pilot sight target detection and target localization with high resolution. The ROSAR concept has potential benefits for civil and military helicopterborne imaging applications, if the antennas are mounted at the tips of the rotor blades. The concept has two main potential benefits, the imaging field of view is 360 deg and there is no need for a forward velocity of the carrier platform. As opposed to SAR systems based on linear movement of the antenna, ROSAR imaging is based on synthetic aperture of a circular shape. Thus, the image formation process requires a polar format processing architecture. The ROSAR principle is also applicable for other radar mapping systems with rotating antennas, not only for helicopters. Author

N90-21230# Marconi Space Systems Ltd., Portsmouth (England).
CAPABILITIES OF BISTATIC SYNTHETIC APERTURE RADAR FOR COVERT BATTLEFIELD SURVEILLANCE
C. D. HALL In AGARD, High Resolution Air- and Spaceborne Radar 8 p (SEE N90-21223 14-32) Oct. 1989
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The capabilities of bistatic synthetic aperture radar to provide rapid update rate, real time covert radar surveillance to the military user are considered. The spatial resolution and sensitivity achievable from a tactical system using a small remotely piloted vehicle-borne transmitter and a static ground based receiver are discussed and the relative advantages of two distinct types of emission modulation are examined. Finally, a number of areas requiring further study are identified. Author

N90-21231# Selenia S.p.A., Rome (Italy). Dept. of Radar.
MMW SAR ON RPV FOR BATTLEFIELD SURVEILLANCE
A. FARINA, U. CARLETTI, E. DADDIO, C. MORABITO, and R. PANGRAZI In AGARD, High Resolution Air- and Spaceborne Radar 11 p (SEE N90-21223 14-32) Oct. 1989
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The capabilities and features of airborne synthetic aperture radar (SAR), operating in the millimeter wave (mmw) region, are discussed with reference to a battlefield surveillance application. The SAR system provides high resolution real time imaging of the battlefield and moving target detection, under adverse environmental conditions (e.g., weather, dust, smoke, obscurants). The most relevant and original aspects of the system described are the band of operation (i.e., mmw in lieu of the more traditional microwave region) and the use of an unmanned platform. The former implies reduced weight and size requirements, thus allowing use of small unmanned platforms. The latter enhances the system operational effectiveness by permitting accomplishment of recognition missions in depth beyond the forward edge battle area. An overall system architecture is described based on the onboard sensor, the platform, the communication equipment, and a mobile ground station. The relevant problem of detecting and imaging of moving target is also described. Author

N90-21232# Alcatel Espace, Toulouse (France).
PROGRAMMABLE GENERATION OF LINEAR FREQUENCY MODULATED PULSES [GENERATION PROGRAMMABLE DES IMPULSIONS MODULEES LINEAIREMENT EN FREQUENCE]
JACQUES RICHARD and JEAN-MARC FALLOT In AGARD, High Resolution Air- and Spaceborne Radar 12 p (SEE N90-21223 14-32) Oct. 1989 In FRENCH
(AGARD-CP-459) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The ability to program pulse characteristics emitted from satellite-borne radar is necessary for future radars. In an altimeter radar, a very short pulse allows the accurate measurement of centimeters of distance above the ocean but is not useful above ice or land, because of a weaker signal and large contours encountered beneath the surface. The diminishing signal range on ice and land increases the transmission loss and widens the signal acquisition in the case of an altimeter radar using the full-deramp technique. In a SAR or SLAR incapable of changing its pulse characteristics, the transverse resolution image is inversely proportional to the sine of the incidence angle. For example, certain images contain between 15 to 65 degs of incidence, with the resolution increased by a factor of 3 to 5. The use of a chirp with a programmable range solves the problem without a large transmission loss. The techniques for programming the chirp characteristics are discussed. Most of the techniques are numerical, with some interesting technical examples given. Transl. by E.R.

N90-21233# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Wesseling (Germany, F.R.). Inst. for Radio Frequency Technology.
REAL-TIME ADAPTIVE RADIOMETRIC CORRECTION FOR IMAGING RADARS SYSTEMS
JOAO R. MOREIRA and WINFRIED POETZSCH In AGARD, High Resolution Air- and Spaceborne Radar 6 p (SEE N90-21223 14-32) Oct. 1989
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A new solution is given of a real time radiometric image correction that also minimizes the quantization and saturation noise introduced by the process of analog-to-digital conversion of raw data of coherent and noncoherent imaging radar systems. The implementation of this procedure was successfully performed with the experimental SAR System (E-SAR) of the DLR. Author

N90-21234# Siemens A.G., Munich (Germany, F.R.). Telecommunication/Semiconductors.
CONCEPT FOR A SPACEBORNE SYNTHETIC APERTURE RADAR (SAR) SENSOR BASED ON ACTIVE PHASED ARRAY TECHNOLOGY
A. BRUNNER, E. LANGER, H. OETTL, and K. H. ZELLER (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen, Germany, F.R.) In AGARD, High Resolution Air- and Spaceborne Radar 10 p (SEE N90-21223 14-32) Oct. 1989
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For surveillance with spaceborne remote sensing systems, quite often a spatial resolution of 1 m or less is requested. A SAR concept is presented for a low flying satellite. Assuming a peak power of 5 kW and using active phased array technology, a swath width of about 30 km at an off nadir angle of 35 deg is considered to be reasonable. A wide swath width combined with a high resolution can only be achieved if a fixed antenna beam is used for transmitting which illuminates the whole swath width, while a very narrow antenna beam scans the swath in the manner as the reflected pulse travels from the near range to the far range across the swath width. For the active antenna system, a high efficiency of the transmit/receive modulus, low losses in the feeding network and doubly polarized radiating elements with high polarization purity are considered of utmost importance. An antenna based on the slotted waveguide principle is described. The technology of the GaAs based modules with special respect to space requirement resulting in an economic solution of the power generation below 3 W per module is described. Author

N90-21235# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, The Hague (Netherlands). Radar and Communications Div.

A MOTION COMPENSATION STUDY FOR THE PHARUS PROJECT

M. P. G. OTTEN *In* AGARD, High Resolution Air- and Spaceborne Radar 12 p (SEE N90-21223 14-32) Oct. 1989
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In the PHARUS project, a polarimetric C band SAR is being developed, which will be preceded by a nonpolarimetric test system called PHARS. A motion compensation study is also part of preparatory studies for the final PHARUS design. A SAR data simulator was developed as a tool for the study of the effects of aircraft motion on the SAR image. From the SAR mapping geometry, a terrain description, the radar parameters, and detailed trajectory and attitude data of a non-maneuvering aircraft, the simulator generates raw data with a given range resolution. This can be processed, by azimuth compression, into the SAR image. A secondary purpose of the simulation is to determine the impact of several design parameter choices, and to provide well defined test input for SAR processing software. The results of test runs with real flight data were verified theoretically, and have shown the need for motion compensation. It was also shown that a major advantage of simulation, in that it can take many factors into account at the same time, including for instance the SAR processing method, which is hard to do theoretically. Author

N90-21236# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Wesseling (Germany, F.R.). Inst. for Radio Frequency Technology.

A SOLUTION FOR REAL TIME MOTION COMPENSATION FOR SAR WITHOUT USING INERTIAL NAVIGATION SYSTEMS

JOAO R. MOREIRA *In* AGARD, High Resolution Air- and Spaceborne Radar 6 p (SEE N90-21223 14-32) Oct. 1989
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A new solution is given for real time motion compensation. The main idea is to extract all the necessary motions of the aircraft from the radar backscatter signal using a new radar configuration and new methods for evaluating the azimuth spectra of the radar signal. Hence an inertial navigation system becomes unnecessary for many applications. The motion compensation parameters for real time motion error correction are the range delay, the range dependent phase shift and the pulse repetition frequency. The motions of the aircraft to be extracted are the displacement in line of sight direction, the aircraft's yaw and drift angle and forward velocity. Results show that a three look image with an azimuth resolution of 3m in the L-band using a small aircraft is achievable and the implementation of this method in real time using an array processor is feasible. Author

N90-21237# Thomson-CSF, Malakoff (France).
SAR AND ISAR IMAGERY OF MARINE TARGETS [L'IMAGERIE DES CIBLES MARINES A LA FRONTIERE ENTRE LE SAR ET L'ISAR]

MARIE FENOU *In* AGARD, High Resolution Air- and Spaceborne Radar 10 p (SEE N90-21223 14-32) Oct. 1989 In FRENCH
(AGARD-CP-459) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

For a working arrangement of marine targets of an airport radar used for ocean surveillance, Thomson-CSF developed a high resolution imaging system. A waveform was used to get natural resolution from the antenna. The usual method for synthetic imagery of synthetic aperture radar or inverse SAR is not directly applicable because the target and radar are not stable. The adaptation of a treatment considers the specificity of the problem and its location between SAR and ISAR treatment. On the other hand, the resulting image is a hybrid of the two, and its interpretation is not possible until the two phenomena are stable. Improvements in the signature are seen from effective returns by manual identification or automatic target detection. Transl. by E.R.

N90-21238# Forschungsinstitut fuer Hochfrequenzphysik, Werthhoven (Germany, F.R.).
PROBLEMS IN ISAR PROCESSING WITH RANGE RESOLUTION BY STEPPED FREQUENCY BURSTS

GERD KRAEMER *In* AGARD, High Resolution Air- and Spaceborne Radar 5 p (SEE N90-21223 14-32) Oct. 1989
(AGARD-CP-459) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

If a target image is reconstructed from an ISAR (Inverse Synthetic Aperture Radar) measurement by immediate application of the Discrete Fourier Transform, the image becomes blurred with increasing distance from its center. It is shown that with an ISAR sensor applying stepped frequency bursts, samples of the 2-D Fourier Transform of a 2-D scatterer density are measured and how a target image can be reconstructed. Author

N90-21239# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany, F.R.). Inst. fuer Hochfrequenztechnik.
A FAST ISAR-IMAGING PROCESS AND ITS INHERENT DEGRADING EFFECTS ON IMAGE QUALITY

K.-H. BETHKE and B. ROEDE *In* AGARD, High Resolution Air- and Spaceborne Radar 12 p (SEE N90-21223 14-32) Oct. 1989
(AGARD-CP-459) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A method for a fast 2-D inverse synthetic aperture radar (ISAR) imaging process is presented. A coherent short pulse radar is used to sample amplitude and phase of the backscattered field from a continuously rotating object. This is being done while a narrow range gate is sweeping in range steps of 15 cm across the target plane at a typical speed of 150 m/s. Applying fast SAR principles, in an off-line process for each range cell, an acceptable good cross range resolution can be obtained when processing angle intervals of less than 30 deg. The influence of analytical approximations as well as the effect of moving scattering centers through several range resolution cells during the process interval can cause severe image degradations. Two methods for partial and complete compensation of these effects under the aspect of minimum loss in processing speed were developed and are presented. Author

N90-21240# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, The Hague (Netherlands). Physics and Electronics Lab.
RADAR OBSERVATIONS OF A FORMATION OF TWO FIGHTERS: A CASE STUDY FOR ISAR IMAGING

FRITS WILLEMS *In* AGARD, High Resolution Air- and Spaceborne Radar 12 p (SEE N90-21223 14-32) Oct. 1989
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A study was made of Inverse Synthetic Aperture Radar imaging of a formation of two fighters. The observations are interpreted in terms of relative motions of the two aircraft by use of model study and computer simulation. Author

N90-21241# Forschungsinstitut fuer Funk und Mathematik, Werthoven (Germany, F.R.).
THE 1D-ISAR IMAGING OF MANOEUVERING AIRCRAFT

J. ENDER *In* AGARD, High Resolution Air- and Spaceborne Radar 9 p (SEE N90-21223 14-32) Oct. 1989
(AGARD-CP-459) Copyright Avail: NTIS HC A10/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Most operating radar systems don't provide sufficient range resolution to resolve flying targets in range direction. Nevertheless, high cross range resolution can be obtained by 1-D imaging. This procedure will be successful only, if the target motion is compensated with a high accuracy. A motion compensation technique is introduced based on Kalman forward-backward smoothing on radar position estimates together with spectral information. An iterative error correction procedure (autofocus) yields a cross range image with sufficient resolution. Correct scaling and estimation of the imaging axis direction are derived from the flight path by a simple orientation model. Some experimental study of this kind of ISAR processing was done with the electronic

radar phased array. Echo sequences of targets of opportunity were recorded and off-line processed. With the autofocus procedure, coherence times up to 6 sec could be achieved providing resolution cells in the magnitude of 1 m. Images during straight flight periods as well as along curved flight paths were generated. The reliability of the information given by the signatures was examined.   Author

N90-21242#   Selenia S.p.A., Rome (Italy). Dept. of Radar.
RADAR TARGET IMAGE BY ISAR CASE STUDY
S. MARINI, S. PARDINI, and F. PRODI *In* AGARD, High Resolution Air- and Spaceborne Radar 14 p (SEE N90-21223 14-32)   Oct. 1989
(AGARD-CP-459) Copyright Avail: NTIS HC A10/MF A02;
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    Target imaging based on Inverse Synthetic Aperture Radar techniques are described. Theoretical and experimental results are presented. Theoretical topics illustrate the set of processing functions needed to obtain the target image starting from the radar echoes. Key processing steps include motion compensation and reconstruction of the reflectivity function. An experimental setup based on a currently available tracking radar, a data recorder and off-line processing facilities are illustrated. A high cross range resolution image of a MB-339 aircraft was obtained by processing recorded radar echoes from a Selenia X band tracking radar.
    Author

N90-21243*#   National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AIRBORNE DOPPLER RADAR FLIGHT EXPERIMENTS FOR THE DETECTION OF MICROBURSTS
HANS-J. C. BLUME, C. D. LYTLE, W. R. JONES, E. M. BRACALENTE, and C. L. BRITT (Research Triangle Inst., Research Triangle Park, NC.) *In* AGARD, High Resolution Air- and Spaceborne Radar 14 p (SEE N90-21223 14-32)   Oct. 1989
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AGARD/Scientific Publications Executive CSCL 17/9
    In the interest of aviation safety, NASA and the FAA are jointly conducting research to determine the applicability of airborne, coherent Doppler radar techniques to detect early microburst in wind shear conditions during aircraft takeoff and landing. Researchers have developed a computer model of the radar which predicts its response when viewing a simulated microburst against the simulated clutter background of an airport, the so-called radar microburst ground clutter model. Studies employing this model revealed that Doppler radar can accurately detect microburst ahead of the aircraft in time for pilot evasive response, but flight experiments will be required for complete performance evaluation of the system. An experimental X band radar is being developed for future flight experiments to verify the simulation modeling results. A description of the experimental radar, recording equipment, and its installation on the NASA 515 aircraft is presented. The flight experiments to be conducted are also described.   Author

N90-21244#   Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany, F.R.). Inst. for Radio Frequency Technology.
CONCEPT AND RESULTS OF THE DLR REALTIME SAR PROCESSOR
ALBERTO MOREIRA *In* AGARD, High Resolution Air- and Spaceborne Radar 6 p (SEE N90-21223 14-32)   Oct. 1989
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    A real time azimuth processor was developed for the airborne E-SAR system (Experimental Synthetic Aperture Radar). The processor works with an unfocused compression method. This method greatly simplifies the data processing and is easily implemented by a moving average approach. A SAR image processed by a traditional unfocused processing method has a lower contrast, higher sidelobes, and worse resolution than in the focused case. A new algorithm was developed, so that a triangular amplitude weighting could be implemented into the unfocused processing method without additional complications. Images processed in real time are presented. They show good contrast and strong suppression of the sidelobes. The processor hardware can be implemented with reduced costs in small aircraft and is

suitable for several applications such as the detection of oil pollution over the sea.   Author

N90-21245#   Aerospatiale, Les Mureaux (France). Dept. Mesures.
IMAGE SIMULATION OF GEOMETRIC TARGETS FOR SYNTHETIC APERTURE RADAR [SIMULATION D'IMAGES DE CIBLES GEOMETRIQUES POUR RADAR A OUVERTURE SYNTHETIQUE]
J. M. NASR *In* AGARD, High Resolution Air- and Spaceborne Radar 7 p (SEE N90-21223 14-32)   Oct. 1989 In FRENCH
(AGARD-CP-459) Copyright Avail: NTIS HC A10/MF A02;
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    A new technique for image simulation which comes from a synthetic aperture radar is presented. The method is based on the embedding of an artificially simulated target in a real radar image captured by an operational antenna window on a satellite (SEASAT or SIR-B). A L and C band was used for the capture. The target dimensions studied were large enough for use with long waves provided the calculation techniques used with high frequencies were for an equivalent area radar (SER). The calculation of SER allows the capture of a raw signal received from the antennas. So that the possibility of simulation is low, some restrictions are made. The results are sufficiently interesting enough to let the study of the behavior of a particular target become of use to civilians or the military, in the functional bounds of radar waves.   Transl. by E.R.

N90-21246#   Thomson-CSF, Paris (France).
SAR IMAGE CODING [CODAGE D'IMAGES SAR]
P. TOURTIER *In* AGARD, High Resolution Air- and Spaceborne Radar 6 p (SEE N90-21223 14-32)   Oct. 1989 In FRENCH
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    The Synthetic Aperture Radar imagery causes a very large flow rate, to the extent that the data flow is at a record level. The image coding technique reduces the flow rate so that the original quality is preserved. This permits the reduction of the transmission channel capacity and improves the flow rate. A different technique is presented for data flow compression. The technique performs best at low cosine transform and is described in detail. The results obtained by Thomson-CSF show that a compression rate of the magnitude of 4 or 5 is possible without visible image degradation.
    Transl. by E.R.

N90-21907#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
ATMOSPHERIC PROPAGATION IN THE UV, VISIBLE, IR, AND MM-WAVE REGION AND RELATED SYSTEMS ASPECTS
Mar. 1990   363 p   In ENGLISH and FRENCH   Meeting held in Copenhagen, Denmark, 9-13 Oct. 1989
(AGARD-CP-454; ISBN-92-835-0548-4; AD-A221594) Copyright
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    Atmospheric propagation of electromagnetic waves at frequencies above 30 GHz is of importance to many current and future military applications. Propagation phenomena affect and often limit navigation, communications, surveillance, search, target acquisition, fire control, autonomous weapons guidance, kill assessment, countermeasures and medium to high power laser applications. Recent advances in components and technology have prompted extensive studies and applications in the above wavelength region. An exchange of information between scientists and engineers involved in research and development in this wavelength region is expected to benefit further development of systems and explore new areas of research as well as military and civilian applications. Topics discussed are: propagation measurements; propagation modes; sensing of the propagation environment; system aspects and performance modeling; and countermeasures. For individual titles, see N90-21908 through N90-21942.

N90-21913# Science Research Council, Didcot (England).
MILLIMETRIC, INFRARED, AND OPTICAL PROPAGATION STUDIES OVER A 500 M PATH
C. J. GIBBINS *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 13 p (SEE N90-21907 15-32) Mar. 1990
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A 500 m propagation range was developed with transmission links operating at frequencies of 37, 57, 97, 137, and 210 GHz and at wavelengths of 10.6 and 0.63 microns. A comprehensive set of meteorological observations includes rainfall and snowfall rates, raindrop size distributions, temperature and humidity, microwave refractive index, surface pressure, and wind velocity. Measurements from the range are being used to compile an extensive propagation and meteorological database with which a variety of studies are being carried out; these include detailed investigations into individual events, aimed towards obtaining a deeper understanding of the interaction between electromagnetic radiation and the prevailing meteorological phenomena such as rain, snow, fog, and atmospheric turbulence. Statistical analysis of the database, on the other hand, is directed towards obtaining information on the reliability of future communications systems, so that average and extreme values of systems performance can be assessed. Such studies facilitate the development of prediction procedures based on existing meteorological data for future systems planning, and an assessment of the relative merits of different wavebands, important to the increasing development and deployment of multi-spectral sensors. Author

N90-21914# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
EVAPORATION DUCT EFFECTS AT MILLIMETER WAVELENGTHS
K. D. ANDERSON *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 13 p (SEE N90-21907 15-32) Mar. 1990
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The evaporation duct strongly influences low-altitude over-the-horizon propagation at millimeter wavelengths. Results from more than 2000 hours of propagation and meteorological measurements were made at 94 GHz on a 40.6 km over-horizon, over-water path along the southern California coast show that the average received power was 63 dB greater than expected for propagation in a nonconducting, or normal, atmosphere; 90 percent of the measurements were at least 55 dB greater than the normal atmosphere. A numerical model of transmission loss based on observed surface meteorology is discussed and results are compared to measured transmission loss. On average, modeling results underestimate the transmission loss by 10 dB. In addition, results from modeling based on an independent climatology of evaporation duct heights for the area are shown to be adequate for most propagation assessment purposes. The reliability and reasonable accuracy of the model provide a strong justification for utilizing the technique to assess millimeter wave communication and radar systems operating in many, if not all, ocean regions.
Author

N90-21915# Shape Technical Center, The Hague (Netherlands).
REPORT ON STC/TECHNISCHE UNIVERSITEIT (TU) DELFT EXTREMELY HIGH FREQUENCY (EHF) RADIO RELAY STUDY
N. P. MANSFIELD, L. P. LIGTHART, R. J. NIEMEIJER, and J. S. VANSINTTRUYEN (Technische Hogeschool, Delft, Netherlands) *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 6 p (SEE N90-21907 15-32) Mar. 1990
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Preliminary results of a joint extremely high frequency (EHF) radio relay trial between SHAPE Technical Center (STC) and the Delft University of Technology (DUT) are presented. The trial was established to study the effects of meteorological disturbances, of which rain is the principal cause, on a digital radio relay path 12.7

km long operating at 37.5 GHz. Practical use for these radio relay links is found in local grade connections in an Integrated Services Digital Network (ISDN). Author

N90-21916# Selenia S.p.A., Rome (Italy).
THE MM-WAVE REGION PROPAGATION EXPERIMENTS BY SATELLITE
PAOLO RICCI and ANTONIO FLORIO *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 10 p (SEE N90-21907 15-32) Mar. 1990
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The RF propagation experiments, related to the earth space communications by means of geostationary satellites, at frequencies exceeding the 30 GHz value, as lower limit of the mm-wave region, are examined. The Selenia Spazio activity is outlined. Olympus system in-orbit tests will have experiments at 20/30 GHz, just below the mm-wave band, and includes a 12.5 GHz beacon which will be used as reference to crosscorrelate the behavior at different frequencies, to extend the measurement dynamics of the coherent receivers, and as possible reference for antenna autotracking. The next step will be with Italsat, the Italian satellite scheduled for launch at the end of '90, allowing the first mm-wave propagation experiment for space communications at 40/50 GHz, across the outmost of the European zone. A third beacon at lower frequency (20 GHz) is foreseen as multipurpose reference. The functional configuration of the earth stations is presented and the related propagation experiments are described in terms of performances and from an operational point of view. Copolar/crosspolar characteristics and scintillation phenomena are included. The triple frequency configuration (20/40/50 GHz) and the use of radiometric and meteorological sensors, associated with the earth station, will give the opportunity to crosscorrelate the experiments results and to extend their dynamics capabilities. The propagation experiments results at 40/50 GHz will have interest for secure communications and countermeasures. The use of higher frequency values, until and beyond 100 GHz, is envisaged in other study activities for atmospheric propagation experiments. The mm-wave propagation experiment results can provide suitable guidelines for link design optimization and to identify the opportunity of using frequency/polarization/site diversity configurations in the different communication scenarios. Author

N90-21917# Air Force Geophysics Lab., Hanscom AFB, MA.
LOWTRAN 7: STATUS, REVIEW, AND IMPACT FOR SHORT-TO-LONG-WAVELENGTH INFRARED APPLICATIONS
F. X. KNEIZYS, G. P. ANDERSON, ERIC P. SHETTLE, L. W. ABREU, J. H. CHETWYND, JR., J. E. A. SELBY, W. O. GALLERY, and S. A. CLOUGH (Atmospheric and Environmental Research, Inc., Cambridge, MA.) *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 11 p (SEE N90-21907 15-32) Mar. 1990
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A summary of the recent improvements, modifications, and updates to the LOWTRAN 7 atmospheric transmittance and radiance computer program will be given. There were some significant changes to the LOWTRAN model in the latest version, LOWTRAN 7, that affect the manner in which the basic atmospheric transmittance and radiance calculations are performed as well as providing the user with greater flexibility and more capabilities. The LOWTRAN 7 code now calculates atmospheric transmittance, atmospheric background radiance, single-scattered and earth-reflected solar and lunar radiance, direct solar irradiance, and multiple-scattered solar and thermal radiance. The spectral range of the code was extended from 0 to 50,000 cm at a spectral resolution of 20 cm. The program can cope with an observer/target geometry and can include the effects of molecular, aerosol, fog, rain, and cloud absorption and scattering. Some of the basic changes to LOWTRAN 7, in particular the introduction of new molecular absorption transmission functions and separating the transmittances due to CO_2, N_2O, CO, CH_4 and O_2, will give rise to differences in the transmittance and radiance calculations (compared to those obtained with LOWTRAN 6) depending on the observer/target viewing geometry and spectral region. The

dual purpose is to indicate how the new changes to LOWTRAN 7 affect atmospheric transmittance and background radiance calculations for specific applications. Both high-altitude, long-range and low-altitude, moderate-range scenarios are stressed and will show the impact that the recent changes to LOWTRAN 7 have made on the short, medium and long wavelength infrared atmospheric attenuation and background radiance, compared to calculations with LOWTRAN 6.   Author

N90-21918# Atmospheric Sciences Lab., White Sands Missile Range, NM.
PROPAGATION ENVIRONMENTS, EFFECTS, AND DECISION AIDS
F. E. NILES, M. G. HEAPS, R. C. SHIRKEY, L. D. DUNCAN, and M. A. SEAGRAVES *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 8 p (SEE N90-21907 15-32)   Mar. 1990
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        Reconnaissance, surveillance, target acquisition, communications, and weapon systems are becoming more sophisticated and are becoming more dependent on the propagation of electromagnetic or acoustic energy through the atmosphere. Weather and battle activity will constantly change the atmospheric conditions and hence the propagation environments when the systems are employed. The effects of these changing propagation environments must be understood for optimum system design, assessment of system performance, development of countermeasures, development of tactics and doctrine, and development of decision aids. In 1978 the U.S. Army Atmospheric Effects Laboratory (ASL) began the development of the Electro-Optical Systems Atmospheric Effects Library (EOSAEL) in order to quantify some of the battlefield atmospheric effects. EOSAEL has had several releases; and the latest, EOSAEL 87, contains 26 modules that can be separated into 6 generic classes: gases, natural aerosols, battlefield aerosols, radiative transfer, laser propagation, and target acquisition and system performance. Combining information on weather and battle activity with an understanding of atmospheric effects has allowed ASL to produce tactical decision aids (TDAs) for many friendly and threat electro-optical systems. This developmental software is scheduled to be fielded on the Integrated Meteorological System (IMETS).
                                                                Author

N90-21922# Institute for Telecommunication Sciences, Boulder, CO.
MODELING MILLIMETER-WAVE PROPAGATION EFFECTS IN THE ATMOSPHERE
H. J. LIEBE and G. A. HUFFORD *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 13 p (SEE N90-21907 15-32)   Mar. 1990   Sponsored in part by Naval Ocean Systems Center
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        Two millimeter-wave propagation models, called MPM and MZM, are discussed. The first one predicts, at frequencies up to 1000 GHz, loss and delay effects for a nonprecipitating atmosphere. Contributions from dry air and water vapor are addressed, as well as suspended water droplets that simulate fog or cloud conditions. For clear air, a local spectral line base is employed (44 O_2 + 30 H_2O lines) complemented by an empirical water-vapor continuum. Droplet effects are treated with the approximate Rayleigh scattering theory. Input variables are barometric pressure, temperature, relative humidity, and droplet concentration. At heights between 30 and 100 km, the spectral lines of oxygen result in an anisotropic medium due to the geomagnetic Zeeman effect. The computer program MZM was developed to analyze propagation of plane, polarized radio waves in the vicinity (+ or · MHz) of O_2 line centers positioned in the 60-GHz band and at 119 GHz. Results are displayed that demonstrate many aspects of the unusual wave propagation through the mesosphere.   Author

N90-21925# York Univ. (Ontario). Centre for Research in Earth and Space Science.
INCLUSION OF CLOUDS AND RAIN IN ATMOSPHERIC SLANT PATH CALCULATIONS
C. W. LUI, M. W. P. CANN, and R. W. NICHOLLS *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 9 p (SEE N90-21907 15-32)   Mar. 1990   Prepared in cooperation with Institute for Space and Terrestrial Science, York, Ontario
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        The computation of aerosol absorption and scattering coefficients is normally a lengthy process, so that atmospheric slant path calculations rely on selections from pre-calculated data. An investigation in which the calculated coefficients are stored in a parameterized form is described. The object was to encompass a wide variety of cloud and rain types in a data set of manageable proportions. Atmospheric aerosols and rain are characterized by the mass density, size distribution $n(r)$, and shapes of the constituent water drops or ice crystals. Particle shapes may be irregular - in ice clouds, snow and rain for example - but for the calculations reported here are assumed to be spheres of equivalent volume. The modified gamma function, first proposed by D. Deirmendjian, as $n(r)$ is adopted. The original form of the function contains four parameters. To facilitate the parameterization, we regroup them into two physically meaningful parameters $r(sub\ c)$ (critical radius) and delta = alpha gamma, proportional to the slope of $n(r)$ around $r(sub\ c)$. Then the absorption and scattering coefficients calculated from Mie theory are expressed as a polynomial in temperature and frequency. These coefficients in the polynomials are stored for retrieval and interpolation during a slant path calculation. The parameterization is quite general and includes the Marshall-Palmer relation for rain, the Laws and Parsons and inverse power distributions.   Author

N90-21926# GEC-Marconi Electronics Ltd., Chelmsford (England).
INFRARED PROPAGATION IN THE AIR-SEA BOUNDARY LAYER
R. LARSEN, K. A. PREEDY, and G. DRAKE (GEC Sensors Ltd., Basildon, England) *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 6 p (SEE N90-21907 15-32)   Mar. 1990   Sponsored by Ministry of Defence, England
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        Over the oceans and other large bodies of water the structure of the lowest layers of the atmosphere is often strongly modified by evaporation of water vapor from the water surface. At radio wavelengths this layer will usually be strongly refracting or ducting, and the layer is commonly known as the evaporation duct. However, the refractive index of air at infrared wavelengths differs from that at radio wavelengths, and the effects of the marine boundary layer on the propagation of infrared radiation are examined. Meteorological models of the air-sea boundary layer are used to compute vertical profiles of temperature and water-vapor pressure. From these are derived profiles of atmospheric refractive index at radio wavelengths and at infrared wavelengths in the window regions of low absorption. For duct propagation to occur it is necessary that the refractivity of air decreases rapidly with increasing height above the surface. At radio wavelengths this usually occurs when there is a strong lapse of water vapor pressure with increasing height. By contrast, at infrared wavelengths the refractive index is almost independent of water vapor pressure, and it is found that an infrared duct is formed only when there is a temperature inversion.   Author

N90-21927# Defence Research Establishment Valcartier (Quebec).
A TEMPERATURE-DEPENDENT REGULAR INFRARED BAND MODEL FOR ABSORPTION AND DISPERSION
P. L. RONEY *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 10 p (SEE N90-21907 15-32) Mar. 1990
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A temperature-dependent infrared band model for the absorption and refraction of spectral lines, simultaneously broadened by Doppler and collisional effects, is developed. The model also takes into account the effects of line-coupling. The case of a simple diatomatic molecule, in the rotating oscillator approximation is treated. The result is given in the form of an infinite series which converges rapidly and is appropriate for efficient computation. Author

N90-21928# Air Force Geophysics Lab., Hanscom AFB, MA.
UV SPECTRAL SIMULATIONS USING LOWTRAN 7
G. P. ANDERSON, F. X. KNEIZYS, ERIC P. SHETTLE, L. W. ABREU, J. H. CHETWYND, JR., R. E. HUFFMAN, and L. A. HALL *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 9 p (SEE N90-21907 15-32) Mar. 1990
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LOWTRAN 7 is a low-resolution propagation model and computer code for predicting atmospheric transmittance and background radiance from 0 to 50,000/cm (wavelengths greater than 0.2 micron). The current model, released in February 1989, is a major extension of the LOWTRAN 6 model. In addition to incorporating new and improved molecular band models (primarily influencing IR calculations), LOWTRAN 7 was particularly adapted for basic ultraviolet transmittance and radiance calculations. It now contains a 0.2 nm resolution extra-terrestrial solar source function along with temperature-dependent O3 (Hartley-Huggins) and pressure-dependent O2 (Herzberg continuum) absorption cross sections. The O2 Schumann-Runge band absorption was patterned after the IR band model. As with past versions of LOWTRAN, the line-of-sight viewing and solar incidence geometry can be arbitrarily configured for either direct or backscattered calculations. Both solar and thermal multiple scattering are accommodated. Initial validations of the UV portions of LOWTRAN 7 were made against two separate A-GL spectrometers. Excellent agreement was found with UV data from a balloon-borne spectrometer designed to measure in situ solar irradiance within the stratosphere. These direct solar observations, all at high sun angles, were made at stratospheric altitudes. Ultraviolet background measurements in the 0.2 to 0.29 micron wavelength region were made from the S3-4 satellite in a polar, sun-synchronous, nadir-viewing orbit. For moderate to high solar incidence angles, the backscatter comparisons with LOWTRAN 7 are again reasonable (generally within 10 percent). With the sun on the horizon, however, the twilight airglow becomes a dominant feature; such emission sources are not incorporated into LOWTRAN. Author

N90-21929# Science Research Council, Didcot (England). Radio Communications Research Unit.
MILLIMETRE-WAVE PROPAGATION IN THE EVAPORATION DUCT
M. F. LEVY and K. H. CRAIG *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 10 p (SEE N90-21907 15-32) Mar. 1990
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Recent developments in propagation modeling based on the Parabolic Equation Method allow the forecasting of two-dimensional antenna coverage diagrams at millimeter wavelengths, in a dispersive atmosphere with arbitrary two-dimensional variation of the refractive index. The model was applied successfully to mm-wave propagation in the evaporation duct. The evaporation duct height is not sufficient to characterize mm-wave propagation, and information on the water vapor content is essential for the correct modeling of atmospheric absorption. Turbulence simulations

were carried out, showing marked scintillation, effects in the evaporation duct. The method can be applied to arbitrary refractivity spectra, and gives a complete numerical description of the field statistics. Author

N90-21930# Maryland Univ., College Park. Inst. for Physical Science and Technology.
LIDAR MEASUREMENTS OF THE OPTICAL PROPAGATION ENVIRONMENT
THOMAS D. WILKERSON, UPENDRA N. SINGH, ANTHONY NOTARI, and W. CHARLES BRAUN *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 12 p (SEE N90-21907 15-32) Mar. 1990
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Results of lidar measurements are reported, particularly the layering of tropospheric haze and extinction/backscatter by cirrus clouds at visible wavelengths. This work includes the operation of a fixed lidar at College Park, and a transportable lidar for geographic locations of interest to DoD. A sensitivity baseline for these lidars was established using Rayleigh backscatter from the altitude molecular atmosphere. Profiles of temperature and density cover the altitude range 30 to 80 km. For cirrus clouds, measured relationships between extinction and backscatter make it possible to estimate the long-range horizontal visibility through cirrus layers via calibrated backscatter observations. Inversion of tropospheric haze measurements to vertical profiles of extinction is reported. Applicability of lidar probe methods to energy and information transfer through the atmosphere is summarized. Upper atmosphere observations are discussed, relevant to the prediction of atmospheric effects on reentry vehicles. Author

N90-21931# Defence Research Establishment Valcartier (Quebec).
LIDAR MEASUREMENT OF CONCENTRATION AND TURBULENCE IN BATTLEFIELD OBSCURANTS
B. T. N. EVANS and G. ROY *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 12 p (SEE N90-21907 15-32) Mar. 1990
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Concentration inhomogeneities, caused by turbulence, in obscurant clouds are studied by using a rapidly scanning lidar. Spatial correlograms in the three spatial directions are derived and are related to atmospheric stability. Implications of these inhomogeneities for obscurant effectiveness and interdevice comparison are discussed. Author

N90-21932# Wisconsin Univ., Madison.
CIRRUS CLOUD OPTICAL PROPERTIES MEASURED WITH THE UNIVERSITY OF WISCONSIN HIGH SPECTRAL RESOLUTION AND VOLUME IMAGING LIDARS
E. W. ELORANTA and C. J. GRUND *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 5 p (SEE N90-21907 15-32) Mar. 1990
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The High Spectral Resolution Lidar (HSRL) provides calibrated range-resolved measurements of atmospheric optical parameters. These measurements include: the optical backscatter cross section, extinction cross section, optical depth and, when the absorption cross section is negligible, the backscatter phase function. Calibrated measurements are achieved by partitioning the lidar signal into separate aerosol and molecular scattering components. The separation is possible because the molecular signal is spectrally broadened by Doppler shifts from the thermal velocities of the molecules while the aerosol return spectrum is nearly unaffected by the slow Brownian motions of the aerosols. Visible and subvisible cirrus cloud optical properties measured at a wavelength of 510 nm with the HSRL are presented. Backscatter cross sections between 10(exp -5)/(km sr) to 0.18/(km sr) were measured along with backscatter phase functions in the range

between .02/sr and .065/sr. Clouds with optical depths ranging from .003 to 2.9 were observed. An example of the tenuous enhanced backscattering often observed with the HSRL at cirrus altitudes is presented. Examples are provided of the mid-cloud altitudes, the optical thickness, and the backscatter phase function observed in cirrus clouds with the HSRL. The mid-cloud temperatures reported were derived from radiosonde data. Optical thickness of cirrus clouds are plotted as a function of their mid-cloud temperature. Results are presented along with measurements obtained from the HSRL. A comparison is shown of cirrus cloud optical depths measured with the HSRL and thermal emissivities measured by satellite with the CO(sup -2) slicing method. These preliminary observations lend support to the model results of Hansen (1971). A Volume Imaging Lidar (VIL) optimized for three-dimensional mapping of atmospheric structure was also operated. This lidar couples a 0.6J, 30 Hz Nd-YAG laser, with a 0.5 m diameter receiver, a 20 degree/sec beam scanning unit and data system capable of acquiring, displaying and storing data at sustained high rates. Author

N90-21933# Fraunhofer-Inst. fuer Atmosphaerische Umweltforschung, Garmisch-Partenkirchen (Germany, F.R.).
VERIFICATION OF KLETT'S METHOD BY COMPARISON OF LIDAR AND TRANSMISSOMETER MEASUREMENTS
WALTER CARNUTH In AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 12 p (SEE N90-21907 15-32) Mar. 1990
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Lidar measurements are performed in 532 nm wavelength along a slant path from ground level at 730 m MSL to a 1780 m mountain peak at 7 km horizontal distance, and extinction profiles derived from them by Klett's inversion method. This method, proceeding in the backward direction, avoids the instabilities occurring with the classical forward inversion, but requires a reference extinction value at the end of the lidar path. In this case, it is derived from visual range data obtained by an integrating nephelometer which is operated by a broadband optical transmissometer (350 to 900 nm). The data are compared with those calculated by integration of the lidar extinction profiles. Author

N90-21934# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
TECHNIQUE FOR SELECTING AN AEROSOL MODEL USEFUL FOR INFRARED ATMOSPHERIC TRANSMITTANCE CALCULATIONS
HERBERT G. HUGHES In AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 8 p (SEE N90-21907 15-32) Mar. 1990
(Contract NR PROJ. RM-35G80)
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Vertical profiles of meteorological parameters are used with the LOWTRAN 6 atmospheric transmittance/radiance computer code to model measurements of near horizon infrared radiances. It is shown that calculations with the Navy Maritime Aerosol Model can exactly reproduce the measured horizon pixel radiance using non-unique combinations of air mass factors and surface visibilities. This feature is the result of the visibility scaling factor of the size distribution remaining nearly constant for any appropriate combination of the two factors, and the relative insensitivity of the calculated extinction coefficients for the far infrared wavelengths to the air mass factor term. Using measurements taken on two consecutive days during low wind speed conditions, it is shown that any appropriate combination of the two factors will allow the calculated and measured radiances at other angles above the horizon to differ less than 2 percent. These agreements place confidence in using the selected aerosol model in transmittance calculations for the far infrared wavelength bands over other propagation paths. Author

N90-21935# Massachusetts Univ., Amherst. Microwave Remote Sensing Lab.
RADAR SCATTEROMETRY AND POLARIMETRY AT 220 GHZ
ROBERT E. MCINTOSH and JAMES B. MEAD In AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 8 p (SEE N90-21907 15-32) Mar. 1990
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Two high-power portable radars operating in the 220 GHz absorption window were developed. The first, an incoherent 215 GHz scatterometer was used for reflectivity measurements of foliage, fallen snow, clouds and fog between ranges of .1 and 2 km. An incoherent 225 GHz polarimetric radar was also developed which is capable of fully characterizing the Stokes scattering matrix of distributed targets. Both radars employ an Extended Interaction (Klystron) Oscillator (EIO) as the transmitting source. These tubes produce a 60 W pulse of 50 to 600 ns duration and operate at a maximum duty cycle of .005. High efficiency Schottky barrier diode mixers are attached directly to the feed horns of the receiver antennas to minimize loss. Work at 215 GHz, including a review of the hardware and measurements of clouds and fog is summarized. The 225 GHz polarimeter will be discussed in greater depth, including a review of the theory of polarimetry, a description of the hardware and a calibration technique requiring only a single in-scene reflector. Preliminary polarimetric measurements of a dihedral reflector and foliage are presented and discussed. Author

N90-21936# Michigan Univ., Ann Arbor. Dept. of Electrical Engineering and Computer Science.
MILLIMETER-WAVE BISTATIC SCATTERING BY TERRAIN
FAWWAZ T. ULABY In AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 12 p (SEE N90-21907 15-32) Mar. 1990
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Interference caused by bistatic and forward scattering by terrain can often lead to degradation in performance for electromagnetic sensors and communications systems. The results of a study conducted to evaluate the directional distribution of bistatic scattering from terrain surfaces at 35 GHz are described. A calibrated radar system was used in a bistatic mode to measure the scattering from a variety of smooth and rough surfaces and from standing trees for all four linear polarization combinations HH, HV, VH, and VV. The measurements were made as a function of the azimuth and elevation angles of the receive antenna direction for fixed directions of the transmit antenna. The scattering data for trees were used to develop a new model for the phase matrix of foliage which can then be used in conjunction with transport theory to compute bistatic scattering by forest canopies for any incident and scattered directions. This approach was found to give excellent agreement with backscatter measurements conducted at 35 GHz, 94 GHz, and 140 GHz. Author

N90-21937# Naval Research Lab., Washington, DC.
MODELLING UV-VISIBLE RADIATION OBSERVED FROM SPACE
D. E. ANDERSON, JR. and D. J. STRICKLAND (Computational Physics, Inc., Annandale, VA.) In AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 11 p (SEE N90-21907 15-32) Mar. 1990
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Development of space-based passive remote systems for observing and tracking artificial radiation sources in the earth's atmosphere requires the characterization of the natural radiation background. Recent advances in detector technology and theoretical modeling have led to improved understanding of the UV-visible (1000 to 5000A) atmospheric background radiation. There are two principal sources of naturally occurring UV-visible atmospheric radiation: Rayleigh and Mie scattering of sunlight; and auroral and airglow emission. The first source is generated primarily in the troposphere, but is affected by the presence of aerosols

and ozone in the stratosphere up to 40 km. In addition, clouds, surface reflection and multiple scattering can have a significant affect on the radiation field. The relative importance of these sources to nadir emission is shown. In particular, it is found that for wavelengths greater than 3000 A as much as 60 percent of the nadir emission can be due to multiple scattering. The second source, auroral and airglow emission, emanates from the mesosphere above 50 km and the thermosphere below 1000 km altitude and exhibits remarkable geographic and geomagnetic variability. A description of these radiation fields and models developed to analyze satellite remote sensing data in the UV-visible region of the spectrum are presented. Emission levels from both sources are compared and expected geographic and solar cycle variability identified.   Author

N90-21938#   Admiralty Research Establishment, Portsmouth (England).
CALCULATION OF IR PROPAGATION STATISTICS IN THE EASTERN ATLANTIC FOR SURVEILLANCE SYSTEM PERFORMANCE ASSESSMENT
J. M. RIDOUT   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 5 p (SEE N90-21907 15-32)   Mar. 1990
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The assessment of Infrared Search and Track systems requires a knowledge of the atmospheric propagation conditions in the geographic region of interest and how often these conditions arise. One area of interest to the UK Royal Navy is the Eastern Atlantic from the Iberian Basin in the South to the Greenland Sea in the North. A description of the meteorological conditions in this area in terms of air mass type has become available under NATO. The data were used with the LOWTRAN 6 computer program to determine the atmospheric transmissions in the 3 to 5 and 8 to 12 micron bands and the associated occurrence values used to produce cumulative probabilities of occurrence of a given transmission. This data base gives the conditions in terms of air mass type which may distort the probability curves. A further meteorological data base is available which gives the atmospheric conditions over a period of several years for Weather Ship J in the West European Basin and a subset of this was used to provide a check on the above calculations for this restricted region. It is shown that the degree of correlation between the two methods is reasonably good and that using the air mass type of approach is satisfactory. The effect of the calculated probability curves in sub regions of the Eastern Atlantic region on the selection of IR surveillance systems is indicated.   Author

N90-21939#   Science and Technology Corp., Las Cruces, NM.
COMPUTATION OF BROAD SPECTRAL BAND ELECTRO-OPTICAL SYSTEM TRANSMITTANCE RESPONSE CHARACTERISTICS TO MILITARY SMOKES AND OBSCURANTS USING FIELD TEST DATA FROM TRANSMISSOMETER SYSTEM MEASUREMENTS
W. MICHAEL FARMER, ROGER DAVIS, ROBERT LAUGHMAN, and WENDALL WATKINS (Atmospheric Sciences Lab., White Sands Missile Range, NM.)   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 12 p (SEE N90-21907 15-32)   Mar. 1990
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Electro-optical weapon system developers and users must know the smoke/obscurant countermeasure transmittance levels required to defeat their systems. This information is required in order o establish both operational smoke screen requirements and system scenario applicability. Transmittance data acquired in field tests such as the Smoke Week tests, Smoke/Obscurants were developed for this purpose. Narrow-band transmittance data can be analyzed using the Beer-Bouguer transmittance law to evaluate the performance of narrow-band electro-optical weapon systems such as laser rangefinders. However, broadband transmittance data for smokes such as phosphorus, fog oil, and dust in the visible, 3 to 5, or 8 to 12 micron bands cannot be evaluated directly using the Beer-Bouguer transmission law for broadband electro-optical systems such as FLIRs. A method for transforming field-measured transmittance data into equivalent

electro-optical system transmittance is required. The transmissometer system analysis developed in the Project Manager, Smoke/Obscurants TRANSmissometer VALidation (TRANSVAL) program has provided the basis for developing such a method. The method developed in the TRANSVAL program for computing equivalent broadband electro-optical sensor transmittance from field test data is described. It is shown that band averages of the mass extinction coefficient used with the Beer-Bouguer transmission law do not yield correct estimates of equivalent electro-optical system transmittance. Examples are provided to illustrate the kinds of errors that can arise if sensor performance is incorrectly interpreted using field test data.   Author

N90-21940#   Atmospheric Sciences Lab., White Sands Missile Range, NM.
EFFECT OF ATMOSPHERIC TURBULENCE ON ELECTRO-OPTICAL SYSTEMS
WALTER B. MILLER, JENNIFER C. RICKLIN, and DAVID H. MARLIN   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 10 p (SEE N90-21907 15-32)   Mar. 1990
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The IMTURB model characterizes the effects of clear air optical turbulence on electro-optical (EO) imaging devices and laser transmitters operating in the atmospheric surface boundary layer and is valid for wavelengths from the visible through the far infrared. Similarity theory and the Kolmogorov principle of universal equilibrium are employed to characterize optical turbulence structure over regions typical of applications, based on simple environmental observables. A profile for the refractive index structure parameter is estimated, then used as input to a weak perturbation propagation model. Receiver coherence diameter, log-amplitude variance, scintillation averaging length, isoplanatism effective path length, and related subsidiary propagation statistics are then estimated for a selected propagation path. Outer and inner scale profiles are also estimated for advanced applications. Model results for two sample cases are discussed.   Author

N90-21941#   British Aerospace Public Ltd. Co., Bristol (England). Dept. of Advanced Information Processing.
ATMOSPHERIC MODELLING STUDIES: A MODELLING COMPARISON BETWEEN IR AND MILLIMETRIC ATMOSPHERIC PROPAGATION
A. R. TOOTH   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 5 p (SEE N90-21907 15-32)   Mar. 1990
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When viewing through the atmosphere, whether by naked eye or with some electro-optic sensor, viewing performance is largely dictated by the composition of the intervening atmosphere. The composition of this atmosphere is continually changing with the fluctuations of the prevailing meteorology and will also differ in different geographical locations. Despite the fact that it is known that prevailing meteorology affects sensor and consequently overall system performance the phenomena is seldom explored and is often made excessively complicated. A technique developed at the Sowerby Research Centre, at British Aerospace, allows the meteorological effect to be rigorously, but simply, evaluated. Using the technique that was developed, in conjunction with atmospheric propagation models, for example LOWTRAN, realistic comparisons can be performed between different waveband IR systems and different millimetric frequency systems.   Author

N90-21942# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
FAST METHOD FOR COMPUTING INFRARED TRANSMISSION, COMPUTATION EXAMPLES
A. M. BOUCHARDY and A. P. JUNCHAT (Centre d'Electronique de l'Armement, Rennes Armees, France) In AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 8 p (SEE N90-21907 15-32) Mar. 1990 In FRENCH
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A fast method for computing infrared transmission is described, it allows an effective transmission computation of a horizontal path with good precision. Two examples of applications of this method are presented. The first is a description of a weather station which allows the determination of infrared transmission from the ground. The second is from an atlas of infrared transmissions in France. Transl. by E.R.

N90-21997# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany, F.R.). Institut fuer Hochfrequenztechnik.
THE SOLUTION OF SCATTERING AND RADIATION PROBLEMS FOR COMPLEX CONFIGURATIONS BASED ON 3-D GRID AND PATCH MODELS
V. STEIN In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 22 p (SEE N90-21975 15-34) Mar. 1990 Sponsored in part by Bundesamt fuer Wehrtechnik und Beschaffung, Koblenz, Fed. Republic of Germany
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The increasing interest in predicting the scattering and radiation characteristics of objects with a complicated structure has stimulated the development of several theories. A rigorous treatment of the electrodynamic problem requires the solution of a boundary value problem based on Maxwell's differential equations or on the equivalent integral equations. The application of rigorous methods for objects whose dimensions are large compared to the wavelength is limited by the required computer memory and execution time. Therefore, methods which solve the boundary value problem approximately come into consideration. Each type of solution method involves a typical model either of the surface or the volume of the structure and its surroundings. So, geometric models consisting of canonical shapes, wire-grids, surface patches, and volume cells are described and the requirements of the specific solution methods are discussed. In some cases estimations for the necessary modeling accuracy are given. Methods which are based on geometrical-optics principles require models where the surface parts which are illuminated by the incident wave and the surface parts which are hidden can be separated for each aspect angle. Such a procedure is discussed as well as the procedure to treat double reflections. Some computational examples for radiation and scattering processes are given and comparisons with measurements are made. Author

N90-26178# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
PROPAGATION EFFECTS AND CIRCUIT PERFORMANCE OF MODERN MILITARY RADIO SYSTEMS WITH PARTICULAR EMPHASIS ON THOSE EMPLOYING BANDSPREADING
Dec. 1989 422 p In ENGLISH and FRENCH Symposium held in Paris, France, 17-21 Oct. 1988
(AGARD-CP-442; ISBN-92-835-0511-5; AD-A218763) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The importance of understanding radio wave propagation increases as radar and communication systems become increasingly complex. Signal processing for modern systems can be realized in software. The recent development of such signal processors is radically changing the engineering approach to designing communications equipment. Advanced realizations for tactical communications in modern armies, now include digital transmission, voice and data capability and ECM resistant systems. Various techniques are needed to enhance security of communications and to improve resistance to jamming. The

state-of- the-art in development of present day radio communication systems; the role and the need for radio propagation research; the assessed effects of propagation on existing systems and proposed improvements for new systems to meet operational requirements are examined. For individual titles, see N90-26179 through N90-26208.

N90-26179# Communications Research Centre, Ottawa (Ontario).
AN OVERVIEW OF CANADIAN RADIO PROPAGATION/COMMUNICATIONS TECHNOLOGIES RESEARCH
J. S. BELROSE, R. BULTITUDE, D. CLARK, R. W. JENKINS, W. LAUBER, G. NOURRY, N. M. SERINKEN, and G. VENIER In AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 30 p (SEE N90-26178 20-32) Dec. 1989
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The Communications Research Center (CRC) has and is carrying out research in radio propagation and radio communications technologies. Some of this research is briefly overviewed. The overview will begin with a brief tutorial on the characteristics of fading channels. Topics to be addressed include: characterization and simulation of the channel (HF and land mobile channels); simulation of the HF spread spectrum channel; broad band adaptive antennas; and coding and packet switching technologies (particularly for the HF channel). The subject of miniprocessors and radio will be briefly mentioned. B.G.

N90-26180# Hull Univ. (England). Dept. of Electronic Engineering.
A GLOBAL COMMON-USER SYSTEM FOR THE PROVISION OF HF PROPAGATION DATA
M. DARNELL, J. HAGUE, and A. CHAN In AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 14 p (SEE N90-26178 20-32) Dec. 1989
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The system design described comprises a world-wide network of HF transmitters and receivers designed to allow the collection of field strength and other propagation data. The primary objective of the system is to enable the effectiveness of HF propagation/noise prediction methods to be enhanced by means of real-time measurement data. Historically, control of HF broadcasts and communications was heavily dependent on off-line path predictions; however, the degree of precision associated with such propagation analysis is somewhat limited. Some use was also made of passive monitoring of known transmitters to update off-line models, but problems of transmitter identification and inappropriate signal formats limit the efficiency of this approach. For these reasons, a system was designed comprising a number of dedicated HF transmitters, sited in different parts of the world, and emitting signals with a defined format, unique to each site. Reception of the signals can take place at various levels of sophistication, depending on the requirements and resources of the users. Information about transmitter identification, signal strength, phase stability, fading, multipath structure, signal-to-noise ratio, noise/interference, and predicted error rates for digital traffic can all be extracted from the transmissions. The signals can be received and exploited by a range of users. Facilities for system evolution in response to user requirements are incorporated. The detailed design philosophy of the system, the implementation of a prototype system, and the results of trials carried out with the prototype system over a medium range skywave path are described. Problems of system deployment and global data collection and analysis are also discussed. B.G.

N90-26181# Centre National d'Etudes des Telecommunications, Lannion (France).
EXPERIMENTAL ANALYSIS OF THE HF LINKAGE [ANALYSE EXPERIMENTALE DE LIAISONS HF]
Y. M. LEROUX, R. FLEURY, J. MENARD, and J. P. JOLIVET In AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 9 p (SEE N90-26178 20-32) Dec. 1989 In FRENCH
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The improvement of the quality and reliability of decametric scale transmission through a better understanding of the mechanics of ionospheric wave propagation was attempted. Accordingly, an experimental characterization tool was prepared at CNET. This system is operational at about 650 km, located at midlatitude. It allows simultaneous measurement of on the one hand, the impulse channel response at a frequency of 10 KHz, with a response period of 10 ms, and on the other hand, at 50 KHz, with parameters of set time, attenuation, and instant phases relative to each mode or propagation path. Analysis of characteristics of noise and interference are possible. The system and the main functional modes are described. There are examples of the experiment results. An important conclusion is that from their performance, the analysis of the links give insufficient evidence of the real existing channel (Watterson type), to explain in its totality the conduction of the ionospheric wave propagation. A general model of the channel, based on a representation of a linear system varying in time, is in being validated. Transl. by E.R.

N90-26182# Institute for Telecommunication Sciences, Boulder, CO.
PROGRESS AND REMAINING ISSUES IN THE DEVELOPMENT OF A WIDEBAND HF CHANNEL MODEL AND SIMULATION
L. VOGLER, J. HOFFMEYER, J. LEMMON, and M. NESENBERGS In AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 20 p (SEE N90-26178 20-32) Dec. 1989 Sponsored in part by RADC
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Although high frequency (HF) communication systems were used for many decades, these systems are currently the subject of renewed interest, particularly in assessing the capabilities of the HF channel with regard to wideband (of the order of 12 to 1000 KHz) signals. This interest has generated a need for wideband HF channel propagation measurements and the development of wideband channel models and simulators. Recent work in wideband HF is briefly reviewed, some limitations of existing HF channel models discussed, on-going work at the Institute for Telecommunication Sciences in the development of a validated wideband HF channel model described, and key technical issues remaining in the development of this model are discussed. B.G.

N90-26183# Laboratoire d'Etude des Transmissions Ionospheriques, Cachan (France).
OPTIMAL SYNCHRONIZATION OF SPREAD SPECTRUM SEQUENCED BY NONTRANSFERABLE SWITCHING OPERATORS [SEQUENCES D'ETALEMENT A SYNCHRONISATION OPTIMALE PAR COMMUTATION D'OPERATEURS INCOMMUTABLES]
C. GOUTELARD In AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 7 p (SEE N90-26178 20-32) Dec. 1989 In FRENCH
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One of the main problems in spread spectrum transmission lies in the difficulty of acquiring of synchronization of spread spectrum sequencing. The procedure is based on the correlation of the long sequences necessary for the large number of operations considered nontransferable in the classical method. Meanwhile, there are the sequences in which the switching operations are possible, which reduces the number of operations, alleviates the complexity of decoders, and assures with maximum security,

synchronization in minimum time. The mathematical limits that must be respected in sequencing in order to obtain the switchability of the operators are defined and a sequencing structure is proposed. A series of sequences is given as an example. Transl. by E. R.

N90-26184# British Telecom Research Labs., Ipswich (England).
RADIO CHANNEL MEASUREMENT AND MODELLING FOR FUTURE MOBILE RADIO SYSTEMS
E. GUERDENLI and P. W. HUISH In AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 11 p (SEE N90-26178 20-32) Dec. 1989
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Digital mobile radio systems will require planning methods that provide accurate predictions of signal strength, distortion, and interference for situations ranging from very small cells in dense urban locations to large rural cells. Topographic and land usage data will find increasing use to enhance the accuracy of prediction models. The implications of these issues are discussed and the work in progress at British Telecommunications Research Laboratories on land mobile radio propagation modeling and wide-band channel measurements is presented. B.G.

N90-26185# Thomson-CSF, Gennevilliers (France).
BROADBAND ANALYSIS OF GROUND WAVE PROPAGATION AT A50 TO 400 MHZ [ANALYSE LARGE BANDE DE LA PROPAGATION DES ONDES DE SOL DANS LA BANDE 150-400 MHZ]
D. SORAIS In AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 11 p (SEE N90-26178 20-32) Dec. 1989 In FRENCH
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Broadband ground wave propagation is studied in a semirural geographic area by measuring the complex impulse response from a fixed and a mobile station. The distribution of the main statistical estimators is presented for 150, 250, and 400 MHz. The analysis of multipaths is presented and the identification of their physical causes is shown by the location of their particular measurement. Transl. by E.R.

N90-26186# Forschungsinstitut der Deutschen Bundespost, Darmstadt (Germany, F.R.).
MEASUREMENT AND SIMULATION OF WIDESPREAD MOBILE RADIO CHANNEL CHARACTERISTICS
RUDOLF WERNER LORENZ In AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 7 p (SEE N90-26178 20-32) Dec. 1989
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The general model of the transmission characteristics in mobile radio is derived. It is shown which abstractions are necessary to come up with the wide-sense stationary uncorrelated scattering (WSSUS) model. This model, well known from troposcatter propagation, is valid in mobile radio only for small vehicle travel distances. Nevertheless, the WSSUS model proved to be ideal for system test performance in mobile radio. The reasons are explained. A frequency-selective fading simulator recently developed in France and Germany is described, which is based on the WSSUS model and proved to be a very suitable tool for hardware test of mobile radio equipment. The key dates of mobile radio channel characteristics standardized by COST 207 are briefly presented. B.G.

N90-26187# Institut National des Sciences Appliquees, Rennes (France). Laboratoire Structures Rayonnantes.
ESTIMATION OF THE IMPULSE RESPONSE OF A BROADBAND MOBILE RADIO CHANNEL IN SUBURBIA AT 910 MHZ [ESTIMATION DE LA REPONSE IMPULSIONNELLE DU CANAL RADIOMOBILE LARGE BANDE EN SITE SUBURBAIN A 910 MHZ]
M. SALEHUDIN, G. ELZEIN, J. J. BAI, A. DANIEL, and J. CITERNE *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 9 p (SEE N90-26178 20-32) Dec. 1989 In FRENCH
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A method is presented for the estimation of impulse response of a broadband radio channel, in UHF, beginning with the parameters relating to the environment. It covers the relative position of the transmitter to that of the mobile radio. These transmitters are distributed randomly in a homogeneous environment and function like a secondary source of waves emitting only one beam in the direction of the receiver. The environmental parameters are drawn, beginning with the existing topographic map sections. The height of the transmitters, conducting a 3-D geometric model, is introduced by an effective bistatic radar section. The radar determines the reflectance of the transmitters. Comparison of the results of the estimation which was drawn from the measurement of the actual channel was given a functional form by use of the paths of intervals of a known delay. This shows agreement in suburban areas.   Transl. by E.R.

N90-26188# CyberCom Corp., Arlington, VA.
WIDEBAND CHARACTERIZATION OF FOREST PROPAGATION CHANNELS
ALLAN SCHNEIDER, FREDERICK J. ALTMAN, and KEVIN LACKEY (Army Communications-Electronics Command, Fort Monmouth, NJ.) *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 14 p (SEE N90-26178 20-32) Dec. 1989
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Wideband propagation measurements within the frequency band 200 to 2000 MHz were made through a coniferous forest of Douglas fir at Fort Lewis, Washington, and through a deciduous forest of red maple in Coventry, Connecticut. Measurements were repeated at Fort Lewis in successive years following thinning of the forest, and twice within the same year at Coventry, before and after the autumn fall of leaves. These field measurements utilized wideband impulse-response measurements to characterize the UHF wideband forest propagation channel. The effort relied upon the U.S. Army's Wideband Propagation Measurement System (WPMS), a self-contained, mobile, automated, wideband propagation data acquisition and recording system. This measurement program was closely coupled to an analytic effort to develop a UHF forest propagation model suitable for predicting the transmission loss and delay spread experienced by a radiowave propagating through the forest. Both measured and predicted values of transmission loss and delay spread are reviewed as they relate to distance, antenna height, frequency, polarization, and biophysical forest parameters. Concepts bearing on the analysis and interpretation of the measured data are discussed, and conclusions drawn relating to communication system deployment in forests.   B.G.

N90-26189# Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux (France).
IN-BAND AMPLITUDE DISPERSION ON A MICROWAVE LINK
Y. K. LI (China Research Inst. of Radiowave Propagation, Xinxiang.), P. GOLE, and M. SYLVAIN *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 13 p (SEE N90-26178 20-32) Dec. 1989
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Statistical results of in-band amplitude dispersion on a microwave link during 1985 with diversity reception in France are represented. The large time extent of the data base allowed an analysis of the seasonal variations of in-band amplitude dispersion distributions. Worst-month distributions are also presented for each channel. Idealized switch diversity is investigated with the decision criterion of in-band amplitude dispersion. It was found that the potential improvement due to the space diversity technique in terms of the reduction in amplitude dispersion was remarkable. The frequency correlation coefficient of received amplitudes and powers in the summer of 1985 was computed on the experimental data base. Comparisons between experimental results and theoretical results were made for the two non-diversity channels for the summer period of 1985.   Author

N90-26190# Hull Univ. (England). Dept. of Electronic Engineering.
A DIGITAL METEOR-BURST COMMUNICATION (MBC) PROPAGATION PATH SIMULATOR
K. WATSON *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 15 p (SEE N90-26178 20-32) Dec. 1989
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An MBC propagation path simulator which was developed is discussed and the specification of this simulator is contrasted with that of a typical HF simulator. A discussion of how the simulator was implemented and how it is to be employed then follows. Finally, there is included a brief discussion of a few concepts which are to be investigated using the simulator. The final aim of the research is to produce an MBC system which makes more efficient use of the available capacity than previously reported systems.   B.G.

N90-26191# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, The Hague (Netherlands). Physics and Electronics Lab.
MAN-MADE NOISE IN A MILITARY ENVIRONMENT
K. S. KHO and P. A. VANDERVIS *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 7 p (SEE N90-26178 20-32) Dec. 1989
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Over the last few years the laboratory was involved in studies concerning the design of future radio systems and of electronic support measures (ESM). Within the ESM-scope special attention is paid to direction finding (DF), as it offers a powerful means of locating enemy transmitters. Because environmental noise may seriously confine the range of reliable operation of both systems, the availability of relevant data is of crucial importance. Attention is given to noise in the lower end of the VHF band, i.e., between 30 and 90 MHz. Statistics on atmospheric and galactic noise may be found in CCIR Report 322, and CCIR Report 258-3 provides information about man-made noise for areas described as urban, suburban, or industrial, etc., the military environment is (understandably) not mentioned. As it goes without saying that military equipment must above all work well in wartime, there is an obvious need to gather information on what is to be expected if it comes to the worst. Because a better way of filling this information gap was not found, measurements were performed during military maneuvers, by making use of Certain Strike, a large scale NATO exercise in Europe in September 1987. The idea

was supported by the Royal Netherlands Army (RNLA). The 4th division of the 1st NL corps hosted the team in Germany. B.G.

N90-26192# Communications Research Centre, Ottawa (Ontario). Dept. of Communications.
A NARROWBAND TACTICAL COMMUNICATION SYSTEM FOR THE VHF AND UHF MOBILE RADIO BANDS
L. BOUCHER, Y. JOLLY, and J. H. LODGE *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 14 p (SEE N90-26178 20-32) Dec. 1989 Sponsored by National Defence Headquarters
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A description of the research effort, performed in accordance with a National Defense (DND) sponsored Research Program, is presented. Goals fixed for the program aim at achieving good quality, encryptable voice communications in the VHF and UHF mobile bands within a channel spacing of about 3 kHz. A review of the desirable performance objectives of a land-mobile tactical voice communications system is presented, and the design strategy suggested to achieve this performance is described. Implementation includes the use of techniques such as frequency domain digital signal processing of single sideband speech, speech bandwidth reduction, and linear modulation. A study, and in some cases experimental evaluation, on promising bandwidth reduction techniques was done, and a method, called the dynamic frequency band extraction technique, was developed for this application. With this technique, a good voice quality is obtained by dynamically saving only about 1200 Hz of the original 3000 Hz voice spectrum. Taking into account the extra bandwidth required by the data, the frequency domain filtering, and the pulse shaping of the discrete-time samples, and using a highly linear power amplifier, the RF channel spacing of the modulated signal is expected to be approx. of 2.5 kHz. Author

N90-26193# Hull Univ. (England). Dept. of Electronic Engineering.
CHANNEL SELECTION AND CONTROL PROCEDURES IN AN AUTOMATIC HF SYSTEM
J. HAGUE *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 13 p (SEE N90-26178 20-32) Dec. 1989 Sponsored by Science and Engineering Research Council
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Conventional HF systems rely on a combination of human operators and off-line propagation prediction programs to determine an optimum operating frequency in what is a time-varying medium. Both these methods suffer drawbacks in that the rapidly varying nature of many HF paths lead to greatly reduced performance, since the system is unable to respond to the changing state of the medium. An automatic HF system is described which is intended to overcome many of the drawbacks associated with conventional methods of control. By utilizing cheap, amateur-grade equipment coupled with simple antenna systems, the system is able to carry data on one channel while assessing the usability of other channels assigned to that particular system. Measurements taken on alternative channels (probing channels) are compared with those of the current channel. The best channel currently available at each end of the link is then relayed to the other end by means of a robust data header on the user data channel. Thus each end of the link will always be transmitting on the optimum channel. In order to assess the usability of the channel, some means of real time channel evaluation (RTCE) is needed, both on the user's data and probing channels. The overall architecture of the automatic HF system is discussed and the methods of channel assessment performed detailed. A description of a variable-redundancy coding scheme utilized by the system is also given, since this enables the system to optimize the data throughout. Finally, a performance of various aspects of the system over an HF path are given. B.G.

N90-26194# Manchester Coll. of Science and Technology (England). Dept. of Electrical Engineering and Electronics.
AN EXPERIMENTAL MEDIUM SPEED WIDEBAND MODEM
ALASTAIR N. BRYDON and GEOFFREY F. GOTT *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 10 p (SEE N90-26178 20-32) Dec. 1989 Sponsored by Royal Signals and Radar Establishment, England
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An experimental high frequency (HF) modem which uses chirp signals swept across a voice channel bandwidth is discussed. The modem is able to adaptively excise interference from other HF users, and has inherent tolerance to frequency selective fading and additive white Gaussian noise. A number of experimental chirp signal formats were incorporated so as to achieve data transmission at rates of 75, 150, 300, and 600 bits per second, and error correction via interleaved Golay (23,12,3) code is included. The principles behind the experimental formats are outlined, and how they performed during 156 hours of tests over a 125 km HF sky-wave link is indicated. B.G.

N90-26195# Norwegian Defence Research Establishment, Kjeller. Div. for Electronics.
CORA: A DIRECT SEQUENCE SPREAD SPECTRUM RADIO FOR VOICE AND DATA
T. THORVALDSEN *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 16 p (SEE N90-26178 20-32) Dec. 1989
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For many years the ordinary FM radio (e.g., the VRC 12 family) was the workhorse in military forces throughout the world. This type of radio has some advantages; it is relatively simple and cheap, it has a low power consumption as a man-pack, and an excellent voice quality. Since the modulation type and details are known by everyone, however, the messages are easily intercepted and even rebroadcasted in order to fool the enemy. Age is also becoming an important argument for introducing a new radio generation on the market. Radios operating in the military VHF band 30 to 88 MHz are discussed. The requirements for such a radio will of course vary from country to country. The most important requirements are given. B.G.

N90-26196# Hull Univ. (England). Dept. of Electronic Engineering.
MULTIPLE-ACCESS TECHNIQUES FOR COMMUNICATION OVER DISPERSIVE RADIO CHANNELS
M. DARNELL and B. HONARY (Warwick Univ., Coventry, England) *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading p 16 (SEE N90-26178 20-32) Dec. 1989 Sponsored by Science and Engineering Research Council, England
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Conventional multiple-user/multiple-access techniques are reviewed which were employed on various types of radio channels. These techniques are time-division multiple access (TDMA), frequency-division multiple-access (FDMA), and code-division multiple-access (CDMA). Attention is turned to CDMA-type systems which appear to offer promise of reliable operation over dispersive radio paths. First consider the use of completely uncorrelated, as opposed to near-correlated, code sets. In practical CDMA systems designed to date, the latter class of codes was used. It is shown that completely uncorrelated sets have distinct advantages (particularly for packet data operations). Secondly, collaborative coding techniques are used to permit simultaneous transmission by several users sharing a common channel, with overall transmission rates in excess of that achievable with TDMA. The performance of three new collaborative coding multiple-access (CCMA) schemes, each with two users, under Gaussian noise conditions are described. Author

N90-26197# Thomson-CSF, Gennevilliers (France). Div. Telecommunications.
A VERSATILE INTEGRATED BLOCK CODES ENCODER-DECODER
P. A. LAURENT *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 10 p (SEE N90-26178 20-32) Dec. 1989 In FRENCH; ENGLISH summary (AGARD-CP-442) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A new Very Large Scale Integrated (VLSI) circuit which is designed to perform encoding and decoding of almost all Reed-Solomon and BCH codes (including generalized BCH) using symbol sizes from 1 to 8 bits. It is fully programmable by many standard microprocessors which consider it like any other more common co-processor. Its architecture allows a high bit rate and a great flexibility. The interfacing protocol is optimized for minimizing time constraint (mail boxes) and limiting programming effort: no advanced knowledge of codes is required to use it.   Author

N90-26198# Laboratoire d'Etude des Transmissions Ionospheriques, Cachan (France).
MINIMIZATION OF THE COST OF INFORMATION TRANSFER IN HF SPREAD SPECTRUM TRANSMISSION [MINIMISATION DU COUT DE TRANSFERT DE L'INFORMATION DANS LES TRANSMISSIONS HF A ETALEMENT DE SPECTRE]
C. GOUTELARD and J. CARATORI *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 12 p (SEE N90-26178 20-32) Dec. 1989 In FRENCH (AGARD-CP-442) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The spread spectrum is a well known technique with certain forms of HF because of the dispersivity of the channel and, more importantly, interference. The limits imposed by these channels and their effects on the signal are analyzed. The characteristics of the interference noise are determined by a series of measurements which are analyzed statistically. The effects of the limits due to the channel and interference are taken into account to help explain the different strategies possible. It is then shown that it is possible to minimize the cost of data transmission determined by the amount of energy used for the transmission of a Shannon of Information, as in the case of a perfect or semiperfect spread spectrum. A comparison of the different strategies is made. The choice is affected by the complexity of effective operation allowed by the detection.   Transl. by E.R.

N90-26199# Hull Univ. (England). Dept. of Electronic Engineering.
NEW SYNCHRONISATION TECHNIQUES APPLICABLE TO MULTI-TONE TRANSMISSION SYSTEMS
M. DARNELL and B. HONARY (Warwick Univ., Coventry, England) *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 8 p (SEE N90-26178 20-32) Dec. 1989 (AGARD-CP-442) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The synchronization techniques are applicable to both narrowband, multiple frequency shift keyed (MFSK) digital transmission systems and wideband frequency hopping systems. The techniques do not require specific synchronization overheads to be incorporated into the transmissions, but operate using the normal traffic signal formats. It is required that digital signal processing be employed at the receiver for the procedures to be effective. Three distinct synchronization methods are discussed: modulation-derived synchronization; code-derived synchronization; and combined modulation- and code-derived synchronization.   B.G.

N90-26200# Telecommunications Radioelectriques et Telephoniques, Le Plessis-Robinson (France).
SYNCHRONIZATION OF FREQUENCY SHIFT TRANSMISSION AND THE EFFECT OF OVERSAMPLING [SYNCHRONISATION DES TRANSMISSIONS EN EVASION DE FREQUENCE EFFET DU SURECHANTILLONNAGE]
J. P. VANUFFELEN *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 8 p (SEE N90-26178 20-32) Dec. 1989 In FRENCH (AGARD-CP-442) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

There are numerous communications necessary for the establishment of the synchronization of the receiver as related to the message received. In the course of initialization, several phases are defined: (1) The synchronization sequence over the frequency in the case of communication using frequency shifts; (2) The synchronization where the network goal is defined by the instant of message arrival and refinding the network again; (3) The synchronization of symbols sometimes called synchronization bits, which allows the definition of the instant of decision; and (4) The synchronization of the carrier in the case of coherent demodulation. One can also consider code synchronization in the case of encoded communications and synchronization of spread spectrum sequence for transmissions of this type. Herein, the main interest is in the synchronization and the sequence shift frequency and its impact on symbol synchronization.   Transl. by E.R.

N90-26201# Marconi Secure Radio Systems Ltd., Portsmouth (England).
NEW APPROACHES FOR RAPID SYNCHRONISATION FREQUENCY HOPPERS
A. D. BISSET *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 20 p (SEE N90-26178 20-32) Dec. 1989 (AGARD-CP-442) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The analysis and simulation of a typical synchronization protocol employed in a medium rate frequency hopper, specifically under poor signal conditions are described in detail. Bit slippage within the initial synchronization frame was identified as the major source of reduced performance of synchronization protocols. A set of performance curves is presented to enable the dependence on correlation threshold, and the ultimate receive probability for a given protocol, to be evaluated. The dependence on bit synchronizer phase locked loop (PLL) bandwidth was simulated, indicating that major improvement was possible at limit signal conditions. However, this was off-set by a reduced performance for better signal conditions. An effective solution to such a problem can be achieved by employing a combined bit and frame synchronizer. Simulation results for such a technique are also presented for comparison.   B.G.

N90-26202# Center for Remote Sensing, McLean, VA.
EFFECTS OF IONOSPHERIC MODIFICATION ON SYSTEM PERFORMANCE
SUMAN GANGULY *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 11 p (SEE N90-26178 20-32) Dec. 1989 (AGARD-CP-442) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Controlled ionospheric modification can be used for disrupting as well as facilitating communication and radar systems. After briefly describing the results achieved with the present day ionospheric modification facilities, a scenario is presented for the generation of strong and significant ionospheric modification. A few schemes are presented for the development of modern high power facilities using the state of the art technology and then the impact of such facilities on the system performance is described.   Author

N90-26203# Rediffusion Radio Systems Ltd., Crawley (England).
HF SPREAD SPECTRUM, AN AUDIT OF THE POWER REQUIREMENTS AND LPI VULNERABILITY
C. S. DENBRINKER *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 9 p (SEE N90-26178 20-32) Dec. 1989
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Electronic Countermeasures (ECM) and the response to ECM was widely introduced in frequency bands other than HF. The unique characteristics of HF generate a different set of problems. In this overview, the normal hygienic measures that can be adopted for communication are reviewed. Force fitting of trends in spectral occupancy has revealed that the power penalty to be paid for low error rate frequency hopping could be prohibitive. The arguments used here may shed new light on the differing views taken with respect to the VHF band, where the choice of location could influence the efficacy assessment. Parallel diversity over a restricted bandwidth appears to offer a low probability of intercept in the case of dense occupancy and thus negate the need for excessive frequency hopping powers. Author

N90-26204# Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux (France).
COMBINED EFFECTS OF FAST AND SELECTIVE FADING ON PERFORMANCE OF PSK AND MSK WITH COHERENT DETECTION
ARMAND J. LEVY *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 8 p (SEE N90-26178 20-32) Dec. 1989
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Depending on the symbol rate and on the particular channel conditions, mobile radio communications can be affected by fast fading, by selective fading, or by both of them. In order to determine when each effect should be considered, the performance of PSK and MSK with coherent detection is theoretically evaluated in the presence of a fast and selective fading channel. A numerical method of analysis is derived for Gaussian Wide Sense Stationary Uncorrelated Scattering channel, taking into account the phase recovery error induced by the degraded channel. Results are presented for cases of practical interest. It appears that for some severe channel conditions, none of the fast and selective fading can be neglected. Author

N90-26205# Institut National des Sciences Appliquees, Rennes (France). Laboratoire Structures Rayonnants.
EXPERIMENTAL STUDY OF A DIGITAL MOBILE RADIO SPREAD SPECTRUM IN AN URBAN SITE [ETUDE EXPERIMENTALE D'UNE LIAISON NUMERIQUE RADIOMOBILE A ETALEMENT DE SPECTRE EN SITE URBAIN]
G. ELZEIN, M. SALEHUDIN, A. DANIEL, J. J. BAI, and J. CITERNE *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 12 p (SEE N90-26178 20-32) Dec. 1989 In FRENCH
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The investigation and results of a digital mobile radio at 910 MHz, using the spread spectrum for immediate sequencing is reported. The use of this links is with a communication system or a measuring system for characterization of the urban mobile radio channel. Effective performance measurement, accomplished with good theoretical agreement, is obviously better than spread spectrum. Effective propagation measurement on the true linkage is shown from the spatial and temporal variations on the external signal reception and also on the instantaneous flutter fadings of the impulse response of channel transmissions. These measurements allow the termination of a statistical model of channel transmission and the improvement of the quality of the multipath linkage. Transl. by E.R.

N90-26206# Norwegian Defence Research Establishment, Kjeller.
PACKET RADIO NETWORK CONCEPTS FOR THE NORWEGIAN FIELD ARMY
TORE BERG, JOHN ERIK RUSTAD, and OLE HENRIK STOREN *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 26 p (SEE N90-26178 20-32) Dec. 1989
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The Norwegian army has taken a very close look at the advantages in integrating weapon control systems, general CCIS, and tactical communication. All these services are provided by the commumication area system TADKOM consisting of a nodal trunk part and a mobile radio part. The concept laid down for TADKOM is based on the idea of a unified system with decentralized net-control and where voice and data are integrated into one system. The mobile radio part of TADKOM is presented and what is identified as the most critical design issue is stressed. Author

N90-26207# Thomson-CSF, Gennevilliers (France).
EXPERIMENTATION OF A TRANSMISSION SYSTEM DATA PROCESSING BY METEOR BURSTS [EXPERIMENTATION D'UN SYSTEME DE TRANSMISSION DE DONNEES PAR CANAL METEORIQUE: THEOREME]
P. SICILA, D. SORAIS, and F. BARRIER *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those Employing Bandspreading 19 p (SEE N90-26178 20-32) Dec. 1989 In FRENCH
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A data transmission system was made using meteor burst theory. The project was accomplished in three phases. The first phase was with point to point links alternating between 2 stations 350 km apart, phases 2 and 3 were linked by broadcasting from a vehicle and air paths, respectively. The experiments were conducted at several powers (1 kW, 200, 100, and 50 W) in VHF and in fixed frequency range of 40 to 43 MHz. The model permits an effective measuring test of the opening and closing of the channel and the error rate as well as the message transmission. The measured mean flow is in the range of 100 to 185 characters/per sec with a maximum of 300 to 400 characerters/sec. Transl. by E.R.

N90-26208# Massachusetts Technological Lab., Inc., Bethesda, MD.
SYSTEM FACTORS TO BE CONSIDERED IN ASSESSING PROPAGATION EFFECTS ON MODERN DIGITAL SATELLITE COMMUNICATIONS SYSTEMS
D. J. FANG and H. SOICHER (Army Communications-Electronics Command, Fort Monmouth, NJ.) *In* AGARD, Propagation Effects and Circuit Performance of Modern Military Radio Systems with Particular Emphasis on those employing bandspreading 12 p (SEE N90-26178 20-32) Dec. 1989
(Contract DAAB07-88-C-A007)
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In the traditional approach of assessing system impact due to propagation anomalies, the primary effort is on the characterization of a propagation channel to the maximum extent possible. In such an approach, environmental parameters (which affect the channel transfer function) and the system parameters (which dictate the system performance) are largely uncoupled. For instance, the transfer function for an ionospheric scintillation channel is characterized by ionospheric irregularity parameters, irrespective of whether the communications system is digital or analog, with or without interleave/coding, in the prescence or absence of diversity. From assessing the system impact's viewpoint, the lack of coupling is acceptable to the conventional analog system (an 8 dB propagation degradation implies an 8 dB reduction of S/N irrespective of whether the system is AM or FM, single side band or double side band), but is not acceptable for the modern digital system (an 8 dB propagation degradation can imply $10(exp -3)$

BER for a QPSK system without coding but can also imply 10(exp -6) BER for the same system with coding and interleave). System factors to be considered in the assessment of propagation effects are outlined.The essence is to point out, for modern digital satellite communications systems, propagation assessment has to have proper system reference in order to provide readily useful conclusions for system engineers. Author

N90-27006# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
SPEECH ANALYSIS AND SYNTHESIS AND MAN-MACHINE SPEECH COMMUNICATIONS FOR AIR OPERATIONS
May 1990 128 p Lecture series held in Trondheim, Norway, 14-15 May 1990, in Ankara, Turkey, 17-18 May 1990, and in Asbury Park, NJ, 22-23 May 1990
(AGARD-LS-170; ISBN-92-835-0561-1; AD-A223777) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Following an explanation and discussion of the importance of voice communications for military operations, including the environmental and propagation effects and ECM, the Lectures will outline: speech coding which is mainly concerned with man-to-man voice communication; speech synthesis which deals with machine-to-man communication; and speech recognition which is related to man-to-machine communication. All these are techniques which involve speech compression or speech coding at low-bit rates are needed for transmitting speech messages with a high level of security and reliability over low data-rate channels and for other applications such as memory-efficient systems for voice storage and response. For individual titles, see N90-27007 through N90-27014.

N90-27007# Technical Univ. of Istanbul (Turkey).
OVERVIEW OF REQUIREMENTS AND NETWORKS FOR VOICE COMMUNICATIONS AND SPEECH PROCESSING
A. NEJAT INCE In AGARD, Speech Analysis and Synthesis and Man-Machine Speech Communications for Air Operations 27 p (SEE N90-27006 21-32) May 1990
(AGARD-LS-170) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The use of voice for military and civil communications are discussed. The military operational requirements are outlined in relation to air operations, including the effects of propagational factors and electronic warfare. Structures of the existing NATO communications network and the evolving Integrated Service Digital Network (ISDN) are reviewed to show how they meet the requirements. It is concluded that speech coding at low-bit rates is a growing need for transmitting speech messages with a high level of security and reliability over low data-rate channels and for memory-efficient systems for voice storage, voice response, and voice mail. Furthermore, it is pointed out that the low-bit rate voice coding can ease the transition to shared channels for voice and data and can readily adopt voice messages for packet switching. The speech processing techniques and systems are then outlined as an introduction to the lectures of this series in terms of: the character of the speech signal, its generation and perception; speech coding which is mainly concerned with man-to-man voice communication, speech synthesis which deals with machine-to-man communication; speech recognition which is related to man-to-machine communication; and quality assessment of speech system and standards. Author

N90-27008# Marconi Speech and Information Systems, Portsmouth (England).
THE SPEECH SIGNAL
MELVYN J. HYNT In AGARD, Speech Analysis and Synthesis and Man-Machine Speech Communications for Air Operations 12 p (SEE N90-27006 21-32) May 1990
(AGARD-LS-170) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A non-mathematical introduction is provided to the speech signal. The production of speech is first described, including a survey of the categories into which speech sounds are grouped. This is followed by an account of some properties of human perception of sounds in general and of speech in particular. Speech is then compared with other signals. It is argued that it is more complex than artificial message bearing signals, and that unlike such signals speech contains no easily identified context-independent units that can be used in bottom-up decoding. Words and phonemes are examined, and phonemes are shown to have no simple manifestation in the acoustic signal. Speech communication is presented as an interactive process, in which the listner actively reconstructs the message from a combination of acoustic cues and prior knowledge, and the speaker takes the listner's capacities into account in deciding how much acoustic information to provide. The final section compares speech and text, arguing that cultural emphasis on written communication causes projection of the properties of text onto speech and that there are large differences between the styles of language appropriate for the two modes of communication. These differences are often ignored, with unfortunate results. Author

N90-27009# California Univ., Santa Barbara. Center for Information Processing Research.
SPEECH CODING
ALLEN GERSHO In AGARD, Speech Analysis and Synthesis and Man-Machine Speech Communications for Air Operations 14 p (SEE N90-27006 21-32) May 1990 Sponsored in part by Bell Communications Research, Inc., Bell-Northern Research, Inc., Rockwell International Corp., and the California State MICRO Program
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Recent advances in algorithms and techniques for speech coding now permit high quality voice reproduction at remarkably low bit rates. The advent of powerful single-chip signal processors has made it cost effective to implement these new and sophisticated speech coding algorithms for many important applications in voice communication and storage. Some of the main ideas underlying the algorithms of major interest today are reviewed. The concept of removing redundancy by linear prediction is reviewed, first in the context of predictive quantization or DPCM. Then linear predictive coding, adaptive predictive coding, and vector quantization are discussed. The concepts of excitation coding via analysis-by-synthesis, vector sum excitation codebooks, and adaptive postfiltering are explained. The main idea of vector excitation coding (VXC) or code excited linear prediction (CELP) are presented. Finally low-delay VXC coding and phonetic segmentation for VXC are described. Author

N90-27010# Bell Telephone Labs., Inc., Murray Hill, NJ. Speech Research Dept.
CURRENT METHODS OF DIGITAL SPEECH PROCESSING
LAWRENCE R. RABINER, B. S. ATAL, and J. L. FLANAGAN In AGARD, Speech Analysis and Synthesis and Man-Machine Speech Communications for Air Operations 9 p(SEE N90-27006 21-32) May 1990 Submitted for publication
(AGARD-LS-170) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The field of digital speech processing includes the areas of speech coding, speech synthesis, and speech recognition. With the advent of faster computation and high speed VLSI circuits, speech processing algorithms are becoming more sophisticated, more robust, and more reliable. As a result, significant advances have been made in coding, synthesis, and recognition, but, in each area, there still remain great challenges in harnessing speech technology to human needs. In the area of speech coding, current algorithms perform well at bit rates down to 16 kbits/sec. Current research is directed at further reducing the coding rate for high-quality speech into the data speed range, even as low as 2.4 kbits/sec. In text-to-speech synthesis speech is produced which is very intelligible but is not yet completely natural. Current research aims at providing higher quality and intelligibility to the synthesis speech produced by these systems. Finally, in the area of speech and speaker recognition, present systems provide excellent performance on limited tasks; i.e., limited vocabulary, modest syntax, small talker populations, constrained inputs, and favorable signal-to-noise ratios. Current research is directed at solving the problem of continuous speech recognition for large vocabularies, and at verifying talker's identities from a limited amount of spoken text. Author

N90-27011# Bell Telephone Labs., Inc., Murray Hill, NJ. Speech Research Dept.
SPEECH RECOGNITION BASED ON PATTERN RECOGNITION TECHNIQUES
LAWRENCE R. RABINER   *In* AGARD, Speech Analysis and Synthesis and Man-Machine Speech Communications for Air Operations 10 p (SEE N90-27006 21-32)   May 1990
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Algorithms for speech recognition can be characterized broadly as pattern recognition approaches and acoustic phonetic approaches. To date, the greatest degree of success in speech recognition has been obtained using pattern recognition paradigms. The use of pattern recognition techniques were applied to the problems of isolated word (or discrete utterance) recognition, connected word recognition, and continuous speech recognition. It is shown that understanding (and consequently the resulting recognizer performance) is best to the simplest recognition tasks and is considerably less well developed for large scale recognition systems.   Author

N90-27012#   Institute for Perception RVO-TNO, Soesterberg (Netherlands).
QUALITY EVALUATION OF SPEECH PROCESSING SYSTEMS
HERMAN J. M. STEENEKEN   *In* AGARD, Speech Analysis and Synthesis and Man-Machine Speech Communications for Air Operations 10 p (SEE N90-27006 21-32)   May 1990
(AGARD-LS-170)   Copyright   Avail: NTIS HC A07/MF A01;
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An overview of assessment methods is given for speech communication systems, speech synthesis systems, and speech recognition systems. The first two systems require an evaluation in terms of intelligibility measures. Several subjective and objective measures will be discussed. Evaluation of speech recognizers requires a different approach as the recognition rate normally depends on recognizer-specific parameters and external factors. Some results of the assessment methods for recognition systems will be discussed. Case studies are given for each group of systems.   Author

N90-27013#   Technical Univ. of Istanbul (Turkey).
SPEECH PROCESSING STANDARDS
A. NEJAT INCE   *In* AGARD, Speech Analysis and Synthesis and Man-Machine Speech Communications for Air Operations 14 p (SEE N90-27006 21-32)   May 1990
(AGARD-LS-170)   Copyright   Avail: NTIS HC A07/MF A01;
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Speech processing standards are given for 64, 32, 16 kb/s and lower rate speech and more generally, speech-band signals which are or will be promulgated by CCITT and NATO. The International Telegraph and Telephone Consultative Committee (CCITT) of the International body which deals, among other things, with speech processing within the context of ISDN. Within NATO there are also bodies promulgating standards which make interoperability, possible without complex and expensive interfaces. Some of the applications for low-bit rate voice and the related work undertaken by CCITT Study Groups which are responsible for developing standards in terms of encoding algorithms, codec design objectives as well as standards on the assessment of speech quality, are highlighted.   Author

N90-27014#   Rome Air Development Center, Griffiss AFB, NY.
APPLICATION OF AUDIO/SPEECH RECOGNITION FOR MILITARY APPLICATIONS
EDWARD J. CUPPLES and BRUNO BEEK   *In* AGARD, Speech Analysis and Synthesis and Man-Machine Speech Communications for Air Operations 10 p (SEE N90-27006 21-32)   May 1990
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Increases in the functional capabilities of military systems have made these systems increasingly more difficult to operate. Increased operator workload in modern workstations and aircraft have produced operator stress and fatigue, resulting in degraded operator performance, especially in time critical tasks. One reason for this problem is that both data entry and system control functions are often controlled via the systems keyboard. In some systems functions are nested many layers deep making the system inefficient and difficult to use. For this reason RADC has been developing technology to improve the interface between the Air Force system and its operator. Many efforts and several technologies are being pursued in speech recognition and synthesis, multimodal interface techniques, and voice interactive concepts and methods. This work is being conducted to satisfy the Air Force requirements for modern communication stations and the FORECAST 2 Battle Management and Super Cockpit Programs.   Author

N90-27454#   Microtel Pacific Research Ltd., Burnaby (British Columbia).
TACTICAL EHF SATELLITE COMMUNICATIONS FOR NATO EMPLOYING NON-GEOSTATIONARY ORBITS
M. JAMIL AHMED   *In* AGARD, Tactical Applications of Space Systems 17 p (SEE N90-27438 21-66)   May 1990
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Most of the world's satellite communications employ satellites in the geostationary orbit, for ease of tracking by the ground stations, and the ability to realize coverage of the populated regions of the globe with a set of three satellites. Geostationary satellites, however, afford poor visibility and degraded performance in the northern zones. This area is extensive and it is of strategic military importance. Satellites in the non-geostationary orbits can provide the required coverage in the north. The use of non-geostationary satellites is examined for tactical communication for NATO, their orbits, and implications for on-board processing.   Author

N91-12696*#   Draper (Charles Stark) Lab., Inc., Cambridge, MA. Fault-Tolerant Systems Div.
A HIGHLY RELIABLE, AUTONOMOUS DATA COMMUNICATION SUBSYSTEM FOR AN ADVANCED INFORMATION PROCESSING SYSTEM
GAIL NAGLE, THOMAS MASOTTO, and LINDA ALGER   *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 11 p (SEE N91-12682 04-08)   Apr. 1990
(Contract NAS1-17666; NAS1-18565)
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The need to meet the stringent performance and reliability requirements of advanced avionics systems has frequently led to implementations which are tailored to a specific application and are therefore difficult to modify or extend. Furthermore, many integrated flight critical systems are input/output intensive. By using a design methodology which customizes the input/output mechanism for each new application, the cost of implementing new systems becomes prohibitively expensive. One solution to this dilemma is to design computer systems and input/output subsystems which are general purpose, but which can be easily configured to support the needs of a specific application. The Advanced Information Processing System (AIPS), currently under development has these characteristics. The design and implementation of the prototype I/O communication system for AIPS is described. AIPS addresses reliability issues related to data communications by the use of reconfigurable I/O networks. When a fault or damage event occurs, communication is restored to functioning parts of the network and the failed or damage components are isolated. Performance issues are addressed by using a parallelized computer architecture which decouples Input/Output (I/O) redundancy management and I/O processing from the computational stream of an application. The autonomous nature of the system derives from the highly automated and independent manner in which I/O transactions are conducted for the application as well as from the fact that the hardware redundancy management is entirely transparent to the application.   Author

N91-21404# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
RADIO WAVE PROPAGATION MODELING, PREDICTION AND ASSESSMENT
JUERGEN H. RICHTER, ed. (Naval Ocean Systems Center, San Diego, CA.) 1991 139 p
(AGARD-AG-326; ISBN-92-835-0598-0; AD-A235180) Copyright
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An overview of important topics in radio wave propagation modeling, prediction and assessment is presented. Both propagation in the troposphere and the ionosphere are considered. For tropospheric radio wave propagation major emphasis is given to military systems operating in a marine environment. Various modeling techniques are discussed and operational propagation assessment systems described. Modeling and refractivity sensing of horizontally varying media are identified as topics of high interest. Ionospheric propagation is divided into four areas: long wave, short wave, transionospheric propagation, and scintillation phenomena. Various modeling techniques for long wave propagation and areas which require further attention are discussed. Short wave propagation remains an area of high interest and improvements in propagation assessment can be expected from more complex models and improved sensing techniques. Similarly, future advances for predicting transionospheric propagation require both improved models and sensing techniques. In the areas of ionospheric scintillations, both stochastic and morphological models are described. The need for an improved understanding of the solar and geomagnetic dependence of ionospheric scintillation is stressed. In addition, ground wave propagation is covered. An overview is also presented describing the structure of and the material available from the International Radio Consultative Committee. Author

N91-24472# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
ELECTRONIC COUNTER-COUNTER MEASURES FOR AVIONICS SENSORS AND COMMUNICATION SYSTEMS
Feb. 1991 116 p Symposium held in Ottobrunn, Fed. Republic of Germany, 1-5 Oct. 1990
(AGARD-CP-488; ISBN-92-835-0605-7; AD-A235714) Copyright
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The performance of sensor and communication systems can be limited significantly by hostile Electronic Counter Measures (ECM). These include passive measures such as radar and laser warning receivers, interception, emitter location systems as well as active measures such as jammers in various roles using different techniques and deception devices. Electronic Counter Countermeasures (ECCM) topics were addressed ranging from frequency agility to spread spectrum and data fusion techniques for both sensor and communications systems. For individual titles, see N91-24473 through N91-24483.

N91-24473# Shape Technical Center, The Hague (Netherlands).
A METHOD TO ENHANCE AZIMUTH ACCURACY BY THE USE OF THE A PRIORI KNOWLEDGE OF THE ANTENNA PATTERN
W. E. HOEKSTRA In AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 8 p (SEE N91-24472 16-32) Feb. 1991
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A method is presented to remove sidelobe contamination in antenna measurements for a circular scan antenna. Although the approach described is in principle only applicable to situations where the jamming is constant over one scan of data and requires perfect knowledge of the antenna pattern, it is shown that the method provides a substantial enhancement if these conditions are weakened. The mathematics used are not new, but this particular application might be. Author

N91-24474# Defence Research Establishment, Ottawa (Ontario). Radar Div.
ECCM ADVANTAGES OF ADAPTIVE DIGITAL PULSE COMPRESSION
GUY R. PAINCHAUD and MARTIN BLANCHETTE In AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 8 p (SEE N91-24472 16-32) Feb. 1991
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The Electronic Counter-Counter Measure (ECCM) advantages of an experimental adaptive digital pulse compression (DPC) system are described. This pulse compression system is implemented by a complex correlation between the transmitted waveform and the signal received by the radar. Central to the adaptability of this unit is the use of high speed VLSI digital ICs which permit bandwidths of up to 10 MHz, waveform or pulse code on each transmission. The DPC unit is intended to be used in a multifunction radar (MFR) which would employ many different waveforms. The objective is to describe how waveform adaptability can be used as an ECCM technique. Examples of its use as a counter-measure against both ESM (Electronic Support Measures) and ECM (Electronic Counter Measure) systems are given. Both denial and deceptive ECM are considered. Author

N91-24475# Magnavox Co., Fort Wayne, IN.
SATURN: THE NEXT GENERATION RADIO FOR NATO
JAMES F. KEATING and THOMAS M. SCHUERMAN In AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 9 p (SEE N91-24472 16-32) Feb. 1991
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The Second Generation Antijam Tactical UHF Radio for NATO (SATURN) system is described along with the URC-126 radio which will meet SATURN requirements when it enters production for the USAF. As its name implies, the system approach was jointly developed with NATO countries as STANAG 4372. It is designed to meet UHF Voice and data communication requirements into the next century. The URC-126 radio will replace the ARC-164, and is being developed by the USAF as part of its Have Quick antijam program. The URC-126 will be the first of several SATURN radios. It has completed Full Scale Engineering Development and Qualification Testing using the USAF Have Quick 2A Fast Frequency Hopping (FFH) mode which is a precursor of SATURN. Production radios will have the full SATURN capability. The AF has also developed and qualified the GRC-234 which uses the Have Quick 2A FFH mode. Additionally, a SATURN radio is now in development for the European Fighter Aircraft (EFA). Author

N91-24476# Aerospace Corp., Los Angeles, CA.
OVERVIEW OF SURVIVABILITY TRADEOFFS FOR SELECTED ECCM WAVEFORMS
DONALD P. OLSEN In AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 8 p (SEE N91-24472 16-32) Feb. 1991
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While frequency spreading is the major contributor to antijam capability, it is usually of little help in nonfrequency selective scintillation caused by high altitude nuclear explosions or the natural ionosphere. The selection of modulation, coding, and interleaving parameters are the main determinants of a signal's performance in scintillation. These waveform features also influence the performance in jamming. The performance of slow frequency hopped waveforms is compared. The waveforms examined are the various combinations of modulation, coding, and decision type shown for DPSK and BPSK or MSK with rate 1/2 $K = 7$ convolutional coding or rate 1/4 concatenated coding and with hard or soft decisions. These comparisons are done for the environments of additive white Gaussian noise (AWGN), noise with scintillation, and for jamming. The performance differences range from 5 dB in AWGN to over 14 dB in certain inadequately interleaved partial band jamming cases. MSK with soft decision rate 1/4 coding outperformed DPSK with hard decision rate 1/2 coding in every case. Only the data communication and not the link acquisition waveforms is addressed. Author

N91-24477# Aerospace Corp., Los Angeles, CA.
CONCATENATED CODING WITH TWO LEVELS OF INTERLEAVING
SAMUEL LIM and MICHAEL NEWHOUSE *In* AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 10 p (SEE N91-24472 16-32) Feb. 1991
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A performance evaluation of an electronic counter counter measure (ECCM) communication system in a worst case partial band noise and partial band tone jamming scenario is documented. The ECCM communication system is composed of two levels of channel coding (concatenated coding) and two levels of interleaving. An analysis was performed for a concatenated code consisting of either a Reed-Solomon or a convolutional outer code and a conventional inner code, and the decoded bit error rates for typical binary modulation schemes (BPSK and DPSK) were obtained. The performance of these coded waveforms was compared with convolutionally encoded systems with respect to the required E sub b/N sub j to achieve an overall bit error rate of 10(exp -5). The results demonstrate a significant coding gain achievable from systems which adopt concatenated coding.
Author

N91-24478# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
ADVANCED ECCM TECHNIQUES FOR GPS PROCESSING
EDMUND BALBONI, JOHN DOWDLE, JOSEPH PRZYJEMSKI, and ELLEN MALLERY (Wright Research Development Center, Wright-Patterson AFB, OH.) *In* AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 12 p (SEE N91-24472 16-32) Feb. 1991
(AGARD-CP-488) Copyright Avail: NTIS HC/MF A06;
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Two advanced Electronic Counter Countermeasures (ECCM) enhancement techniques were shown to greatly improve the antijam performance of Global Positioning System (GPS) receivers. The first method, Amplitude Domain Processing (ADP), is a nonlinear precorrelation processing technique which adapts to a changing ECM environment and exploits the statistical properties of strong nonGaussian jammers to significantly reduce their effectiveness. ADP was demonstrated in hardware against a heavily jammed GPS signal; measured performance shows a reduction in continuous wave (CW), pulsed CW and swept CW jammer power of 36, 25, and 26 dB respectively. The second technique, Extended Range Adaptive Tracking, is a correlation process which optimally adjusts tracking loop bandwidths and multiple correlator weights in response to changing levels of GPS signal dynamics and ECM power levels. The extended range feature tolerates the growth of tracking error beyond the 1 or -1 chip conventional limit to + or -5 chips to guard against loss-of-lock under exceptionally severe combinations of jamming and dynamics. Analysis and simulations have shown that this technique can extend the receiver tracking threshold by an additional 26 dB.
Author

N91-24479# Communications Research Centre, Ottawa (Ontario).
IMPROVING THE ECCM PERFORMANCE OF FAST FREQUENCY HOPPING BY DIVERSITY COMBINING
E. BARRY FELSTEAD and T. AARON GULLIVER (Defence Research Establishment, Ottawa, Ontario) *In* AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 11 p (SEE N91-24472 16-32) Feb. 1991
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The antijam performance of fast frequency hopping spread spectrum communications is proportional to the ratio of the spread bandwidth to the hop rate. In fast hopping, there are L greater than or = 1 hops per data symbol transmitted. In the presence of very strong jammers, improvement of the antijam performance may be required. Extra Electronic Counter CounterMeasure (ECCM) performance can be obtained by using the redundancy, L, in a process called diversity combining. To date, the predominant type

of diversity combining uses some nonlinearity to reduce the effect of a very powerful jamming signal on a few of the L hops. Normalized envelope detection (NED) is the best example of this type. A new type, called the moment subtraction method, is introduced. Examples of both types are described and then error performance results are presented for very large noise and multitone jamming (SJR = 0 dB). It is found that bit error rates as high as 0.4 can be reduced to less than 0.1 for L less than 10 by both types of diversity combining and that one of the moment methods does even better than the baseline NED method.
Author

N91-24480# Shape Technical Center, The Hague (Netherlands). Communications Div.
AN OVERVIEW OF ECCM FACTORS IN MILSATCOM SYSTEMS
M. SAFAK *In* AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 12 p (SEE N91-24472 16-32) Feb. 1991
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The relative significance of the factors affecting the Electronic Counter Countermeasure (ECCM) performance of MILSATCOM systems are identified and discussed. These factors are identified through the performance predictions for MILSATCOM systems, operating with geostationary satellites, under up- and downlink jamming. The factors influencing the system performance against signal exploitation and repeat back jamming are also discussed. A discussion is provided of the effects of the frequency of operation (SHF and EHF bands) on the ECCM factors.
Author

N91-24481# Aerospace Corp., Los Angeles, CA.
PERFORMANCE OF MILSATCOM ADAPTIVE ANTENNA SYSTEMS IN PULSE JAMMER ENVIRONMENTS
W. B. GAIL and IRA M. WEISS *In* AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 6 p (SEE N91-24472 16-32) Feb. 1991
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MILSATCOM antennas which use a linear gradient adaptive nulling algorithm to cancel interference respond differently to pulse jammers than to continuous wave (CW) jammers with the same peak output power. For a pulse jammer, the antenna adapts to cancel the interference when the jammer is on and recovers toward the unadapted state when the jammer is off. The adaptation time constants are approximately proportional to the received jammer signal power and the system noise respectively; the attack time constant is generally much smaller than the release time constant. An effective pulse jammer exploits this time dependence to prevent the antenna from fully cancelling the interference. For a particular antenna system, the worst case pulse jammer for a given waveform can be expected to occupy a well defined region of the operating space defined by the aspect angles, signal power, jammer power, duty cycle, and pulse repetition frequency (PRF). The effect of each of these parameters on antenna performance is studied for a multiple pulse jammer environment. The worst case operating space is identified for typical MILSATCOM antennas and the characteristics of the operating space are compared.
Author

N91-24482# Aerospace Corp., Los Angeles, CA.
PERFORMANCE TRADEOFF OF MILSATCOM ADAPTIVE MULTIBEAM ANTENNAS
DAVID H. SENENSIEB, IRA M. WEISS, and YOUNG S. KIM *In* AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 11 p (SEE N91-24472 16-32) Feb. 1991
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MILSATCOM satellite communication applications may require servicing a collection of users distributed over a localized geographical area in the presence of interfering noise sources. Recent interest in such applications has focused on the use of adaptive nulling antennas to counter interference by shaping the radiation pattern in response to the signal environment. The nulling performance of gimballed multibeam antennas (GMBAs) are

compared for hexagonal and square feed arrangements for two reflector diameters. Performance is characterized by the percent of the coverage area available for communication parameterized by data rate (area coverage mode) and by user/jammer separation resolution (spot beam mode).   Author

N91-24483#   Wright Research Development Center, Wright-Patterson AFB, OH.
A MODULATION QUALITY FACTOR FOR LOW PROBABILITY OF INTERCEPT (LPI) COMMUNICATIONS SYSTEMS
GLENN PRESCOTT (Kansas Univ., Lawrence.), LAWRENCE GUTMAN, and DAN CONNOLLY   *In* AGARD, Electronic Counter-Counter Measures for Avionics Sensors and Communication Systems 6 p (SEE N91-24472 16-32)   Feb. 1991
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    LPI (low probability of intercept) system quality factors were developed in a previous effort in order to provide a quantitative analysis tool for the system engineer to employ in evaluating the effectiveness of LPI techniques in the presence of jammers and intercept receivers. These LPI system quality factors were derived from the system link equations which describe the signal power gains and losses as a function of system link parameters. The issue is examined of LPI modulation by defining the modulation quality factor. The LPI modulation quality factor is a measure of the covertness of a particular type of modulation when detection is attempted by a particular type of intercept receiver. The utility of this quality factor is illustrated by examples and performance curves which demonstrate the concept.   Author

N91-25905#   Technical Univ. of Norway, Trondheim.
BROADER COMMUNICATION BANDS
GUNNAR STETTE   *In* AGARD, Bridging the Communication Gap 10 p (SEE N91-25902 17-82)   Feb. 1991
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    Telecommunications is transportation of information. Before discussing the capacities of the emerging transportation system for this type of goods, different services are examined and a set of references are established, both for volume of information, which is expressed in bits or Megabits, and for information transfer rates or channel capacities, which is expressed in bits per second, (bit/s). The highways for information, the broadband communications channels and systems are studied, and this means systems where the transmission requires a considerable higher bandwidth or bit rate than what can be accomplished via the ordinary analogue telephone system. Materials for broadband communication include data files, high resolution graphics (including 3-D and animated graphics), documents or images, and moving pictures. Broadband communications will extend the prominent role the image now plays in newspapers, books, brochures, slides and business sector.   Author

N91-25909#   Tome Associates Ltd., London (England).
THE ROLE OF INTELLIGENT ONLINE INTERFACES TO BRIDGE THE COMMUNICATION GAP
A. VICKERY   *In* AGARD, Bridging the Communication Gap 9 p (SEE N91-25902 17-82)   Feb. 1991
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    A great deal of technical and professional communication today, is mediated through documents, or even more indirectly, through computer systems. Communication gaps between man and system are just as real and important as any other, and it is this kind of gap that is considered. The difficulties are listed which arise in accessing computer-based information: (1) the language barriers such as databases in different national languages, concepts having different meanings in different databases (or parts of the same database), variations in command or query languages; (2) the intellectual difficulties, i.e., the gap in knowledge which exists in the searcher's mind during the stage of search formulation, the misunderstandings which can arise during the human/human communication (if the search is done by an intermediary), and errors arising from human/computer communication during the search process; and (3) the technical barriers in achieving a

satisfactory search result, i.e., in communication with various hosts and many databases, in using telecommunication links, in different techniques in interrogating files, in different indexing methods, in variations in structure of vocabularies, in classification. The current achievements in overcoming the barriers to information for online databases and the problems which still need solutions are summarized.   Author

N91-26432#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
DIGITAL SIGNAL CONDITIONING FOR FLIGHT TEST, VOLUME 19
G. A. BEVER (National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.)   Jun. 1991   92 p
(AGARD-AG-160-VOL-19; ISBN-92-835-0621-9; AD-A240140)
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    Flight test instrumentation engineers are provided with an introduction to digital processes on aircraft. Flight test instrumentation systems are rapidly evolving from analog intensive to digital intensive systems, including the use of onboard digital computers. Topics include: measurements that are digital in origin, sampling, encoding, transmitting, and storing of data. Particular emphasis is placed on modern avionic data bus architectures and what to be aware of when extracting data from them. Some example data extractions are given. Tradeoffs between digital logic families, trends in digital development, and design testing techniques are discussed. An introduction to digital filtering is also covered.
          Author

N91-27390#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
ELECTROMAGNETIC INTERFERENCE AND ELECTROMAGNETIC COMPATIBILITY
Jun. 1991   146 p   Lecture Series held in Kjeller, Norway, 10-11 Jun. 1991; in Koenigswinter, Fed. Republic of Germany, 13-14 Jun. 1991; and in Lisbon, Portugal, 17-18 Jun. 1991
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    Two aspects of the current electromagnetic (EM) environment having great significance for NATO systems are: (1) electromagnetic interference (EMI); and (2) electromagnetic compatibility (EMC). The Lecture Series first sets EMC in a NATO operational context. Major EMI generation mechanisms are then reviewed and their characteristics outlined. The manner in which EMI energy couples into EM systems is discussed, together with the analysis and modeling tools available to assist in computing such interactions. Modern EMC testing methods and environments are then examined and their limitations indicated. The relationship between NATO and civilian EMC requirements are examined in the light of the European Community EMC Directive. Consideration is also given to the problems of spectrum management. Finally, design principles and techniques for EM systems with effective EMC characteristic are presented. For individual titles, see N91-27391 through N91-27399.

N91-27391#   SRI International Corp., Arlington, VA. Information and Telecommunications Sciences Center.
NATURAL AND MAN-MADE NOISE AND INTERFERENCE: MECHANISMS AND CHARACTERISTICS Abstract Only
G. H. HAGN   *In* AGARD, Electromagnetic Interference and Electromagnetic Compatibility 2 p (SEE N91-27390 19-32)   Jun. 1991
(AGARD-LS-177) Copyright Avail: NTIS HC/MF A07;
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    The objective is to define noise (a cause) and interference (an effect) and describe some of the sources of both natural and man-made radio noise and interference which have the potential to degrade the performance of radio and other electromagnetic systems of interest to NATO. The following types of sources are included: natural noise (e.g., from lightning, the sun, and the cosmos); and man-made noise (e.g., from external sources such as powerlines and ignition systems and from sources internal to a

receiving system associated with electronic devices and components). The source mechanisms are discussed as well as the characteristics of the sources and their signatures in the bands from extremely low frequency through super high frequency. The Consultative Committee for International Radio (CCIR) estimates of worldwide minimum effective antenna noise figures versus frequency and empirical noise models (for noise of natural and man-made origin) are presented and discussed. Modeling the composite noise environment generated by multiple types of sources is discussed. The analytical models of Hall and Middleton are described. The proper combining (in a model of overall system noise figure) of the predictions of models for individual external and internal noise sources are discussed. The effect of noise on analog voice and on digital communications systems also discussed. High frequency channel occupancy and band congestion are defined, and the measurement and modeling of congestion are discussed. Noise measurements and standards are reviewed, and future noise trends are discussed.   Author

N91-27392# York Univ. (England). Dept. of Electronics.
PROPAGATION AND COUPLING MECHANISMS
A. C. MARVIN *In* AGARD, Electromagnetic Interference and Electromagnetic Compatibility 13 p (SEE N91-27390 19-32) Jun. 1991
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The background electromagnetic theory needed to understand the phenomena that lead to (EMC) problems, the techniques used to alleviate the problems, and the measurement techniques used to assess the problems are covered. A discussion of the concepts associated with vector and scalar fields are discussed and then Maxwell's Equations and their solution in the form of electromagnetic waves are reviewed. The structure and properties of electromagnetic waves are also reviewed. Concepts associated with inductive and radiative coupling between circuits are discussed, and the boundary between the two coupling types is explored in terms of the separation of the coupled circuits as a fraction of the wavelength.   Author

N91-27393# Concordia Univ., Loyola Campus, Montreal (Quebec).
Electromagnetic Compatibility Lab.
NUMERICAL ANALYSIS AND MODELLING TECHNIQUES
STANLEY J. KUBINA *In* AGARD, Electromagnetic Interference and Electromagnetic Compatibility 18 p (SEE N91-27390 19-32) Jun. 1991 Sponsored in part by Department of National Defence and Defence Research Establishment
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The complex task of ensuring the electromagnetic compatibility of modern avionic/weapon systems can be made more manageable by the effective use of numerical analysis and modeling techniques. The acquisition and use of computer codes for system analysis and electromagnetic modeling is rewarded by a clearer appreciation of the individual interactions between systems and by the definition of coupling mechanisms. Such use also involves and requires the generation of a progressively improved data base of information on equipment characteristics and radiating elements. The modern computational tools which can be exploited in the complex task of assuring the electromagnetic compatibility of modern avionic/weapon systems are discussed.   Author

N91-27394# Kentucky Univ., Lexington. Dept. of Electrical Engineering.
CABLES AND CROSSTALK
CLAYTON R. PAUL *In* AGARD, Electromagnetic Interference and Electromagnetic Compatibility 14 p (SEE N91-27390 19-32) Jun. 1991
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Crosstalk is the unintentional electromagnetic coupling between circuits which are connected by parallel conductors that lie in close proximity to each other. Some examples are wires in cable harnesses or metallic lands on printed-circuit boards (PCB's). This unintended interaction between two or more circuits via their

electromagnetic fields can cause interference problems. Signals from one circuit that couple to another circuit appear at the terminals of the devices that are interconnected by the wires. If these signals are of sufficient magnitude or spectral content, they may cause unintended operation of the device or a degradation in its performance. A summary of the standard models used for predicting crosstalk in various types of configurations is presented. The discussion focusses on the relative accuracies, regions of applicability, and computational complexity of the models. A simple explanation of the ability (or inability) of shielded wires and twisted pairs of wires to reduce the crosstalk is also given.   Author

N91-27395# Katholieke Industriele Hogeschool West Vlaanderen, Oostende (Belgium).
GROUNDING, SHIELDING, AND BONDING
J. CATRYSSE *In* AGARD, Electromagnetic Interference and Electromagnetic Compatibility 10 p (SEE N91-27390 19-32) Jun. 1991
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In the electromagnetic compatibility design (EMC) of systems and circuits, both grounding and shielding are related to the coupling mechanisms of the system with (radiated) electromagnetic fields. Grounding is more related to the source or victim circuit (or system) and determines the characteristic of the coupling mechanism between fields and currents/voltages. Shielding is a way of interacting in the radiation path of an electromagnetic field. The basic principles and practical design rules are discussed.
                    Author

N91-27396# FitzSimons (T. K.), Bergerac (France).
A REVIEW OF THE NATO EMC ANALYSIS PROGRAMME AND RELATED EUROPEAN COMMUNITY DEVELOPMENTS
T. K. FITZSIMONS *In* AGARD, Electromagnetic Interference and Electromagnetic Compatibility 12 p (SEE N91-27390 19-32) Jun. 1991
(AGARD-LS-177) Copyright Avail: NTIS HC/MF A07;
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In support of the International Military Staff and the Allied Radio Frequency Agency, there has been a NATO electromagnetic compatibility (EMC) Analysis Program since 1973. Early work involved compatibility of fixed frequency systems and the development of frequency assignment models. More recently, the work has involved problems associated with the compatibility of frequency hopping systems and their management. Increasing competition for limited spectrum space by both military systems themselves and also by civil systems coupled with the need for more dynamic frequency management in the battlefield poses many compatibility interests for the future. Military and civil EMC interests are also becoming more inter-related because of European Community decisions concerning telecommunications and electronic devices. A review of the program and related developments in Europe are presented.   Author

N91-27397# Hull Univ. (England). Communications Research Group.
SPECTRUM MANAGEMENT AND CONSERVATION
M. DARNELL *In* AGARD, Electromagnetic Interference and Electromagnetic Compatibility 25 p (SEE N91-27390 19-32) Jun. 1991
(AGARD-LS-177) Copyright Avail: NTIS HC/MF A07;
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A review of the basic concepts of radio spectrum utilization and the physical mechanisms of electromagnetic (EM) wave propagation of relevance to radio, radar, control, and navigation systems is presented. Then, a survey of the uses of the various bands in the radio frequency (RF) spectrum is also presented. Interactions between the propagation mechanisms introduced previously and frequency planning requirements are considered, making reference to the precision of available modeling and prediction procedures; emphasis is given to interference generation potential. Attention is then turned to equipment and system design features which affect their spectral occupancy characteristics, including RF equipment imperfections, signal design, system design and control, and cositing problems. Finally, the manner in which

the bands of the radio spectrum are allocated and controlled is outlined, and areas of possible future concern in both NATO and civil operations identified. Author

N91-27398# York Univ. (England). Dept. of Electronics.
MEASUREMENT ENVIRONMENTS AND TESTING
A. C. MARVIN   In AGARD, Electromagnetic Interference and Electromagnetic Compatibility 24 p (SEE N91-27390 19-32) Jun. 1991
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The various methods used to assess both the emission (interference generation) performance of electronic equipment and the immunity of electronic equipment to external electromagnetic interference are described. The measurement methods attempt to simulate realistic operating conditions for the equipment being tested, yet at the same time they must be repeatable and practical to operate. This has led to the development of a variety of test methods, each of which has its limitations. Concentration is on the most common measurement methods such as open-field test sites, screened enclosures and transverse electromagnetic (TEM) cells. The physical justification for the methods, their limitations, and measurement precision are described. Ways of relating similar measurements made by different methods are discussed, and some thoughts on future measurement improvements are presented.
Author

N91-27399# Katholieke Industriele Hogeschool West Vlaanderen, Oostende (Belgium).
DESIGN PRINCIPLES OF EFFECTIVE EMC
J. CATRYSSE   In AGARD, Electromagnetic Interference and Electromagnetic Compatibility 15 p (SEE N91-27390 19-32) Jun. 1991
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Effective electromagnetic compatibility (EMC) design is directly related on minimizing the different effects in EMC: electromagnetic environment (EME), electromagnetic susceptibility, and the coupling/transmission paths. A short overview is given of the most important factors concerned with EMC design. It follows design parameters and design rules for each item. Author

N91-28465# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel Working Group 13.
CONSIDERATIONS FOR NATO SATELLITE COMMUNICATIONS IN THE POST 2000 ERA
A. NEJAT INCE, ed. (Marmara Research Inst., Gebze, Turkey) Jun. 1991 322 p
(AGARD-AG-330; ISBN-92-835-0622-7; AD-A239937) Copyright Avail: NTIS HC/MF A14: Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A substantial amount of information, some of it original, is presented on almost every aspect of satellite communications (systems architecture, design, devices, techniques, and technologies for space, ground and system control segments) which, it is hoped, will be found useful by a wide range of readers including military and political decision makers, planners, and the R and D community. Author

N91-30362# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
USE OR REDUCTION OF PROPAGATION AND NOISE EFFECTS IN DISTRIBUTED MILITARY SYSTEMS
C. GOUTELARD 1990 293 p In ENGLISH and FRENCH Symposium held in Rethymno, Greece, 15-18 Oct. 1990
(AGARD-CP-486; ISBN-92-835-0601-4) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The papers presented to symposium held by the Electromagnetic Wave Propagation Panel at its Fall 1990 meeting are compiled. The topics covered on the occasion of that symposium are: (1) effects on distributed systems of the space, the time, and the frequency coherence of waves; (2) jamming and noise reduction effects on distributed systems; and (3)

distributed systems (radio communications, radar systems, satellites, and ECM and ECCM in the systems). For individual titles, see N91-30363 through N91-30383.

N91-30363# Boston Univ., MA. Center for Space Physics.
THE DYNAMICS OF F-LAYER IRREGULARITIES RELATIVE TO SPACE, TIME, AND FREQUENCY DIVERSITY
JULES AARONS   In AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 13 p (SEE N91-30362 22-32) 1990 Sponsored by ONR
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With the statistics of morphology of F-layer irregularities now in hand, it is possible to forecast in broad terms what to expect at equatorial, auroral, and polar latitudes during various levels of solar flux. With the beginning of an understanding of the effect of the various phases of magnetic storms on generating irregularities as noted from the solar wind, ring current, convection, auroral index, and magnetic index parameters, it is possible to roughly forecast levels of F-layer irregularity intensity. With these in hand, the utility of space, time, and frequency diversity can be evaluated. Diversity could be used if forecasting in real time was possible. The dynamics of irregularity generation and inhibition during various phases of ring current and magnetic activity is outlined. Author

N91-30365# Johns Hopkins Univ., Laurel, MD. Applied Physics Lab.
THE UTILITY OF HIGH FREQUENCY GROUND WAVE IN A DISTRIBUTED COMMUNICATION SYSTEM
JAMES R. CHAMPION   In AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 6 p (SEE N91-30362 22-32) 1990
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High frequency ground wave (HFGW) communication in mountain terrain is investigated. Using a broadband, discone antenna and 100 watts of power, communication links in the 20 to 30 MHz band of at least 50 and, in some cases, as much as 115 km were established over mountainous paths. Links were non-line-of-sight, and immune to ionosopheric fading. Digital and wide-band frequency hopping communications were demonstrated using HFGW. The discone antenna is about 3.5 m high when assembled and can be made extremely portable. The spacial characteristics of the 20 to 50 MHz band coupled with the properties of the discone antenna would offer advantages to distributed communication systems in mountainous terrain. HFGW results are presented and it is discussed how this medium may be exploited in a distributed system which uses both frequency and spatial distribution. Author

N91-30366# Physics and Electronics Lab. TNO, The Hague (Netherlands).
RESULTS OF MEASUREMENTS PERFORMED ON HF BACKSCATTER FOR EVALUATING THE INFLUENCE ON SHORT RANGE HF DATA LINKS
P. J. VANVLIET and P. A. VANDERVIS   In AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 12 p (SEE N91-30362 22-32) 1990 Sponsored by Royal Netherlands Army
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On short range HF links, where the receiving station is relatively close to the transmitting station, reception of long delayed echoes (up to 20 ms) may occur due to backscatter. These backscatter signals will interfere with signals received through the legitimate path, which is either groundwave of nearly vertically incident skywave. Even on low data rate links this time dispersion of signals may cause intersymbol interference. In order to assess the influence of HF backscatter on short range HF data links, measurements were performed. Path delays were measured using a direct-sequence spread-spectrum technique. A carrier, BPSK (Binary Phase Shift Keying) modulated with a pseudo-noise (PN) sequence, was transmitted and the received signal was correlated with the same PN sequence. Measurements were taken in the Netherlands and Norway. The measurement results show that

especially on the short range link, long delayed echoes appear. The backscatter effect depends on propagation conditions, thus on frequency, time of day, season, and solar activity. **Author**

N91-30367# Royal Aerospace Establishment, Farnborough (England). Dept. of Applied Ionospheric Physics and Flight Systems.

OPTIMUM ANTENNA SPACING FOR DIVERSITY IN METEOR BURST COMMUNICATIONS SYSTEMS

PAUL S. CANNON, ANIL K. SHUKLA, and MARK LESTER (Leicester Univ., England) *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 13 p (SEE N91-30362 22-32) 1990

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Temperate latitude meteor burst (MB) space diversity measurements, using cross correlation analysis of 37 MHz signals scattered over an 800 km path are reported. Signals of duration greater than or equal to 0.75 s, received on antennas separated by 5, 10, and 20 lambda, are investigated using 6 days of data collected over a 9-day period during February 1990. Signal decorrelation is shown to be achieved by antenna separation of 5 lambda, and there is no apparent variation in average cross correlation coefficient, for antenna separations between 5 and 20 lambda, for any of the signal categories examined. **Author**

N91-30368# Thomson-CSF, Gennevilliers (France).

ANALYSIS OF EXPERIMENTAL RESULTS WITH METEOR LINKS CARRIED OUT AT DIFFERENT RANGES AND FREQUENCIES

D. SORAIS, O. RAVARD, and L. BERTEL (Rennes Univ., France) *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 14 p (SEE N91-30362 22-32) 1990 In FRENCH; ENGLISH summary

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The experimental results of meteor burst communications recorded at ranges from 100 to 1000 km are described. A physical interpretation of these results was obtained by using a statistical distribution of the meteor burst intervals and of the transfer function measurements. The resulting data base completes and improves the information provided by the traditional models. **Author**

N91-30369# SRI International Corp., Menlo Park, CA.

EXPERIMENTAL INVESTIGATION OF METEOR BURST FOOTPRINTS

M. RICH, P. HEILMAN, M. MURRAY, and B. YETSO *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 8 p (SEE N91-30362 22-32) 1990

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Meteor Burst Communication (MBC) provides reliable, beyond-line-of-sight data communications, but some serious throughput limitations are associated with the technology. One limitation is the finite waiting time required to send a message. This waiting time can be reduced by increasing the excess link margin, but this increases the cost and complexity of an MBC system. However, because of the limited footprint of a meteor trail, the waiting time for a system of networked stations can be reduced by spreading the stations over multiple footprints. The effects of spatial diversity on link throughput are described, and preliminary observations of signal footprint size and shape are presented. **Author**

N91-30370# Communications Research Centre, Ottawa (Ontario).

EIGENVECTOR WEIGHTING AS AN ADAPTIVE ARRAY INTERFERENCE CANCELLATION TECHNIQUE

R. W. JENKINS and K. W. MORELAND *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 13 p (SEE N91-30362 22-32) 1990

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Adaptive antenna techniques normally make use of known properties of the desired signal, such as its direction or an embedded code, to distinguish it from interference. When this is not possible, algorithms such as power ratio inversion or Gram-Schmidt are used. These techniques tend to invert the relative powers of signals arriving at the array, and thus are effective when the interference is substantially stronger than the desired signal. However, when signal levels are close, such techniques fail. Analytic and modeling studies are presented of the eigenvector weighting technique. It is shown that this technique performs substantially better than power ratio inversion techniques. Like the power ratio inversion methods, eigenvector weighting is most effective when there is a large separation in signal powers. However, even when the signals are close in power, satisfactory cancellation can be achieved with eigenvector weighting for a large fraction of cases. The actual performance depends on array geometry and number of elements. **Author**

N91-30371# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.

TECHNIQUES FOR ESTIMATING THE EFFECTS OF MAN-MADE RADIO NOISE ON DISTRIBUTED MILITARY SYSTEMS

D. B. SAILORS *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 14 p (SEE N91-30362 22-32) 1990

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Techniques are reviewed available for estimating the effects of man-made radio noise on distributed military systems using empirical man-made noise models. The models given in CCIR Report 258 are reviewed along with the empirical data base upon which they are based. Results of measurements of man-made noise are presented for six Pacific Ocean sites and for three Atlantic Ocean/Europe sites. Accumulative probability distribution models of increasing complexity are reviewed. Tests of fit of these distributions are presented for select samples of measured man-made noise data. **Author**

N91-30372# SRI International Corp., Arlington, VA. Information and Telecommunication Sciences Center.

TOWARD A GLOBAL MODEL OF HF OTHER-USER INTERFERENCE Abstract Only

G. H. HAGN *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 2 p (SEE N91-30362 22-32) 1990

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Information on other-user interference (sometimes called co-channel interference) is important in predicting the performance of HF systems. A method is described for development of a regional model for HF other-user interference in terms of congestion for allocated bands. Congestion is defined as the fraction of the channels in an allocated band of contiguous channels with detected energy exceeding a specified threshold. A global congestion model might eventually be achieved as a combination of regional models. **Author**

N91-30373# University of Southern California, Los Angeles. Communication Science Inst.
TOPOLOGY-SELECTIVE JAMMING OF FULLY-CONNECTED, CODE-DIVISION RANDOM-ACCESS NETWORKS
ANDREAS POLYDOROS and UNJENG CHENG (Jet Propulsion Lab., California Inst. of Tech., Pasadena.) *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 12 p (SEE N91-30362 22-32) 1990
(Contract DAAL03-87-C-0007)
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The purpose is to introduce certain models of topology selective stochastic jamming and examine its impact on a class of fully-connected, spread-spectrum, slotted ALOHA-type random access networks. The theory covers dedicated as well as half-duplex units. The dominant role of the spatial duty factor is established, and connections with the dual concept of time selective jamming are discussed. The optimal choices of coding rate and link access parameters (from the users' side) and the jamming spatial fraction are numerically established for DS and FH spreading. Author

N91-30374# Norwegian Telecommunications Administration, Oslo.
SOME CONSIDERATIONS CONCERNING LOW NOISE RADIO RECEIVING SYSTEMS
KNUT N. STOKKE *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 13 p (SEE N91-30362 22-32) 1990
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In order to get a good signal to noise ratio at very high frequencies (higher than 20 to 40 MHz), low noise amplifiers are often used. Such amplifiers should have a very low total noise factor (noise figure). Normally it is the noise factor of the first stage of an amplifier which is decisive for the total noise factor. Losses in the system will also influence the noise factor of the system. Consequently, the losses in cables and waveguides must be taken into account when considering the total noise factor. The thermal noise radiation from the surroundings may increase the noise temperature of an antenna. For reflector antennas, such as parabolic reflector antennas, the noise temperature is dependent on the elevation angle, but also on the form of the surroundings (mountains, hills, buildings, etc.). Author

N91-30375# Standard Elektrik Lorenz A.G., Pforzheim (Germany, F.R.).
PROPAGATION STUDIES OF A 60 GHZ COMMUNICATION SYSTEM
H.-J. OSTERTAG *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 7 p (SEE N91-30362 22-32) 1990
(AGARD-CP-486) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Measurement equipment for 60 GHz propagation measurements is described. Measuring conditions and environments, and measurements with mobile and fixed transmitters are discussed. The results of the propagation measurements were helpful in designing a 60 GHz radio system. Author

N91-30376# Nebraska Univ., Lincoln. Dept. of Electrical Engineering.
UTILIZATION OR REDUCTION OF THE EFFECTS OF SEA CLUTTER FOR REAL AND SYNTHETIC APERTURE POLARIMETRIC RADARS
EZEKIEL BAHAR *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 7 p (SEE N91-30362 22-32) 1990
(Contract DAAL03-87-K-0085; N00014-87-K-0177)
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The principal elements of the full wave solutions are summarized. The full wave solutions are invariant to coordinate transformations and they satisfy the reciprocity, realizability, and duality relationships in electromagnetic theory. Limiting forms of the full wave solutions are shown to reduce to the low frequency small perturbation solutions and the high frequency physical optics solution. Thus, the full wave solution provides the only direct relationship between the low frequency perturbation and the high frequency physical optics solutions. Tracing this relationship was a rather elusive endeavor, since even for surfaces that simultaneously satisfy the small perturbation limitation and the large radii of curvature restriction, these two solutions are not in agreement. Thus, there are no complications in applying the full wave solutions to scattering by composite surfaces with multiple scales of roughness, and there is no need to adopt hybrid (perturbed physical optics) solutions based on artificial decomposition of the surface into two surfaces with different scales of roughness. These hybrid solutions critically depend on the choice of the spatial wave number at which it is assumed that the separation occurs between the large and the small scale surface. Author

N91-30377# McDonnell-Douglas Research Labs., Saint Louis, MO.
EMISSIVITY AND TRANSMISSIVITY OF A RANDOMLY LAMINAR STRUCTURE
CORNEL EFTIMIU *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 10 p (SEE N91-30362 22-32) 1990
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Researchers considered a randomly laminar structure of constant width and investigated the scattering of scalar waves for active remote sensing and radiometric purposes. The approach is based on analytic wave theory involving the expansion of the field in Wiener-Hermite functionals, which are statistically orthogonal. A hierarchy of approximations is established and shown to represent in each order a partial summation of perturbation theory terms. The average field as well as the incoherently scattered field are determined, yielding the emissivity and transmissivity of the randomly laminar medium. The special case of small correlation length is examined in detail and proved to fulfill the energy conservation requirement. Author

N91-30378*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE NASA RADIOWAVE PROPAGATION PROGRAM
FARAMAZ DAVARIAN *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 6 p (SEE N91-30362 22-32) 1990
(Contract NAS7-100)
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The objectives of the NASA radiowave Propagation Program are to enable new satellite communication applications and to enhance existing satellite communication networks. These objectives are achieved by supporting radio wave propagation studies and disseminating the study results in a timely fashion. Studies initiated by this program in the 1980s enabled the infant concept of conducting mobile communications via satellite to reach a state of relative maturity in 1990. The program also supported the satellite communications community by publishing and revising two handbooks dealing with radio wave propagation effects for frequencies below and above 10 GHz, respectively. The program has served the international community through its support of the International Telecommunications Union. It supports state of the art work at universities. Currently, the program is focusing on the Advanced Communications Technology Satellite (ACTS) and its propagation needs. An overview of the program's involvement in the ACTS project is given. Author

N91-30379# Hull Univ. (England). Communications Research Group.
COMBINING OF SIGNALS IN A GEOGRAPHICAL DIVERSITY SYSTEM
T. J. SPEIGHT *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 11 p (SEE N91-30362 22-32) 1990
(AGARD-CP-486) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A technique which will improve the performance of microscopic diversity processing while minimizing additional computational and communications channel overheads is described. The focus is on the use of such diversity processing in the high frequency environment. Author

N91-30380# Hull Univ. (England). Communications Research Group.
DISTRIBUTED LONG-RANGE RADIO SYSTEMS EMPLOYING MULTIPLE PROPAGATION MECHANISMS AND AN EXTENDED FREQUENCY RANGE
M. DARNELL *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 12 p (SEE N91-30362 22-32) 1990
(AGARD-CP-486) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
With the aid of data from real radio paths of different types, the concept of multiple propagation mechanism radio communication in the high frequency and low- very high frequency bands up to about 100 MHz is introduced. The radio system architecture necessary to exploit such a multiple mechanism environment is considered, with particular reference to the channel encoding and channel evaluation procedures required. Digital signal processing is assumed. Author

N91-30381# Hull Univ. (England). Communications Research Group.
A RELIABLE MULTI-USER DISTRIBUTIVE HF COMMUNICATIONS SYSTEM USING NARROWBAND CDMA
T. E. MILLER *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 8 p (SEE N91-30362 22-32) 1990 Sponsored in part by Royal Airforce Establishment
(AGARD-CP-486) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
It is shown that the sequences and signals described can essentially provide the bearer signals in a code division multiple access (CDMA) communications system. A technique for modulating these bearer signals with information is discussed. The initial tests with this system show that it exhibits ideal properties for a reliable multi-user high frequency communications system. Simulated and field trials will be carried out to further demonstrate the effectiveness of these techniques over shared 3 kHz bandwidth high frequency single-side band channels. Author

N91-30382# Hull Univ. (England). Communications Research Group.
A DESIGN TESTBED FOR DISTRIBUTED V/UHF NETWORKS WITH MOBILE TERMINALS
ANDREW CARNEGIE *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 8 p (SEE N91-30362 22-32) 1990
(AGARD-CP-486) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A flexible design tool for mobile radio networks was implemented. Both low level areas such as modulation, coding, and synchronization, and high level techniques involving protocol details can be analyzed simultaneously. The simulation software is based on a Rayleigh fading channel model with a network layer protocol implementation. Described here is how a Rayleigh distribution can be generated and how it is used to implement the channel simulation by a conversion to a probability of error based on the modulation technique required. The network model is discussed with reference to the OSI Open Systems Interconnection reference model, and the variable configuration is described. To

access the success of the system, an investigation into the use of variable, optimum length packets is illustrated. Author

N91-30383# Royal Aerospace Establishment, Farnborough (England).
DOPPLER-MULTIPATH TOLERANT VOICE COMMUNICATION
R. M. HARRIS *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 11 p (SEE N91-30362 22-32) 1990
(AGARD-CP-486) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Line of sight communication between high performance aircraft has been found to be subject to a peculiar form of multipath radio wave propagation - Doppler multipath. It degrades analogue voice reception on the standard fit ultrahigh frequency radio, producing low frequency random noise and warbling. Various modifications were carried out on the aircraft's communications system, but the problem remained. All the evidence points to a natural phenomenon. The reported observations are corroborated by theoretical studies and laboratory simulations of multipath radio wave propagation between two points moving relative to a diffusely scattering reflector. Theoretical predictions of Rician fading have explained the disruption of speech transmitted using conventional dsb(am) modulation. This also indicated suppressing the carrier as a radical cure. Double sideband suppressed carrier radios have been developed for airborne evaluation in comparison with standard dsb(am). The air to air flying trials proved the superior performance of the suppressed carrier system under conditions of Doppler multipath. Author

N91-32241# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
PROPAGATION LIMITATIONS FOR SYSTEMS USING BAND-SPREADING
C. GOUTELARD, ed. 1990 180 p Lecture Series held in Issy-les-Moulineaux, France, 7-8 Jun. 1990; also held in Rome, Italy, 11-12 Jun. 1990; and at Hanscom AFB, MA, 19-20 Jun. 1990; sponsored in part by the Consultant and Exchange Program
(AGARD-LS-172; ISBN-92-835-0569-7; AD-A239924) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The use of spread spectrum signals in telecoms, detection, and remote sensing boosts system performance, ensures greater discretion, and improves ruggedness. State-of-the-art signal processing and the latest advances in processor technology use sophisticated techniques which point the way to new systems. The phenomena linked to propagation, noise and channel jamming, which limit performance, is examined together with procedures which either use or combat their effects. For individual titles, see N91-32242 through N91-32244.

N91-32242# Kaiserslautern Univ. (Germany, F.R.). Lehrstuhl fuer Hochfrequente Signaluebertragung und -Verarbeitung.
WIDE BAND SYSTEMS
PAUL WALTER BAIER and WERNER KLEINHEMPEL *In* AGARD, Propagation Limitations for Systems Using Band-Spreading 20 p (SEE N91-32241 24-32) 1990
(AGARD-LS-172) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Most radio communication systems being presently introduced are digital systems. Depending on the transmission bandwidth relative to the information rate, such systems can be divided into the class of narrow band systems and wide band systems. The advantages that wide band systems offer under adverse propagation conditions are studied. After introducing digital information transmission, digital wide band systems are defined on the basis of the used transmission signal forms and are compared with narrow band systems. The need for the application of wide band systems is pointed out referring to information theory, with the resistance against noise and interference as well as the capabilities of multiple access and selective addressing being addressed. Different types of wide band systems including spread spectrum are presented. The quantitative treatment of propagation problems in narrow band and wide band systems due to time

variant multipath propagation is tackled and the potential of wide band systems in combatting propagation effects is shown. It is explained that properly designed spread spectrum systems are less affected by multipath reception than narrow band systems.

Author

N91-32243# Universite Catholique de Louvain (Belgium).
PROPAGATION LIMITATIONS FOR TRANSIONOSPHERIC SYSTEMS FROM 10 TO 300 GHZ
A. VANDERVORST and D. VANHOENACKER *In* AGARD, Propagation Limitations for Systems Using Band-Spreading 19 p (SEE N91-32241 24-32) 1990
(AGARD-LS-172) Copyright Avail: NTIS HC/MF A09;
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Broadband characterization of the transionospheric propagation channel requires a study of physical phenomena which are often neglected, and, in particular, the frequency dependence of the parameters of the link. It may be due to water vapor, liquid water, and time dependent inhomogeneities. The 10 to 100 GHz band is studied with an emphasis on the 20 to 30 GHz band, and some indications for higher frequencies. Atmospheric turbulence is especially looked at, because it yields fluctuations of the refractive index, leading to amplitude, phase, and angle of arrival variations on the signal. A model developed is presented. It takes into account the various parameters of the link: frequency, dielectric constant, losses, antenna diameter, inhomogeneity size, and altitude. The influence on actual signals is discussed, as well as frequency response, impulse and step response, and group delay. Author

N91-32244# Manchester Coll. of Science and Technology (England).
HF SYSTEMS OPERATING BENEATH THE IONOSPHERE
G. F. GOTT and E. D. R. SHEARMAN (Birmingham Univ. England) *In* AGARD, Propagation Limitations for Systems Using Band-Spreading 27 p (SEE N91-32241 24-32) 1990 Sponsored in part by Ministry of Defence and Science Research Council
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The features of HF terrestrial and aeromobile wideband systems, all of which use ionospheric propagation or are interfered with by ionospherically propagated signals, are outlined. These systems include radio communication (predominantly digital), and HF radar. The properties which limit ionospheric propagation are discussed and their implications for systems illustrated by means of the scattering function and sweep frequency sounding data. Other problems of the ionospheric channel are atmospheric and man made noise, and spectral occupancy. Noise is briefly reviewed, but special attention is given to spectral occupancy, with the inclusion of measured statistics and a mathematical model. Examples are given of wideband communication systems using frequency hopping and chirp signals. The measures which can be taken to sustain operation in severe spectral congestion are illustrated. The rather different requirements of HF radar systems, both sky wave and ground wave, which demand the achievement of very wide dynamic range and Doppler discrimination, are also outlined and illustrated. Author

N92-12525# Mission Research Corp., Santa Barbara, CA.
AUTOMATED THREAT RESPONSE RECOMMENDATION IN ENVIRONMENTS OF HIGH DATA UNCERTAINTY USING THE COUNTERMEASURE ASSOCIATION TECHNIQUE (CMAT)
GEORGE B. CHAPMAN, GLENN JOHNSON, and ROBERT BURDICK *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 12 p (SEE N92-12517 03-63) Sep. 1991
(Contract F33657-89-C-2175)
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The CounterMeasure Association Technique (CMAT) is discussed which was developed for the Air Force, and is used to automatically recommend countermeasure and maneuver response to a pilot while he is under missile attack. The overall system is discussed, as well as several key technical components. These components include use of fuzzy sets to specify data uncertainty, use of mimic nets to train the CMAT algorithm to make the same resource optimization tradeoffs as made in a data base of library

of training scenarios, and use of several data compression techniques to store the countermeasure effectiveness data base.

Author

N92-12526# Lockheed Canada, Inc., Sittsville (Ontario).
FUTURE ESM SYSTEMS AND THE POTENTIAL FOR NEURAL PROCESSING
ARTHUR G. SELF and GREGORY P. BOURASSA *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 10 p (SEE N92-12517 03-63) Sep. 1991
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The projected radar electromagnetic environments (eme) for the future include: higher pulse densities; frequencies to 40 GHz and higher; stable, jittered, staggered and pseudo-random pulse repetition intervals (PRIs) with multiple frequencies; spread spectrum techniques; multiple agile radar beams and multimode missile seekers. Electronic Support Measures (ESM) concerns the passive detection and identification of radar signals. Thus, an ESM system which can measure such signal characteristics will most likely flood its main processor with information to such an extent that it may not be able to cope. A number of likely solutions exist ranging from special purpose hardware to new processing techniques. A radically different processing approach is reviewed, namely that of neural networks. The likely applicability is indicated of a neural processing approach to a range of ESM functions together with results from some preliminary proof of concept investigations. Author

N92-12537# Intelligent Electronics, Tel Aviv (Israel).
USING AITEST TO TROUBLESHOOT A RADAR MODULATOR (RM) UNIT: A CASE STUDY IN THE APPLICATION OF EXPERT SYSTEMS TO INTERMEDIATE-LEVEL TESTING
MOSHE BEN-BASSAT (Tel-Aviv Univ., Israel), DAPHNA BEN ARIE, ISRAEL BENIAMINY, JONATHAN CHEIFETZ, MICHAL ESHEL, NOAM FOGEL, YAEL KAROV, IRENE MENKIN, MORDECHAI SELA, MICHAL SHALEV et al. *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 8 p (SEE N92-12517 03-63) Sep. 1991
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AITEST is a real life expert system designed to serve as a decision aid and productivity tool for test engineers and technicians. Oriented for the functional level, AITEST is designed to troubleshoot large scale UUT's (Unit Under Test) that contain analog, digital, and mechanical modules in electronic, electrooptic, hydraulic, or mechanical systems and devices. Described here is a typical application of AITEST in an intermediate level manitenance facility. The UUT discussed is a radar modulator embedded in the radar system of a military aircraft. Author

N92-12541# Rome Air Development Center, Griffiss AFB, NY.
C3I GRAPHICAL APPLICATIONS
EARL C. LABATT, JR. *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 11 p (SEE N92-12517 03-63) Sep. 1991
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Past research efforts in the field of command, control, communications, and intelligence (C3I), have concentrated on the application and refinement of advanced artificial intelligence (AI) concepts. However, the man-machine interface to these advanced applications has experienced little improvement and does not adequately reflect some of the AI concepts embedded within these systems. The development of more advanced computing techniques requires a more sophisticated interface to the system. These enhancements cannot be adequately conceived by a user using traditional display techniques. The underlying AI concepts that help facilitate the transfer of information between acquired C3I data and an operator are revealed. Many of these concepts are discussed in regard to their application in current Tactical Air Force Research Projects. In addition, the limitations of previous program interfaces and the current advances in graphical interface techniques are discussed. The focus is on two decision aid systems that incorporate several AI concepts: the Tactical Expert Mission

Planner (TEMPLAR) and the Identification of Command and Control Operations Nodes (ICON).   Author

N92-19136#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Electromagnetic Wave Propagation Panel.
TARGET AND CLUTTER SCATTERING AND THEIR EFFECTS ON MILITARY RADAR PERFORMANCE
Sep. 1991   334 p   In ENGLISH and FRENCH   Meeting held in Ottawa, Ontario, 6-9 May 1991   Original contains color illustrations
(AGARD-CP-501; ISBN-92-835-0633-2)   Copyright   Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The symposium was organized into six sessions: two on clutter modeling and measurements, one on target scattering, one on signal processing, one on polarimetrics, one on applications, and two on classified topics. Specific topics covered include radar ground clutter measurements, a model of coherent radar land backscatter, parabolic equation modeling of backscatter from the rough sea surface, millimeter wave scattering from snow covered terrain, aspects of radar cross section calculation for targets of complex structure, grazing angle dependency of synthetic aperture radar, polarimetric monopulse radar scattering measurements at 95 and 225 GHz, and the reduction of target scattering by tropospheric modification. For individual titles, see N92-19137 through N92-19166.

N92-19137#   Massachusetts Inst. of Tech., Lexington.   Lincoln Lab.
RADAR GROUND CLUTTER MEASUREMENTS AND MODELS. PART 1: SPATIAL AMPLITUDE STATISTICS
J. BARRIE BILLINGSLEY   *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 15 p (SEE N92-19136 10-32)   Sep. 1991   Sponsored in part by Dept. of National Defence
(AGARD-CP-501)   Copyright   Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

We have collected a large multifrequency data base of radar clutter measurements from many sites. We employ our clutter data to develop clutter models. Of particular interest to us is the site-specific prediction of PPI ground clutter maps for ground sited radars. Discussed here are our measurements, a statistical clutter model for spatial amplitude statistics based on depression angle, terrain type, radio frequency, and radar resolution.   Author

N92-19138#   Defence Research Establishment, Ottawa (Ontario). Radar Div.
RADAR GROUND CLUTTER MEASUREMENTS AND MODELS. PART 2: SPECTRAL CHARACTERISTICS AND TEMPORAL STATISTICS
HING C. CHAN   *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 14 p (SEE N92-19136 10-32)   Sep. 1991
(AGARD-CP-501)   Copyright   Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The results of the spectral analysis show that ground clutter, as observed by a coherent radar with a stationary antenna, comprises three components: a coherent component, a slow-diffuse component, and a fast-diffuse component. These components can be described by relatively simple models. The model parameters are functions of radar frequency, waveform resolution, land cover, and wind speed. The results of the statistical analysis show that the Ricean distribution and its limiting case, the Rayleigh distribution, are appropriate models for ground clutter amplitude statistics in steady state wind conditions. The relative frequency of fit of the ground clutter statistics to each model depends on radar frequency, land cover, and wind speed. However, at any given time, there is a significant proportion of resolution cells in a surveillance area which exhibits non-stationary statistics. This non-stationary statistical behavior was a consequence of rapidly changing wind conditions. The results presented here are of use for the development of ground clutter spectral and statistical models, constant false alarm rate (CFAR) processors, and algorithms for improved low velocity target detection.   Author

N92-19139#   GEC-Marconi   Electronics   Ltd.,   Chelmsford (England).
A MODEL OF COHERENT RADAR LAND BACKSCATTER
G. C. SARNO   *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 11 p (SEE N92-19136 10-32)   Sep. 1991   Sponsored in part by Ministry of Defence
(Contract F19629-85-C-0002; ARPA ORDER 3724)
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The detection of targets in a land clutter background is a problem for most ground based and airborne pulse Doppler radars. Understanding how ground clutter behaves can lead to modified clutter suppression techniques for improving radar target detection performance. Presented here is a model of land clutter which was validated against a number of different land types observed at different frequencies. The characteristics of the clutter which limit target detection are discussed.   Author

N92-19140#   Rome Air Development Center, Hanscom AFB, MA.
A MODEL FOR BISTATIC SCATTERING OF ELECTROMAGNETIC WAVES FROM FOLIAGE COVERED ROUGH TERRAIN
ROBERT J. PAPA and DOUGLAS T. TAMASANIS (Arcon Corp., Waltham, MA.)   *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 12 p (SEE N92-19136 10-32)   Sep. 1991
(AGARD-CP-501)   Copyright   Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The problem of determining the electromagnetic (EM) power received by an antenna located over foliage covered rough terrain in a bistatic scattering geometry is important and quite complex. A model was developed which can quantitatively determine the effect of a foliage layer on EM waves scattered from rough terrain. The theoretical approximations obtained from this model are compared with data at two levels; the loss in penetrating the foliage and the total normalized scattering cross section sigma degrees. The results of this theoretical modeling are compared with experimental data at two levels. First, the effective dielectric constants for a foliage environment were used to calculate the attenuation constants of coherent waves propagating through a dense forest. The attenuation constants given by the model were compared with data taken at 200MHz, 500MHz and 800MHz, resulting in good agreement. Then, the entire bistatic scattering model was used to calculate an effective normalized scattering cross section (sigma degrees) for a sod field, grass, and forest covered terrain. This was compared with L-band data resulting in excellent agreement between theory and experimental data.
Author

N92-19141#   Rome Air Development Center, Hanscom AFB, MA.
BISTATIC SCATTERING STATISTICS OF DECIDUOUS TREES
K. V. N. RAO, W. G. STEVENS, and J. MENDONCA   *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 12 p (SEE N92-19136 10-32)   Sep. 1991
(AGARD-CP-501)   Copyright   Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Theoretical predictions have shown that significant variations in the power scattered by a rough surface exist when the orientation of a linearly polarized bistatic receiver is changed with respect to the transmitter polarization. Experiments conducted at laser frequencies have verified the existence of these polarization variations. This present work was performed to determine if this behavior could be observed at microwave frequencies at a field test site. The experimental results on the polarization dependence of bistatic scattering from deciduous trees are described. The bistatic scattered power from foliage (mixture of Birch, Maple, Ash and grass) at 3.2 GHz was measured as a function of the receiver polarization angle. Here data for one configuration is reported: incidence angle of 80 degrees, elevation scattering angle of 84 degrees, and one azimuthal scattering angle of 105 degrees. The scattering surface size was approximately 4.5 square meters. A wide band (200 MHz) S-band radar system was used to conduct these measurements. Both vertically and horizontally polarized

signals were transmitted. A brief discussion on the dependence of the location and depth of polarization nulls on the complex permittivity and roughness characteristics of the scattering surface is also given. Results of experiments show that measured and theoretical null locations are in reasonable agreement. Further measurements at additional azimuthal scattering angles will be made. Future plans include phase and amplitude measurements with a dual orthogonal-polarized receiving antenna to determine the ellipticity of scattered signals.　　　　　　　Author

N92-19142# Mission Research Corp., Monterey, CA.
ALTAIR UHF OBSERVATIONS OF BACKSCATTER ENHANCEMENT
DENNIS L. KNEPP　*In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 7 p (SEE N92-19136 10-32)　Sep. 1991　Previously announced in IAA as A91-42416
(Contract DNA001-87-C-0169; N00014-87-C-2336)
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　During the Defense Nuclear Agency (DNA) PEAK (Propagation Effects Assessment - Kwajalein) experiment in Aug. 1988, the ALTAIR VHF/UHF wide bandwidth radar was used to track spherical satellites in low earth orbit. The purpose of the experiment was to obtain radar data during the most severe propagation disturbances available naturally. The PEAK experiment was quite successful, giving many measurements of strong scintillation as well as the first measurements of frequency selective fading on propagating radar pulses. The experimental results are used to show an enhancement, due to scattering, in the average received power that is observed during severe scintillation. The observed statistics of the enhancement are compared to analytic calculations using the Nakagami-m distribution with very good agreement. This enhancement is predictable on the basis of the first order amplitude statistics for two way radar propagation in a monostatic propagation geometry as well as by a more thorough analysis using reciprocity; both analytic approaches are presented. The enhancement is important for both ground and space based radars that have to operate during scintillation.　　　　　　　Author

N92-19143# Rutherford Appleton Lab., Chilton (England). Radio Communications Research Unit.
PARABOLIC EQUATION MODELLING OF BACKSCATTER FROM THE ROUGH SEA SURFACE
M. F. LEVY　*In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 10 p (SEE N92-19136 10-32)　Sep. 1991
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　A physically based numerical method is presented for calculating sea clutter at low grazing angles for microwave frequencies. Sea clutter is modeled as a two scale phenomenon: at low grazing angles, the backscattered energy is generated by ripples on the sea surface. A first order perturbation method gives the backscatter from a small patch of surface, as a function of the angle of incidence and of the magnitude of the incident field. Returns from a clutter cell are obtained by incoherent summation of these echoes. Shadowing and tilting effects due to the larger scale components of the sea surface are modeled using a finite difference implementation of the parabolic equation method, which also deals with atmospheric refraction effects. Realizations of the sea surface with the desired spectral characteristics are generated with a Monte Carlo method. Results are presented at S band and X band for a variety of propagation conditions.　　　　　　　Author

N92-19144# Pisa Univ. (Italy).　Dept. of Information Engineering.
EXPERIMENTAL CHARACTERIZATION OF AMPLITUDE DISTRIBUTION OF MEDITERRANEAN SEA CLUTTER
G. CORSINI, E. DALLEMESE, M. DEPALO, A. M. RICCI, L. VANNI (Naval Academy, Livorno, Italy), and L. VERRAZZANI　*In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 10 p (SEE N92-19136 10-32)　Sep. 1991
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　Some results are presented relevant to experimental characterization of Mediterranean sea clutter. The data were collected by using an X band coastal radar sited on an Italian Navy area in Livorno. The aim is the collection of clutter samples in different conditions (weather conditions, carrier frequency, polarization and radar site) for clutter models validation, performance assessment and optimization of the radar processor.
　　　　　　　Author

N92-19145# Michigan Univ., Ann Arbor. Radiation Lab.
MODELING AND MEASURING MILLIMETER-WAVE SCATTERING FROM SNOW-COVERED TERRAIN
FAWWAZ T. ULABY, YASUO KUGA, and RICHARD AUSTIN　*In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 11 p (SEE N92-19136 10-32)　Sep. 1991
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　A radiative transfer model was developed for characterizing radar backscatter from snow covered ground at millimeter wavelengths. The model was used to evaluate the radar response to incidence angle, snow depth, snow surface roughness, and snow liquid water content, for both like and cross polarization configurations. The model behavior was compared with experimental observations made at 35, 95, and 140 GHz, including observations over diurnal cycles. The experimental data were acquired during the 1989 and 1990 winter seasons in Michigan using a truck mounted millimeter wave scatterometer system capable of observing the ground surface over a wide range of incidence angles for all linear combinations of transmit and receive antenna polarizations. Comparison of the measured data with model calculations revealed excellent agreement for dry snow as well as when the surface layer of the snowpack was wet. However, when the surface layer was dry and lower layers wet, the model results were inconsistent with the radar observations. To deal with the general case wherein the liquid water content exhibits a nonlinear profile with depth, a hybrid numerical first order solution of the radiative transfer model was developed.　　　　　　　Author

N92-19146*# Ohio State Univ., Columbus. ElectroScience Lab.
ANALYTICAL PREDICTION OF EM SCATTERING BY COMPLEX OBSTACLES WITHIN ELECTRICALLY LARGE OPEN CAVITIES
PRABHAKAR H. PATHAK　*In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 6 p (SEE N92-19136 10-32)　Sep. 1991　Sponsored in part by GE
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　An analytical technique is described for predicting the electromagnetic (EM) scattering by complex obstacles within electrically large open waveguide cavities. This topic is of relevance to EM scattering and EMC type applications. A general open ended waveguide cavity is illustrated and is assumed to be relatively arbitrarily shaped, and the open front end of the cavity is illuminated by an arbitrarily polarized external plane wave field. The interior obstacle is assumed to be located within the cavity near the back end, and it generally contributes significantly to the fields scattered into the exterior by the entire cavity configuration. The present scattering analysis is restricted to within approximately 70 degs from boresight with respect to the open front end; outside of this region, the scattering by the external features of the cavity are generally more significant than from the interior of the cavity. The scattering analysis is composed of two main parts. One analysis is of the coupling of the incident plane wave field, via the open front end using the high frequency ray or beam shooting methods.

The other analysis deals with separately obtaining the plane wave scattering characteristics of the interior obstacle. Thus the present analysis represents a hybrid combination of an asymptotic high frequency ray/beam method for tracking the fields through the cavity, together with any suitable method for obtaining a plane wave characterization of the interior obstacle. Author

N92-19147# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany, F.R.). Inst. fuer Hochfrequenztechnik.
RCS PREDICTION MODELS BASED ON PO AND PTD AND STATE OF VALIDATION
V. STEIN *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 15 p (SEE N92-19136 10-32) Sep. 1991 Sponsored in part by Bundesamt fuer Wehrtechnik und Beschaffung
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In the microwave case the scattering matrix of complicated targets is often evaluated on the basis of physical optics (PO). In cases where edge diffraction effects become relevant, the physical theory of diffraction (PTD) is used to correct the PO field. Both methods are applied in another paper to determine the radar cross section (RCS) of a series of perfectly conducting structures; a thin flat plate, a thin cylinder, a cone cylinder half sphere, a double dihedral, and a periscope-like object. Since the geometric model of each object consists of panels, internal and external tests were made to estimate the deviations between the true surface and the model surface which can be tolerated to guarantee sufficient accuracy. All predicted RCS values are compared either with measurements or with independent theoretical results as references. Conclusions for the accuracy of PO and PTD are drawn and further work is discussed. Author

N92-19148# Hochschule der Bundeswehr, Hamburg (Germany, F.R.). Inst. of Automation.
ASPECTS OF RADAR-CROSS-SECTION CALCULATION FOR TARGETS OF COMPLEX STRUCTURE
O. WEILAND and J. WENDIGGENSEN *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 12 p (SEE N92-19136 10-32) Sep. 1991
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Minimizing the Radar Cross Section (RCS) of a new warship, it is important to determine the expected RSC in the design phase because of high development costs. Furthermore, it is desirable to identify design dependent scattering centers and analyze their mode of action. This is done most effectively by a graphical representation of the scattering mechanisms on a 3-D drawing of the target itself. The development is summarized of a computer code that combines graphical representation methods with well established theoretical techniques to predict the RCS for targets of complex structures. The tool is based on physical optics, physical theory of diffraction, ray tracing and it accounts for multiple shadowing and scattering up to triple bounce. The method of component technique using primitives is applicable to electrically large bodies and the calculation is limited to the monostatic case for perfectly conducting surfaces. Object coherence is used to reduce computation time during the solution of the hidden surface problem. Author

N92-19149# Ecole Royale Militaire, Brussels (Belgium). Dept. of Mathematics.
RCS CALCULATIONS OF 3-DIMENSIONAL OBJECTS, MODELED BY CAD
I. DELEENEER, E. SCHWEICHER, and A. BAREL (Vrije Univ., Brussels, Belgium) *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 9 p (SEE N92-19136 10-32) Sep. 1991
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All the steps are detailed that one has to perform to enable efficient Radar Cross Section calculation for objects with a complex and general shape. Only cavities are supposed to be nonexistent at this state of the work. Before the actual RCS calculations,

preliminary treatments like systematic modeling, Hidden Faces removal, and automatic recognition of reflection and diffraction centers are realized. After the creation of the object's geometry and its adaptation to the direction of the observator, Physical Optics (PO) was used to determine the backscattered field, and Geometrical Theory of Diffraction (GTD) was used to evaluate the diffracted fields. Only monostatic scattering (i.e., backscattering) is considered. Author

N92-19150# MATRA Espace, Paris-Velizy (France).
HIGH-FREQUENCY CAD-BASED SCATTERING MODEL: SERMAT
D. GOUPIL and M. BOUTILLIER *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 12 p (SEE N92-19136 10-32) Sep. 1991 In FRENCH; ENGLISH summary
(AGARD-CP-501) Copyright Avail: NTIS HC/MF A15;
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Specifications for an industrial radar cross section (RCS) calculation code are given: it must be able to exchange data with many computer aided design (CAD) systems, it must be fast, and it must have powerful graphic tools. Classical physical optics (PO) and equivalent currents (EC) techniques have proven their efficiency on simple objects for a long time. Difficult geometric problems occur when objects with very complex shapes have to be computed. Only a specific geometric code can solve these problems. We have established that, once these problems have been solved: (1) PO and EC give good results on complex objects of large size compared to wavelength; and (2) the implementation of these objects in a software package (SERMAT) allows fast and sufficiently precise domain RCS calculations to meet industry requirements in the domain of stealth. Author

N92-19151# Alenia, Torino (Italy).
PARAMETRIC BICUBIC SPLINE AND CAD TOOLS FOR COMPLEX TARGETS SHAPE MODELLING IN PHYSICAL OPTICS RADAR CROSS SECTION PREDICTION
A. DELOGU and F. FURINI *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 13 p (SEE N92-19136 10-32) Sep. 1991
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Increasing interest in radar cross section (RCS) reduction is placing new demands on theoretical, computation, and graphic techniques for calculating scattering properties of complex targets. In particular, computer codes capable of predicting the RCS of an entire aircraft at high frequency and of achieving RCS control with modest structural changes, are becoming of paramount importance in stealth design. A computer code, evaluating the RCS of arbitrary shaped metallic objects that are computer aided design (CAD) generated, and its validation with measurements carried out using ALENIA RCS test facilities are presented. The code, based on the physical optics method, is characterized by an efficient integration algorithm with error control, in order to contain the computer time within acceptable limits, and by an accurate parametric representation of the target surface in terms of bicubic splines. Author

N92-19152# Electronique Marcel Dassault, Saint Cloud (France).
RADAR CROSS SECTION MEASUREMENTS IN VHF/UHF
JACQUES SAGET *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 6 p (SEE N92-19136 10-32) Sep. 1991 In FRENCH
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Scientists and technicians tasked with developing future radar systems are becoming increasingly interested in the UHF and VHF bands. Some such systems, especially Soviet ones, have existed for several decades and are used for long distance surveillance and advance alert for ABM missiles. Some of the advantages for tactical and strategic military applications are the stealth weapons and missiles and hidden targets, undetectable at hyperfrequency bands, can be detected at VHF/UHF, and propagation in these bands is relatively unaffected by weather conditions such as snow,

rain, or cloud cover. Some of the difficulties linked to radar cross section (RCS) measurement in VHF/UHF are the need for an adequate illumination system, elimination of surrounding clutter, instrumentation, and processing. Techniques for overcoming each of these difficulties are discussed and anechoic chamber experiments carried out in order to verify specific implementations are described. Author

N92-19153# Forschungsinstitut fuer Funk und Mathematik, Wachtberg (Germany, F.R.).
TWO-DIMENSIONAL SIGNAL PROCESSING FOR AIRBORNE MTI
RICHARD KLEMM and JOACHIM ENDER *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 7 p (SEE N92-19136 10-32) Sep. 1991
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An overview of the field of airborne moving target indicator (AMTI) systems is given. For introduction, the problems of airborne MTI is pointed out. Well-known techniques such as conventional MTI and displaced phase center antenna (DPCA) are briefly described. Then, a prospective view of future AMTI-techniques is presented, including an overview of work on novel algorithms, techniques for airborne slow target extraction (TASTE). Although airborne radar is particularly addressed, the results may, with some modifications, be applied to other moving sensor configurations, such as active sonar, spaceborne radar, and synthetic aperture radar (SAR). This is intended to be tutorial and gives an overview of the state of the art in AMTI techniques. Author

N92-19154# Alberta Research Council, Edmonton (Canada). Environmental Research and Engineering Dept.
THE APPLICATION OF LATTICE-STRUCTURE ADAPTIVE FILTERS TO CLUTTER-SUPPRESSION FOR SCANNING RADAR
C. GIBSON *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 10 p (SEE N92-19136 10-32) Sep. 1991 Sponsored in part by Natural Sciences and Engineering Research Council
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The use of an adaptive filter to enhance the detection of moving targets in the presence of clutter is described. The scanning and pulsing rates of a typical surveillance radar produce, within each resolution cell, a time-series of samples at a given range, resulting from the consecutive pulses. In the case of coherent radar, this time-series corresponds to the Doppler spectrum of that resolution cell, containing radial velocity information on both targets and clutter within the cell. An adaptive filter can be used to enhance the target signal over the clutter signal by matching the clutter spectrum, thus whitening the filter output, so that only the target's spectral components stand out. It is possible for the filter to discriminate between the clutter spectrum and the target spectrum because clutter is generally a diffuse source, spread over many adjacent cells, while the target is generally a point source, occupying a single cell. The adaptive digital-filtering structure examined was the lattice-structure prediction-error filter. A number of adaptation algorithms were examined for this structure, with the best results being obtained with the harmonic-mean algorithm. Within this algorithm, two gradient methods were examined for adaptation in a nonstationary environment. To test these algorithms and methods, coherent radar data was gathered from a 10 cm air traffic control surveillance radar. This data included different targets (aircraft and bird flocks) in a variety of clutter conditions (ground, rain, ice pellet, snow, and anomalous propagation clutter). Quantitative results are presented, including improvement factors and sub-clutter visibility factors, that show significantly better performance for these adaptive filters, when compared with conventional moving-target-indicator filters. Author

N92-19155# Aeritalia S.p.A., Rome (Italy).
USE OF TARGET SPECTRUM FOR DETECTION ENHANCEMENT AND IDENTIFICATION
S. PARDINI, P. F. PELLEGRINI (Florence Univ., Italy), and P. PICCINI *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 12 p (SEE N92-19136 10-32) Sep. 1991
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Modulation on the echo signal generated by rotating machinery of an air target is addressed. An extensive measurement campain was carried out by means of an air traffic control radar and some preliminary results are presented. The problem of target spectra characterization and exploitation for detection enhancement and target identification, is considered in relation with the limitation imposed by the present radar features. Some considerations regarding the application of this technique for non-cooperative target recognition, in the radar of future generation, are developed. Author

N92-19156# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
SAR IMAGE CLASSIFICATION FOR TARGET DETECTION
A. BEAUPERE and G. FOULON *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 8 p (SEE N92-19136 10-32) Sep. 1991 In FRENCH Previously announced in IAA as A91-45627
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A simple method for classifying synthetic aperture radar (SAR) images is presented which relies on knowledge of surface roughness and radar backscattering. The proposed simulation algorithm, based on 2-D Fourier transformations, makes it possible to extract various types of urban zones from ground clutter independently on the polarization or inclination. The inverse problem is also treated, and a method for simulating SAR texture on the basis of a 3-D model of surface roughness is proposed. The results obtained are verified on the basis of Varan S images of Neuf-Brisach-Freiburg and Oberpfaffenhofen. Author

N92-19157# Aerospatiale, Cannes (France). Groupe Teledetection.
COMPARISON OF THE DETECTION AND RECONNAISSANCE CAPABILITIES OF AN HH-VV BIPOLAR IMAGING RADAR AND AN HH-HV-VH-VV POLARIMETER
J. M. NASR *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 8 p (SEE N92-19136 10-32) Sep. 1991 In FRENCH Original contains color illustrations
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From the perspective of putting into orbit an observation satellite carrying a military-configuration synthetic aperture radar (SAR), it is important to consider simultaneous measurements of several polarizations to increase system performance. However, the effect of these techniques on data flow is not negligible to the looked-for results. Thus, it is necessary to analyze the impact of these new multipolar methods in terms of improved performances in detecting and recognizing targets and to reach a compromise with classic methods (very high resolution). This article aims to quantify detection-recognition performance of a configuration of highlights using a multipolar imaging radar. Thus, we can confirm that HH-VV bipolarization is sufficient in many cases and that it is not necessary to measure HC and HH crossed channels that are very costly in terms of technology. Author

N92-19158# Institut de Recherche et d'Enseignement Superieur aux Techniques de l'Electronique, Nantes (France).
CONTRIBUTION OF POLARIMETRY IN RADAR TARGETS DISCRIMINATION, CLASSIFICATION, AND IDENTIFICATION
E. POTTIER and J. SAILLARD *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 12 p (SEE N92-19136 10-32) Sep. 1991 In FRENCH
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  Currently, close analysis of a radar target in terms of its characterization and recognition, is of central interest to scientific research. This article is concerned with the improvement of the ability to discriminate and classify highlights of a target by introducing the concept of polarimetry in the domain of high resolution electromagnetic imagery.   Transl. M.G.

N92-19159# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THE USE OF POLARIZATION FOR FINE ANALYSIS OF RADAR TARGETS
C. TITIN-SCHNAIDER *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 7 p (SEE N92-19136 10-32) Sep. 1991 In FRENCH Previously announced in IAA as A91-45639
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  It is demonstrated that the introduction of polarization in radar holography provides high-resolution images linking a complex 2 x 2 matrix to each pixel. The 'highlights' model shows that these matrices correspond to backscattering matrices associated with electromagnetic interactions at the pixel level. Polarimetry is applied at the level of these elementary backscattering matrices. Experimental measurements carried out for various targets confirm that polarimetry applied at the pixel level of a high-resolution radar image can make it possible to determine the nature of 'shining points'.   Author

N92-19160# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Wesseling (Germany, F.R.). Inst. for Radio Frequency Technology.
POLARIMETRIC COVARIANCE MATRIX ANALYSIS OF RANDOM RADAR TARGETS
E. LUENEBURG, V. ZIEGLER, A. SCHROTH, and K. TRAGL *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 12 p (SEE N92-19136 10-32) Sep. 1991
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  Two equivalent approaches for the description of mean polarimetric backscattering features of random radar targets exist, the so-called Mueller matrix and the covariance matrix approach. The covariance matrix contains measurable radar observables and is directly related to the statistics of the elements of the scattering matrix which determines the instantaneous backscattering features of a target. In this paper, a covariance matrix analysis for reciprocal random targets is performed by unitary transformations preserving important polarimetric invariances. The derivatives of covariance matrix elements with respect to the transmitter polarization reveal interesting functional relations between characteristic polarization states and covariance matrix elements. Analytical and numerical algorithms to determine optimal polarizations for cross- and copolar power are presented. The connection of the covariance matrix approach with the Mueller matrix formulation is shown in detail. Polarimetric covariance matrix analysis is illustrated by polarimetric radar measurements of terrain, rain and manmade clutter, and documented with according graphical evaluation.   Author

N92-19161# Michigan Univ., Ann Arbor. Radiation Lab.
MILLIMETER WAVE POLARIMETRIC SCATTEROMETER SYSTEMS: MEASUREMENT AND CALIBRATION TECHNIQUES
Y. KUGA, K. SARABANDI, A. NASHASHIBI, F. T. ULABY, and R. AUSTIN *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 5 p (SEE N92-19136 10-32) Sep. 1991
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  The target and system phase-stability during the time to measure the scattering matrix is a major problem for millimeter wave polarimetric radars. This is particularly true for network analyzer-based systems. To circumvent this phase-stability problem, we have developed new fully polarimetric radars at 35 and 94 GHz. The system is based on a relatively inexpensive network analyzer and is capable of operating in either the coherent or the incoherent polarimetric measurement mode. In the coherent mode, the scattering matrix can be measured within 2 ms. In the incoherent mode, the average Mueller matrix is measured directly by transmitting four different polarizations and measuring the Stokes vector of the backscattered signal. To compare the performance of the true measurement modes, the average Mueller matrix and the statistics of the phase difference of the two co-polarized signals were measured for a rhododendron tree and for a metallic tree. The average Mueller matrices obtained from the coherent and incoherent polarimetric measurement modes were similar. The target motion during the data acquisition period did not change the average Mueller matrix in the incoherent measurement mode. The probability density function of the phase difference of the two co-polarized signals computed from the average Mueller matrix is essentially the same as the one measured with the coherent polarimetric measurement mode.   Author

N92-19162# Massachusetts Univ., Amherst. Microwave Remote Sensing Lab.
POLARIMETRIC TECHNIQUES AND MEASUREMENTS AT 95 AND 225 GHZ
JAMES MEAD, ROBERT MCINTOSH, PHILLIP LANGLOIS, and PAUL CHANG *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 10 p (SEE N92-19136 10-32) Sep. 1991
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  The University of Massachusetts has developed two high-power portable polarimetric radars operating at 95 and 225 GHz. The 95 GHz coherent polarimeter is configured to measure the complex scattering matrix of a target by transmitting a pair of orthogonally polarized pulses in rapid succession. We have also developed a noncoherent 225 GHz polarimetric radar which directly characterizes the target Mueller matrix by transmitting a sequence of four or six polarization states. In addition to reviewing the radar design and calibration, this paper summarizes measurements of natural and man-made objects made to date. These measurements include several varieties of trees, terrain, and snowcover. A model which approximates the Mueller matrix with a single parameter is introduced for a restricted class of clutter and is found to accurately predict the polarimetric behavior of vegetation and terrain at low incidence angles. We also present a two parameter approximation of the Mueller matrix that accurately models scattering from snowcover at large incidence angles.   Author

N92-19163# Harry Diamond Labs., Adelphi, MD.
POLARIMETRIC MONOPULSE RADAR SCATTERING MEASUREMENTS OF TARGETS AT 95 GHZ
R. J. WELLMAN, J. NEMARICH, H. DROPKIN, D. R. HUTCHINS, J. L. SILVIOUS, and D. A. WIKNER *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 13 p (SEE N92-19136 10-32) Sep. 1991
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  This paper describes a 95-GHz polarimetric monopulse instrumentation radar and selected scattering measurement results for an armored vehicle. The radar is all-solid-state, coherent, frequency steppable over a 640-MHz bandwidth, and completely polarimetric for linearly or circularly polarized radiation. Details of

the methods used to perform the amplitude and phase calibrations and the effectiveness of polarization distortion matrix corrections are included in the paper. Measurements made with the radar of various vehicles on a turntable have allowed quasi-three-dimensional polarimetric ISAR images of the targets to be generated. Sample images for an infantry combat vehicle are presented together with high-resolution range profiles of the target for all monopulse channels. Author

N92-19164# Rutherford Appleton Lab., Chilton (England). Radio Communications Research Unit.
REDUCTION OF TARGET SCATTERING BY TROPOSPHERIC MODIFICATION
K. H. CRAIG *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 12 p (SEE N92-19136 10-32) Sep. 1991 Sponsored by European Office of Aerospace Research and Development
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This paper examines the possibility of reducing the effective radar cross-section of an aircraft by actively modifying the refractive index of the air surrounding it. The mechanism proposed is heating of the atmosphere by a laser mounted on the aircraft. The equations for the refractive index changes caused by absorption of laser radiation are derived, and refractive index profiles are calculated. A shielding factor specifying the reduction in target cross-section is introduced. The shielding factor is evaluated for typical laser beam geometries by using these profiles in a parabolic equation based electromagnetic propagation model. A parametric study is presented in orde. to optimize the laser wavelength and beam geometry. It is concluded that laser powers in the megawatt range can yield shielding factors greater than 10 dB. A 10.6 micron CO_2 laser appears to be optimum in terms of efficiency of cross-section reduction, and is also the laser type for which the highest CW powers are achievable. Author

N92-19165# Smith Associates Ltd., Guildford (England).
STOCHASTIC MODEL OF TERRAIN EFFECTS UPON THE PERFORMANCE OF LAND-BASED RADARS
S. P. TONKIN and M. A. WOOD (Royal Signals and Radar Establishment, Malvern, England) *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 9 p (SEE N92-19136 10-32) Sep. 1991 Sponsored in part by Ministry of Defence
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A stochastic model of land clutter visibility and of terrain screening of targets, with particular application to low-flying targets under surveillance by a microwave land-based radar system, is described. The model is not site specific, but it is detailed. It allows radar performance measures such as the mean length of track to be obtained analytically, without averaging large numbers of site specific simulations or requiring high fidelity terrain data. The trajectories of terrain-following targets are described in terms of ensembles of Markov processes. The main dependencies of the model are the following: terrain relief; radar height; target altitude; and distance of closest approach between the target and the radar. The model can be used to generate simulated clutter maps and target screening diagrams, and indeed this is done to compare the model results with experimental data. However, the main aim is to predict the effects of target screening and land clutter directly from the model, rather than from large numbers of simulations. Author

N92-19166# Alberta Research Council, Edmonton (Canada). Environmental Research and Engineering Department.
OVERVIEW OF WEATHER CLUTTER RESEARCH AT THE ALBERTA RESEARCH COUNCIL
C. GIBSON and B. KOCHTUBAJDA *In* AGARD, Target and Clutter Scattering and their Effects on Military Radar Performance 8 p (SEE N92-19136 10-32) Sep. 1991
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The Alberta Research Council operates a unique variable polarization-diversity 10 cm radar at its facility in Penhold, Alberta (located adjacent to CFB Penhold, at 52.2 deg N, 113.8 deg W, and elevation 904 m). This radar is part of a meteorological radar complex owned and operated by the Alberta Research Council. This facility, which also includes 5 cm and 3 cm radars, is primarily used for meteorological and radio propagation research. Author

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ELECTRONICS AND ELECTRICAL ENGINEERING

Includes test equipment and maintainability; components, e.g., tunnel diodes and transistors; microminiaturization; and integrated circuitry.

N91-14040# TRW, Inc., Redondo Beach, CA. Space and Technology Group.
ANALOG SUPERCONDUCTIVE ELECTRONICS FOR AVIONICS
A. H. SILVER and A. D. SMITH *In* AGARD, Applications of Superconductivity to Avionics 5 p (SEE N91-14030 05-76) Oct. 1990
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Superconductive electronics may solve critical problems in avionic sensors and signal processing. This results from both fundamental considerations such as low RF loss and power dissipation, flux quantization, and the Josephson effect. Because new physical mechanisms can be applied, new device configurations can be employed. This presentation describes the state-of-the-art and project near-term applications. Examples of high leverage superconductive technology in analog signal processing, analog-to-digital converters, low noise receivers, and phased array components are presented. Both high temperature copper-oxides and low temperature metallic superconductors are discussed. Author

N91-14041# Air Force Materials Lab., Wright-Patterson AFB, OH.
FABRICATION AND CHARACTERIZATION OF HIGH TEMPERATURE SUPERCONDUCTING THIN FILMS FOR SENSORS AND ELECTRONICS
P. M. HEMENGER, T. L. PETERSON, R. FLETCHER, I. MAARTENSE, P. T. MURRAY, and D. W. CHUNG (San Jose State Univ., CA.) *In* AGARD, Applications of Superconductivity to Avionics 8 p (SEE N91-14030 05-76) Oct. 1990
(Contract F33615-88-C-5423)
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
Superconducting thin films of $YBa_2Cu_3O(x-7)$ that do not require post-annealing were deposited on $SrTiO_3$ substrates using laser ablation. The electrical, magnetic, optical, and structural properties of the films were analyzed in order to identify and control the processing parameters which lead to optimization of the material's properties. The laser deposition process using an ArF excimer laser to grow high temperature superconducting (HTS) films is described. Detailed characterization of the films using ac magnetic susceptibility measurements is emphasized, because this technique is valuable as a screening tool. In one temperature scan from 4.2 to 125 K the critical temperature, Tc, the width of the transition, the presence of additional superconducting phases, the film's response to magnetic fields, and the critical current, Jc, are obtained. The susceptibility results are correlated with transport

measurements of Jc(T) and Tc(R = 0). Process control is essential when fabricating HTS materials for avionics applications. A process optimized to produce the best properties for one particular application such as high Jc, for interconnects will probably not be an optimal process for producing sensor material. High current-carrying capability is generally not important for sensors, but rather good optical properties and low noise characteristics. The material requirements will also differ depending upon the type of sensor, e.g., bolometric or non-equilibrium. Some applications will require more stringent control of surface morphology, grain structure, and crystallographic orientation than will other roplications. For these reasons a parametric study of the process is required in order to fabricate material with properties optimized for each application. Author

N91-14044# Thomson SINTRA ASM (France).
SQUIDS DEVICES MADE FROM HIGH TC SUPERCONDUCTORS: RESULTS AND PERSPECTIVES
RONAN STEPHAN In AGARD, Applications of Superconductivity to Avionics 8 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08;
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AGARD/Scientific Publications Executive
After a brief presentation of magnetic sensoring, results are presented, dealing with thick superconductive films where the intergranular native weak-links were used. The potential of high temperature superconductors (HTSCs) in SQUID magnetometry is introduced with emphasis on the utilization of thin films. Author

N91-14046# American Superconductor Corp., Watertown, MA.
OXIDE SUPERCONDUCTOR COILS: PRESENT SUCCESSES, FUTURE CHALLENGES
CARL J. RUSSO In AGARD, Applications of Superconductivity to Avionics 5 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08;
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AGARD/Scientific Publications Executive
Coils are a fundamental building block for large-scale applications. Successful application of oxide superconductor coils in these applications requires: high quality, superconducting-oxide wire forms; an insulation technology compatible with processing; a mandrel material compatible with processing and operational requirements; a compatible, high-strength, mechanical-support material; ability to maintain superconducting properties while being strained; and compatibility with other subsystems which are part of the application. The present state of coil development is discussed in terms of several applications. Predictions for the future of oxide superconductor coils is examined in terms of several figures of merit and anticipated operational criteria. Author

N91-15161# Electronique Serge Dassault, Saint Cloud (France).
PERFORMANCES OF MMIC X-BAND POWER AMPLIFIERS OBTAINED IN FOUNDRY
GILLES APERCE In AGARD, Advances in Components for Active and Passive Airborne Sensors 7 p (SEE N91-15154 07-06) Sep. 1990 Sponsored in part by Direction des Recherches, Etudes et Techniques, France
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
Two class A X band power Monolithic Microwave Integrated Circuits (MMICs) chips designed for phased array applications are described. Both have been consistently manufactured in just one foundry pass. A 10 GHz pulsed output power of 30 dBm saturated with 29 dB associated gain and 13 percent power added efficiency was achieved for the first power amplifier. The accurate small signal modeling of active and passive elements was the key to obtain these very good performances in the first design iteration. A 18 percent power added efficiency with 29 dBm output power at 1 dB compression gain and 24 dB associated gain in CW was obtained for the second amplifier. CW performance over 9 to 11 GHz was accurately predicted using a large signal Field Effect Transistor model (developed with nonlinear characterization tools) and a harmonic balance analysis. Massive DC and RF measurements were performed on the wafers. Good chips were then sorted out with the help of a database. A 58 percent DC and RF yield was obtained. Author

N91-15162# Telefunken System Technik G.m.b.H., Ulm (Germany, F.R.).
MILLIMETER-WAVE MONOLITHIC INTEGRATED RECEIVER CIRCUITS
LORENZ-PETER SCHMIDT, BERND ADELSECK, ALEXANDER COLQUHOUN, and HEINRICH DAEMBKES (Daimler-Benz A.G., Ulm, Germany, F.R.) In AGARD, Advances in Components for Active and Passive Airborne Sensors 7 p (SEE N91-15154 07-06) Sep. 1990 Sponsored in part by Ministerium fuer Verteidigung and Ministerium fuer Forschung und Technologie
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
Recent advances in the development of millimeter wave semiconductor devices and monolithic integrated circuits are reported. Based on a compatible process, allowing for integration of Schottky diodes and MESFETs on one chip, receiver circuits were developed for the 35, 50 to 60, and 94 GHz frequency ranges. Also, the present status of work on broadband mixers and dielectric resonator oscillators is presented. Further, single and dual gate High Electron Mobility Transistors (HEMTs) with excellent noise figures were developed forming a very promising basis for mm wave low noise amplification. Author

N91-15163# Naval Weapons Center, China Lake, CA.
BROADBAND COUPLING STRUCTURES FOR MICROWAVE ARITHMETIC CIRCUITS AND PHASED ARRAYS
JOSEPH A. MOSKO In AGARD, Advances in Components for Active and Passive Airborne Sensors 13 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
Four specific coupling structures are introduced or are described in detail. Each has important applications now and in future systems. For example, smart skins with integrated microwave circuitry for processing and radiation may make use of a novel coupling aperture. Various rigorous design equations are available for high performance coupler designs, be they on common soft or the newer monolithic microwave integrated circuit (MMICs) capable materials. Numerical solutions are ideally suited to CAD/CAM practices and could be extended to promising newer devices involving multielement coupled transmission lines. Author

N91-15165# Thomson-CSF, Malakoff (France).
THE T/R MODULES FOR PHASED-ARRAY ANTENNAS
COLETTE PEIGNET, YVES MANCUSO, and J. CLAUDE RESNEAU (Thomson-CSF, Meudon-la-Foret, France) In AGARD, Advances in Components for Active and Passive Airborne Sensors 9 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
The concept of phased array radar is critically dependent on the availability of compact, reliable and low power consuming Transmitter/Receiver (T/R) modules. An overview is given on two major programs actually at development stage within the Thomson group and on three major development axis (electrical concept optimization, packaging, and size reduction). The technical feasibility of the concept was proven and the three major axis were enlightened, based on reliability, power added efficiency, and RF tests optimization. Author

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FLUID MECHANICS AND HEAT TRANSFER

Includes boundary layers; hydrodynamics; fluidics; mass transfer; and ablation cooling.

N89-26818# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Aerodynamique Appliquee.
DRAG PREDICTION AND ANALYSIS FROM COMPUTATIONAL FLUID DYNAMICS, STATE-OF-THE-ART IN FRANCE
J. J. THIBERT *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 11 p (SEE N89-26817 21-02) Jun. 1989 In FRENCH; ENGLISH summary Original language document was announced in IAA as A89-29239
(AGARD-AR-256) Copyright Avail: NTIS HC A08/MF A01
Various two-dimensional and three-dimensional inviscid-flow methods for drag component analysis are presented which are based on solving either the potential equation or the Euler equations. Comparison with experimental results demonstrates that coupled methods can predict drag to within a few percent. It is suggested that the pressure term should be replaced in the two-dimensional case by the shock drag term and in the three-dimensional case by the sum of the induced drag and the shock drag. Author

N89-27104# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
VALIDATION OF COMPUTATIONAL FLUID DYNAMICS
P. W. SACHER, R. G. BRADLEY, JR., ed., and W. SCHMIDT, ed. (Dornier-Werke G.m.b.H., Immenstaad, Germany, F.R.) May 1989 26 p Presented at the AGARD Fluid Dynamics Panel Symposium, Lisbon, Portugal, 2-5 May 1988
(AGARD-AR-257; ISBN-92-835-0504-2; AD-A211102) Copyright
Avail: NTIS HC A03/MF A01
The Fluid Dynamics Panel AGARD Symposium entitled Validation of Computational Fluid Dynamics is reviewed and evaluated. The purpose of the Symposium was to assess the state of the art of Validation of Computer Codes and to ensure that the mathematical and numerical schemes employed in the codes correctly model the critical physics of the flow field under consideration. The evaluator addresses each of the papers presented separately and makes general comments on the seven major topic sessions. In addition, a Poster Session is reviewed in detail. It is evident that the new possibilities of CFD provide efficient tools for Analysis and Design in the Aeronautical Industry, but it is also evident that in spite of the existence of a number of excellent experimental databases, there is still a need for efforts in validating the computer programs both by experiment as well as by numerical exercises. Author

N89-28734# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
A SURVEY OF MEASUREMENTS AND MEASURING TECHNIQUES IN RAPIDLY DISTORTED COMPRESSIBLE TURBULENT BOUNDARY LAYERS (Computer Diskette Supplement)
H. H. FERNHOLZ, P. J. FINLEY, J. P. DUSSAUGE, A. J. SMITS, and E. RESHOTKO, ed. (Case Western Reserve Univ., Cleveland, OH.) May 1989 246 p Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315; ISBN-92-835-0506-9;
NONP-SUPPL-DK-89-223860; AD-A211107) Copyright Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set
A wide range of recent work on compressible turbulent boundary layers is described. Special attention was paid to flows with rapid changes in pressure including flows with shock waves, curved walls, and expansions. The application of rapid distortion theory to flows transversing expansion and shock waves is reviewed. This is followed by an account of experiments aimed at elucidating the large scale structures present in supersonic boundary layers. The current status of laser-Doppler and hot-wire anemometry in

supersonic flow is discusse ' and a new interferometric technique for the determination of /all-stress is described. The use of small pressure transduce s to deduce information about the structure of zero pressu -gradient and severely perturbed boundary layers is investiga... Finally, there is an extension of the data presentation of AGARDographs 223, 253 and 263 to cover rapidly distorted boundary layers. For individual titles, see N89-28735 through N89-28745.

N89-28735# Aix-Marseilles Univ. (France). Inst. de Mecanique Statistique de la Turbulence.
RAPIDLY DISTORTED COMPRESSIBLE BOUNDARY-LAYERS (Computer Diskette Supplement)
J. P. DUSSAUGE, J. F. DEBIEVE, and A. J. SMITS (Princeton Univ., NJ.) *In* AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 11 p (SEE N89-28734 23-34) May 1989 Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315) Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set
The theoretical work in rapidly distorted compressible flows can be classed into three distinct groups: analyses based on formal linearizations of the equations of motion (rapid distortion theory, RDT), analyses based on the Rankine-Hugoniot jump relations to study shock/turbulence interactions (RDT and rapid distortion approximation, RDA), and approximations to the Reynolds stress transport equations to obtain second order closure (RDA). These three groups are considered. An attempt is made to classify the currently available analyses in terms of restrictions placed on the mean and fluctuating fields, and on the boundary conditions. Finally, the application of rapid distortion methods to supersonic flows is considered, and the limits of applicability are discussed. M.G.

N89-28737*# Pennsylvania State Univ., University Park. Dept. of Mechanical Engineering.
SKIN-FRICTION MEASUREMENTS BY LASER INTERFEROMETRY (Computer Diskette Supplement)
K.-S. KIM and G. S. SETTLES *In* AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 8 p (SEE N89-28734 23-34) May 1989 Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(Contract NAG3-527)
(AGARD-AG-315) Copyright Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set CSCL 20/4
The measurement of skin friction in rapidly distorted compressible flows is difficult, and very few reliable techniques are available. A recent development, the laser interferometer skin friction (LISF) meter, promises to be useful for this purpose. This technique interferometrically measures the time rate of thinning of an oil film applied to an aerodynamic surface. Under the proper conditions the wall shear stress may thus be found directly, without reference to flow properties. The applicability of the LISF meter to supersonic boundary layers is examined experimentally. Its accuracy and repeatability are assessed, and conditions required for its successful application are considered. Author

N89-28739*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
LASER DOPPLER ANEMOMETRY (Computer Diskette Supplement)
DENNIS A. JOHNSON *In* AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 10 p (SEE N89-28734 23-34) May 1989 Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315) Copyright Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set CSCL 20/4
The application of laser Doppler anemometry (LDA) to compressible flows is discussed. Specifically, burst-counter and dual-beam LDA systems are addressed. Much has been

accomplished with LDA in compressible flows despite the difficulties posed by the high speeds and additionally by the rapid spatial changes in speed or flow direction. The successful application of the technique is difficult because the signal to noise ratios (SNRs) are fairly low even under the best of conditions and highly variable because of variations in particle size and particle location with the sensing volume. The available signal processing is not very effective in discarding signals that are too noisy to provide an accurate velocity measurement. The temptation is to work with particles which are too large to adequately follow the flow but which provide cleaner signals due to increased scattering intensities. For the data to have credibility, some check on the particle response must be made for a given facility and LDA system. The capability, if developed, of being able to determine the size of each particle upon which a measurement is based and the SNR of the corresponding signal burst would be extremely valuable in reducing much of the uncertainty now present in LDA compressible flow measurements.   Author

N89-28741*#   Texas Univ., Austin.   Dept. of Aerospace Engineering and Engineering Mechanics.
FLUCTUATING WALL-PRESSURE MEASUREMENTS (Computer Diskette Supplement)
D. S. DOLLING and J. P. DUSSAUGE (Aix-Marseilles Univ., France) In AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 18 p (SEE N89-28734 23-34) May 1989 Sponsored in part by NASA, Washington, DC and ONR, Washington, DC Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(Contract AF-AFOSR-0112-86)
(AGARD-AG-315) Copyright Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set CSCL 20/4
    The wall pressure fluctuations under zero pressure gradient and perturbed compressible turbulent boundary layers are studied. The method of measurement, common sources of error, and calibration methods are discussed. Analysis of the published data in zero pressure gradient shows that due largely to poor spatial resolution there are few, if any, really reliable measurements. Within the accuracy of the measurements, it does not appear that the structure of turbulence in equilibrium supersonic boundary layers is not significantly altered by compressibility. In perturbed flows most of the data are in shock/boundary layer interactions. Attention is focussed on the separation process which is characterized by large amplitude, low frequency shock-induced pressure fluctuations, on the separated flow, and on the outgoing boundary layer. Results are presented for two- and three-dimensional flows.   Author

N89-28742# Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.
GENERAL COMMENTS ON THE INTERPRETATION OF DATA (Computer Diskette Supplement)
P. J. FINLEY and H. H. FERNHOLZ (Technische Univ., Berlin, Germany, F.R.) In AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 12 p (SEE N89-28734 23-34) May 1989 Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315) Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set
    Mean flow for a number of rapidly distorted turbulent boundary layers is discussed. A majority of the problems arising in the interpretation of mean flow data for such boundary layers are related to the effects of normal pressure gradients. The most serious intractable problem is the determination of wall shear-stress. The flows in question include regions in which a Preston tube can never be expected to give a valid result, though it may be possible to extend the range of validity if calibrations are based on pure wall-law similarity. It is also shown that the Van Driest transformation should not be used for data affected by normal pressure gradients, and profile-derived wall shear-stress values deduced from such profiles can not be trusted. Finally, it is pointed out that the direction of the mean flow may change significantly in a short distance so that it is necessary to take special measures

to ensure that probes sensitive to misalignment, in particular static probes and oblique wires, are correctly oriented   M.G.

N89-28743#   Technische Univ., Berlin (Germany, F.R.).   Inst. fuer Thermo und Fluiddynamik.
REVIEW OF MEAN FLOW DATA (Computer Diskette Supplement)
H. H. FERNHOLZ and P. J. FINLEY (Imperial Coll. of Science and Technology, London, England) In AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 16 p (SEE N89-28734 23-34) May 1989 Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315) Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set
    Mean flow data for three compressible boundary layers are discussed. First, the zero-pressure gradient flow (ZPG) of Spina and Smits (1987, CAT8603T) is addressed followed by the reflected wave case, Fernando and Smits (1986, CAT8601T), providing an adverse pressure gradient (APG) of the same order of magnitude as those in the concavely curved surface flows of Taylor (1984, CAT8401T). The latter flows have appreciable normal pressure gradients as has the expansion flow of Dussauge (1987, CAT8602T). The remaining ten cases are shock/boundary layer interactions which are dealt with in two groups, quasi-normal shock interactions and compression corner flows. Comparisons between measurements and the logarithmic law of the wall on the one hand and the outer law on the other hand were made for all cases in this survey using the van Driest transformation with allowance for the recovery factor.   M.G.

N89-28744#   Technische Univ., Berlin (Germany, F.R.).   Inst. tuer Thermo und Fluiddynamik.
REVIEW OF TURBULENCE DATA (Computer Diskette Supplement)
H. H. FERNHOLZ and P. J. FINLEY (Imperial Coll. of Science and Technology, London, England) In AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 19 p (SEE N89-28734 23-34) May 1989 Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315) Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set
    The physical interpretation of the turbulence data for compressible boundary layers is presented. A listing is provided of investigations in which measurements of fluctuating components were performed. Zero, adverse, and favorable pressure gradient flows are discussed and the behavior of Reynolds normal stresses is examined for the zero and adverse cases. The influence of curved ramp flows is also addressed. Shock/boundary layer interactions are dealt with in two groups, quasi-normal shock interactions and compression corner flows. Finally, measurements of Reynolds shear stress are discussed.   M.G.

N89-28745#   Technische Univ., Berlin (Germany, F.R.).   Inst. fuer Thermo und Fluiddynamik.
THE ENTRIES (Computer Diskette Supplement)
H. H. FERNHOLZ and P. J. FINLEY (Imperial Coll. of Science and Technology, London, England) In AGARD, A Survey of Measurements and Measuring Techniques in Rapidly Distorted Compressible Turbulent Boundary Layers 102 p (SEE N89-28734 23-34) May 1989 Computer diskette supplement (data file): IBM compatible DS HD 5.25-inch formatted 1.2 MB using MS DOS 3.20
(AGARD-AG-315) Avail: NTIS HC A11/MF A02; set of 5 computer diskettes available from NASA Scientific and Technical Information Facility, BWI Airport, MD at $13.00/set
    Mean flow and turbulence data from 12 studies investigating rapidly-distorted turbulent compressible boundary layers are presented. Only a selection of the available profile data is given for each study (complete profile listings are available on computer diskettes). Each of the 12 entries includes a description of the experiment, tables of principle boundary conditions and derived quantities, mean-profile data, and a miscellany of supplementary

data. Only a partial presentation of turbulence data is provided.
M.G.

N90-10356# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
FLUID DYNAMICS OF THREE-DIMENSIONAL TURBULENT SHEAR FLOWS AND TRANSITION
Apr. 1989 415 p In ENGLISH and FRENCH Symposium held in Cesme, Turkey, 3-6 Oct. 1988
(AGARD-CP-438; ISBN-92-835-0502-6; AD-A211101) Copyright
Avail: NTIS HC A18/MF A03
    The trends and achievements of current research activities in three dimensional turbulent shear flows and transitions were determined and the problems on which future research should be focussed were highlighted. Seven sessions devoted to the topic of transition are included, and these sessions well represented the current state of the art. The characteristics of three dimensional turbulent shear flows were dealt with in five sessions, a reflection of the fact that here much more experimental work is needed, and the effort devoted to this difficult topic has not yet reached the level required. For individual titles, see N90-10357 through N90-10383.

N90-10357*# Arizona State Univ., Tempe. Mechanical and Aerospace Engineering.
STABILITY AND TRANSITION OF THREE-DIMENSIONAL BOUNDARY LAYERS
WILLIAM S. SARIC and HELEN L. REED In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 20 p (SEE N90-10356 01-34) Apr. 1989
(Contract NAG1-280; NAG1-402; NAG1-731)
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
CSCL 20/4
    The most recent efforts on the stability and transition of three-dimensional flows are reviewed. These include flows over swept wings, rotating disks, and attachment lines. The generic similarities of their stability behavior is discussed. It is shown that the breakdown process is very complex, often leading to contradictory results. Particular attention is paid to opposing observations of stationary and traveling wave distances. Author

N90-10358# Royal Aircraft Establishment, Farnborough (England).
EXPERIMENTAL INVESTIGATION OF ATTACHMENT-LINE TRANSITION IN LOW-SPEED, HIGH-LIFT WIND-TUNNEL TESTING
B. C. HARDY In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 17 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
    The state of the attachment-line boundary layer on two typical, low-speed, high-lift wind-tunnel models was investigated experimentally. Transition was observed on both models within the Reynolds number range of the Royal Aerospace Establishment 5 meter, low-speed, pressurized Wind Tunnel, but significant differences were found from the behavior previously observed using infinite swept and high-speed wing configurations. An adverse Reynolds number effect on maximum lift, which correlated quite well with the onset of attachment-line transition, was found for one of the models. No such effect was found with the other model but in this case laminarization following transition at the attachment line was observed and is suggested as a probable reason for the absence of any scale effect on the forces within the Reynolds number range of both tests. It is concluded that attachment-line transition and laminarization can both contribute to scale effect in low-speed, high-lift testing and that, for many aircraft, accurate simulation of the full-scale behavior in conventional wind tunnel is unlikely. It is suggested that further work is required to establish whether these effects are likely to give rise to significant discrepancies between high-lift performance measured in the tunnel and in flight. Author

N90-10362# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).
EXPERIMENTAL STUDY OF TRANSITION AND LEADING EDGE CONTAMINATION ON SWEPT WINGS [ETUDE DE LA TRANSITION ET DE LA CONTAMINATION DE BORD D'ATTAQUE SUR AILES EN FLECHE]
D. ARNAL and J. C. JUILLEN In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 14 p (SEE N90-10356 01-34) Apr. 1989 In FRENCH; ENGLISH summary
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
    The transition mechanisms in an incompressible laminar boundary layer developing on swept wings is investigated experimentally. The transition is detected by using hot films glued on the model. Two series of experiments are presented: in the first one, the sensors are placed along the chord and the instantaneous signals allow us to analyse the problems of streamwise instability, crossflow instability, and leading edge contamination. In the second series of experiments, hot films are glued along the span direction, close to the leading edge. The leading edge contamination is studied in detail and the possibilities of relaminarization are examined. Author

N90-10363# Stuttgart Univ. (Germany, F.R.). Inst. A fuer Mechanik.
NUMERICAL INVESTIGATION OF THE EFFECTS OF LONGITUDINAL VORTICES ON THE ONSET OF TRANSITION IN A FLAT PLATE BOUNDARY LAYER
U. KONZELMANN, U. RIST, and H. FASEL (Arizona Univ., Tucson.) In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 13 p (SEE N90-10356 01-34) Apr. 1989
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    The Navier-Stokes equations for three-dimensional, incompressible flows are solved numerically to investigate spatially amplified disturbances in a growing flat plate boundary layer. The disturbances are introduced by time-periodic blowing and suction over a finite slot. The generated disturbances consisted of two-dimensional Tollmien-Schlichting waves, pairs of oblique three-dimensional Tollmien-Schlichting waves, and longitudinal vortices. To isolate nonlinear mechanisms and to identify the importance of longitudinal vortices, two numerical simulations with flow parameters similar to the experiment by Klebanoff with a two-dimensional Tollmien-Schlichting wave of moderate amplitude with two small oblique three-dimensional disturbances of fundamental and subharmonic frequency were performed. In the second calculation an additional longitudinal vortex disturbance was introduced. In both cases the amplification rates for three-dimensional models agreed with the secondary stability theory. The effect of additional longitudinal vortex was such that the initial amplitude for the fundamental three-dimensional disturbance was shifted to higher values. Because of the higher amplitude level for the three-dimensional fundamental disturbances, which is caused by the longitudinal vortices, in this case fundamental resonance would dominate over subharmonic resonance in spite of the lower amplification rate of the fundamental wave. In a numerical simulation of the experiment of Kachanov et al. with larger two-dimensional disturbance amplitudes, neither the subharmonic nor the fundamental resonance model agrees with the numerical Navier-Stokes results. Therefore an improved model was developed which includes two two-dimensional waves and longitudinal vortices. This model yields remarkable agreement with the numerical simulation and with experimental measurements and thus appears to capture the relevant mechanisms. Author

N90-10365# Hellenic Air Force Technology Research Center, Athens (Greece).
THREE-DIMENSIONAL BOUNDARY LAYER TRANSITION ON A CONCAVE SURFACE
G. LEOUTSAKOS and R. I. CRANE (Imperial Coll. of Science and Technology, London, England) In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 11 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
    Measurements of streamwise mean and rms velocity, intermittency factor, and energy spectra are reported for a laminar boundary layer undergoing transition on a concave wall in the presence of a naturally-occurring Goertler vortex system, concentrating on a particular vortex pair. The ratio of boundary

layer thickness to wall radius at the start of curvature was 0.01. Nonlinear amplification of the vortices, followed by spanwise meandering and a secondary instability, preceeded transition, which was defined in terms of the intermittency factor after filtering out low frequencies associated with this vortex behavior. Transition was initiated in the vortex upwash region and apparently completed within a streamwise distance of only a few boundary-layer thicknesses at both upwash and downwash locations, implying rapid lateral spread of turbulence. With considerable velocity profile distortion prior to transition, values of momentum thickness Reynolds number and Goertler number at the start of transition, either upwash-localized or upwash-downwash averaged, did not correspond well with established correlations for flat surfaces or with earlier concave-wall studies. **Author**

N90-10366*# High Technology Corp., Hampton, VA.
CURVATURE EFFECTS ON THE STABILITY OF THREE-DIMENSIONAL LAMINAR BOUNDARY LAYERS
F. S. COLLIER, JR. and MUJEEB R. MALIK *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 15 p (SEE N90-10356 01-34) Apr. 1989
(Contract NAS1-18240)
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03 CSCL 20/4
The linear stability equations for compressible, three-dimensional laminar boundary layer flow are derived in an orthogonal curvilinear coordinate system. The system of equations is solved using a finite difference scheme in order to study the effects of streamline and surface curvature and compressibility on the stability of the flow past a swept wing. It is known that convex surface curvature can have a stabilizing effect on the laminar boundary layer. Conversely, concave surface curvature can be destabilizing. The magnitude of these effects for swept wings is determined. Results indicate that amplification rates and hence, N-factors, for the flow over the convex upper surface of a swept wing can be reduced by about 15 to 45 percent when curvature effects are included in the linear stability analysis. The results of the calculations show that concave curvature destabilizes crossflow type disturbances with a significant increase in amplification rate. In addition, comparisons are made with some experimental results on a swept concave-convex surface. Calculated velocity vector plots show good agreement with observed disturbances in the laminar boundary layer over the concave surface. **Author**

N90-10368*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SIMULTANEOUS DETECTION OF SEPARATION AND TRANSITION IN SURFACE SHEAR LAYERS
SIVA M. MANGALAM (Analytical Services and Materials, Inc., Hampton, VA.), J. P. STACK, and W. G. SEWALL *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 10 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03 CSCL 20/4
Flush-mounted hot-film gages have proved effective in detecting boundary-layer transition and in measuring skin friction but with limited success in detecting laminar separation and reattachment. The development of multielement micro hot-film sensors, and the recent discovery of the phase reversal phenomena associated with low-frequency dynamic shear stress signals across regions of laminar separation and turbulent reattachment, have made it possible to simultaneously and unambiguously detect these surface shear layer characteristics. Experiments were conducted on different airfoils at speeds ranging from low subsonic to transonic speeds to establish the technique for incompressible and compressible flow applications. The multielement dynamic shear stress sensor technique was successfully used to detect laminar separation, turbulent reattachment, as well as, shock induced laminar and turbulent separation. **Author**

N90-10369# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Experimental Fluid Mechanics.
EXPERIMENTAL STUDY OF INSTABILITY MODES IN A THREE-DIMENSIONAL BOUNDARY LAYER
B. MUELLER and H. BIPPES *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 15 p (SEE N90-10356 01-34) Apr. 1989 Sponsored in part by Deutschen Forschungsgemeinschaft
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
Hot-wire measurements were performed to examine the development of stationary and traveling waves in a three-dimensional boundary layer. The appearance of stationary vortices is discussed. The wavelength is independent from the Tu-level, however, if a spanwise periodicity is superimposed upon the flow, the wavelength is initiated by this disturbance. Otherwise, there is evidence that the stationary vortices are triggered by model fixed disturbances like surface roughnesses or manufacturing tolerances of the leading edge of the flat plate. The development of the stationary vortices is examined. In the wind tunnel with a Tu-level Tu is approximately 0.15 percent, an experimental growth of alpha (sub i) is approximately 8 over 60 percent of the plate is first observed, then, the amplification slows down and the stationary vortices reach a final amplitude of about 10 percent for the U-component and 6 percent for the V-component. For a wind tunnel with a Tu-level of about Tu = 0.05 the growth rate for the stationary vortices agrees well with one predicted by linear stability theory for the swept flat plate. The mean velocity profiles are deformed by the stationary vortices. These profiles are very unstable and may introduce secondary oscillations. Besides the stationary vortices, travelling waves are examined. The range of amplified waves is between 50 and 200 Hz which agrees well with the linear stability theory. The areas where nonlinear effects are present is much larger than in two-dimensional flow. Therefore, transition criteria based on the linear stability theory might be limited. **Author**

N90-10370# Universidad Politecnica de Madrid (Spain). School of Aeronautics.
BIFURCATIONS IN POISEUILLE FLOW AND WALL TURBULENCE
JAVIER JIMENEZ *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 11 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
The fully nonlinear stage of two dimensional Poiseuille flow undergoes a limit cycle bifurcation, whose detailed mechanism is studied using full numerical simulations of simple, spatially periodic cases. It is also shown that this mechanism, a periodic ejection from the wall layer, underlies the production of turbulence in more complicated two dimensional situations. Vorticity ejections are also present in the sublayer of three dimensional channels. The behavior is studied briefly in three dimensional simulations. A simplified model system is then proposed and studied. There are important differences between the two ejections mechanisms, due to the presence of three dimensional vorticity. **Author**

N90-10371# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Theoretical Fluid Mechanics.
PRIMARY AND SECONDARY STABILITY ANALYSIS APPLIED TO THE DFVLR-TRANSITION SWEPT-PLATE EXPERIMENT
T. M. FISCHER and U. DALLMANN *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 11 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
A three-dimensional, incompressible boundary-layer flow is investigated theoretically with respect to primary and secondary instability. These investigations accompany a basic transition experiment. Primary stationary and secondary wave disturbances are used to model the measured mean flow and velocity fluctuations in the early transition regime. The analysis is based on a Falkner-Skan-Cooke approximation of the undisturbed flow. **Author**

N90-10372# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Theoretical Fluid Mechanics.
NUMERICAL INVESTIGATION OF TRANSITION IN 3D BOUNDARY LAYERS
F. MEYER and L. KLEISER *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 17 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

Linear and nonlinear stages of the laminar-turbulent transition process in a three-dimensional boundary layer initiated by crossflow instability are investigated by linear stability theory and numerical simulation. The conditions of the investigation are adapted to the swept flat plate transition experiment. The parallel basic flow is defined by Falkner-Skan-Cooke similarity profiles. The observed wavelengths of the crossflow vortices and frequencies of the travelling disturbances are well predicted by the linear theory. In the numerical simulations, the temporal evolution of spatially periodic disturbances are considered. Quasi two-dimensional calculations (excluding variations along the vortex axis) show a nonlinear saturation of stationary crossflow vortex disturbances. Nonlinear interactions of stationary and travelling disturbances are studied by three-dimensional simulations. The disturbance development depends significantly on the chosen initial disturbance field. Generally, close correspondence between the computed and the experimentally observed disturbances is obtained at corresponding stages of development. However, there are also some discrepancies. The ratio of the crossflow component of the disturbances to the streamwise component is always larger in the experiment. Nonlinear disturbance interactions produce a significant distortion of the streamwise and crosswise averaged mean boundary layer profiles and an increase of the wall shear stress.
Author

N90-10374# Manchester Univ. (England). Dept. of Engineering.
NUMERICALLY DETERMINED TRANSITION IN SEPARATED INTERNAL FLOW
J. H. GERRARD *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 9 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

The oscillating axisymmetric flow in a conically tapered tube was studied experimentally and by numerical analysis. The investigation of transition to turbulence was concerned with the position of the tube and the phase at which turbulence occurs for different flow parameters. Numerical computation with an inherently unstable explicit finite difference scheme exhibits breakdown at a phase of the oscillation which can be made independent of the numerical parameters. In this condition it is found that numerical breakdown and observed transition occur at the same phase.
Author

N90-10375# Centre National de la Recherche Scientifique, Toulouse (France). Inst. de Mecanique des Fluides.
NUMERICAL SOLUTION OF THREE-DIMENSIONAL UNSTEADY FLOWS: APPLICATION TO INSTABILITY PROBLEMS [RESOLUTION NUMERIQUE D'ECOULEMENTS TRIDIMENSIONNELS INSTATIONNAIRES: APPLICATION A DES PROBLEMES D'INSTABILITE]
J. B. CAZALBOU, P. CHASSAING, and H. HA MINH *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 11 p (SEE N90-10356 01-34) Apr. 1989 In FRENCH; ENGLISH summary
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

A numerical code solving the complete three dimensional unsteady flows is presented. The code is then applied to several flows presenting three dimensional instabilities. The unsteady Navier-Stokes equations, in velocity-pressure formulation, without or with heat transfers according to the Boussinesq approximation, are integrated by a semi-implicit finite volume method using staggered meshes. Four flow applications are given: purely convective flow in a 3-D driven cavity; mixed convective flow, with thermal aspects; natural convection flow in 3-D square cavity; and Rayleigh-Benard instability in small boxes. Using 2-D result comparison, an attempt is made to isolate the specific 3-D effects and the influence of three dimensional flow structures. Author

N90-10376# Princeton Univ., NJ. Gas Dynamics Lab.
A STUDY OF THE STRUCTURE OF HIGHLY SWEPT SHOCK WAVE TURBULENT BOUNDARY LAYER INTERACTIONS
SEYMOUR M. BOGDONOFF *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 14 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

The combination of detailed flow field studies and extensive calculations were used to construct a model of the three-dimensional interaction of shock waves and turbulent boundary layers. Although different configurations have somewhat different details, a general flow structure consisting of a flattened vortical field, aligned along the shock direction, was found for the fin and swept wedge geometries examined thus far. The lower part of the entering boundary layer is involved in this vortical structure, while the outer part of the layer flows over the initial structure, and is the initial phase of the flow developing downstream of the interaction. Concepts of separation, vortices, reattachment, surface flow visualization observations, and the assumption of steady flow are not supported by the detailed experimental data.
Author

N90-10377# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).
CONTROL AND MODIFICATION OF TURBULENCE [CONTROLE ET MODIFICATION DE LA TURBULENCE]
J. COUSTEIX, E. COUSTOLS, and D. ARNAL *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 34 p (SEE N90-10356 01-34) Apr. 1989 In FRENCH; ENGLISH summary
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

Means devoted to control turbulence in boundary layers developing on aircraft are presented in order to reduce their skin friction drag. These means deal with the laminar flow control and the use of internal or external boundary layer manipulators. The description of the phenomena which are involved is given after recalling a few essential features of the transition process and of the turbulence in boundary layers.
Author

N90-10378# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.
TURBULENCE MANAGEMENT: APPLICATION ASPECTS
E. H. HIRSCHEL, P. THIEDE (Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen, Germany, F.R.), and F. MONNOYER *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 12 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

Turbulence management for the reduction of turbulent friction drag is an important topic. Numerous research programs in this field have demonstrated that valuable net drag reduction is obtainable by techniques which do not involve substantial, expensive modifications or redesign of existing aircraft. Hence, large projects aiming at short term introduction of turbulence management technology into airline service are presently under development. The various points that have to be investigated for this purpose are presented. Both design and operational aspects are considered, the first dealing with optimizing of turbulence management techniques at operating conditions, and the latter defining the technical problems involved by application of turbulence management to in-service aircraft. The cooperative activities of Airbus Industrie and its partners are cited as an example.
Author

N90-10381# Manchester Univ. (England). Dept. of Mechanical Engineering.
TURBULENCE MODELLING OF THREE-DIMENSIONAL SHEAR FLOWS
B. E. LAUNDER *In* AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 20 p (SEE N90-10356 01-34) Apr. 1989
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03

Aspects of modeling the turbulent stress field in three-dimensional strain fields are considered. Special emphasis is given to the level of modeling known as second-moment closure in which, in place of an isotropic effective viscosity, nonlinear constitutive equations are solved for each of the non-zero turbulent stresses. The advantages of this approach over the simpler eddy-viscosity modeling are strikingly brought out by examples of

swirling free and confined flows and three-dimensional flows in straight and curved ducts. The impact of certain fundamental studies now in progress are studied for improving the realism of computations of three-dimensional turbulent flows in the future.

Author

N90-10352,# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
NUMERICAL SIMULATION OF TURBULENT PLANE CHANNEL FLOWS [SIMULATIONS NUMERIQUES D'ECOULEMENTS TURBULENTS]
K. DANG and V. DESCHAMPS   In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 16 p (SEE N90-10356 01-34) Apr. 1989 In FRENCH Previously announced is IAA as A89-31814
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
The unsteady Navier Stokes equations for incompressible fluids are solved by a fourth order finite difference method associated with a semi-implicit time scheme in which pressure is calculated iteratively in a way that satisfies a global incompressibility condition. This algorithm is used to simulate an unsteady, plane-channel turbulent flow with Reynolds numbers of the order of 2000 (based on the mean velocity at the center and half-way point of the channel). The flow, assumed to be homogeneous in both the longitudinal and transverse directions, is maintained with an external contribution of energy realized by imposing a constant mean pressure gradient or a constant flow rate. Although both procedures result in a similar asymptotic flow, the laminar Poiseuille flow is destabilized much more rapidly when the constant flow rate procedure is used. The influence of discretization on the precision of the results is discussed.   Transl. by M.G.

N90-10383# Institut de Mecanique de Grenoble (France).
NUMERICAL SIMULATION OF COHERENT STRUCTURES IN AN INCOMPRESSIBLE MIXING LAYER [SIMULATION NUMERIQUE DES STRUCTURES COHERENTES DANS UNE COUCHE DE MELANGE INCOMPRESSIBLE]
MARCEL LESIEUR, PIERRE COMTE, XAVIER NORMAND, and YVES FOUILLET In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 11 p (SEE N90-10356 01-34) Apr. 1989 In FRENCH; ENGLISH summary
(AGARD-CP-438) Copyright Avail: NTIS HC A18/MF A03
Numerical simulations are presented for mixing layers developing from a hyperbolic tangent basic velocity profile to which is superposed an infinitesimal random perturbation. The velocity and passive temperature charts are visualized. The following cases are envisaged: (1) a two dimensional mixing-layer with periodic boundary condition in the flow direction (the numerical code uses finite difference methods and calculations done at a Reynolds number of 1000 and 10,000); (2) a two dimensional spatially developing mixing layer; and (3) a three dimensional temporal mixing layer (large-eddy simulation, pseudospectral code). In the two dimensional case, it is shown that the coherent structures develop from the Kelvin-Helmholtz instability. The coherent structures undergo successive pairings, are shown to be unpredictable, and possess a broadband spatial spectrum of slope comprised between K(sup -3) and K(sup -4). In the three dimensional case, a spectral subgrid scale eddy-viscosity reaches the high Reynolds numbers. Thus the interaction is studied between large-scale coherent structures and small scale three dimensional turbulence which cascades along a K(sup -5/3) kinetic energy spectrum.   Author

N90-20999# Arnold Engineering Development Center, Arnold Air Force Station, TN.
OPTIMIZATION OF AERODYNAMIC DESIGNS USING COMPUTATIONAL FLUID DYNAMICS
D. H. HUDDLESTON and C. W. MASTIN (Mississippi State Univ., Mississippi State.)   In AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 10 p (SEE N90-20976 14-05) Mar. 1990 Prepared in cooperation with Sverdrup Technology, Inc., Arnold AFS, TN
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AGARD/Scientific Publications Executive
An aerodynamic design optimization technique which couples direct optimization algorithms with the analysis capability provided by appropriate computational fluid dynamics (CFD) programs is

presented. This technique is intended to be an aid in designing the aerodynamic shapes and test conditions required for the successful simulation of aircraft engine inlet conditions in a ground test environment. However, the method is applicable to other aerodynamic design problems. The approach minimizes a nonlinear least-squares objective function which may be defined in a region remote to the geometric surface being optimized. In this study finite-difference Euler and Navier-Stokes codes were applied to obtain the objective function evaluations, although the optimization method could be coupled with any CFD analysis technique. Results are presented for a NACA0012 airfoil, convergent/divergent nozzles, and a planar, supersonic forebody simulator design.

Author

N90-21030# Rolls-Royce Ltd., Derby (England).
DETAILED HEAT TRANSFER MEASUREMENTS IN NOZZLE GUIDE VANE PASSAGES IN LINEAR AND ANNULAR CASCADES IN THE PRESENCE OF SECONDARY FLOWS
N. W. HARVEY, Z. WANG, P. T. IRELAND, and T. V. JONES (Oxford Univ., England)   In AGARD, Secondary Flows in Turbomachines 13 p (SEE N90-21009 14-07) Feb. 1990 Sponsored in part by the Ministry of Defence and Rolls-Royce Plc., England
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02;
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AGARD/Scientific Publications Executive
Two transient techniques are used to measure the heat transfer coefficient distributions in nozzle guide vane passages. The first employs liquid crystal methods in a Cold Heat Transfer Tunnel and examines the flow in a two-dimensional cascade. The second uses localized thin film heat transfer gauges within an annular cascade at engine representative Mach numbers and Reynolds numbers. The techniques are described and the resulting heat transfer coefficient distributions are discussed and interpreted in terms of the secondary flows and vortex structures. Typical heat transfer distributions are presented over the endwalls and blade surfaces. An analysis of the endwall heat transfer results is presented for the annular cascade.   Author

N90-21031# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mechanical Engineering.
EFFECTS OF SECONDARY FLOW ON HEAT TRANSFER IN ROTATING PASSAGES
JOAN G. MOORE and JOHN MOORE   In AGARD, Secondary Flows in Turbomachines 13 p (SEE N90-21009 14-07) Feb. 1990 Sponsored by Rolls-Royce Plc.
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AGARD/Scientific Publications Executive
Secondary flow in rotating cooling passages of jet engine turbine rotors is considered. A Navier-Stokes calculation procedure for turbulent flow is used to compute flow development in a radially outward flow channel, round a sharp 180 degree bend, and in the radially inward flow channel downstream. Areas of high and low heat transfer are explained by secondary flow development and quantitative results show regions of design interest.   Author

N90-21032# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THEORETICAL STUDY OF THE FLOW IN A ROTATING CHANNEL. EXPERIMENTAL STUDY THROUGH FLOW VISUALIZATION IN A CURVED CHANNEL
JOEL GUIDEZ, PIERRE-JACQUES MICHARD, and DENIS DUTOYA   In AGARD, Secondary Flows in Turbomachines 14 p (SEE N90-21009 14-07) Feb. 1990 Sponsored by Direction des Recherches et Etudes Techniques
(AGARD-CP-469) Copyright Avail: NTIS HC A15/MF A02;
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An experimental and theoretical study of the heat transfer and flow in rotating channels is in development at ONERA. These channels simulate some simple internal cavities of turbine blades. It was experimentally demonstrated that the rotation speed induces a global enhancement of the heat transfer coefficient. The phenomenon can be explained by the secondary flows connected to the Coriolis force. Theoretically, the Navier-Stokes equations that govern this problem are numerically solved in 3D (time marching, ADI method). For laminar and turbulent flows, the results

obtained point out the secondary structures (two and four vortices). In addition, by means of rotation-curvature analogy, the visualization of the streamlines in a water-channel flow with air or hydrogen bubbles shows the same flow structures. Author

N90-21975# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
APPLICATIONS OF MESH GENERATION TO COMPLEX 3-D CONFIGURATIONS
Mar. 1990 302 p In ENGLISH and FRENCH Meeting held in Loen, Norway, 24-25 May 1989
(AGARD-CP-464; ISBN-92-835-0551-4; AD-A221593) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

This Symposium was sponsored to provide a survey of the capabilities of the CFD community for griding complex 3-D configurations. The intent was to provide some insight to the present state of grid generation for complex configurations to help assess whether this task presents a long-term stumbling block to the routine use of CFD in aerodynamic applications. To this end, the meeting was structured in five sessions: General Surveys, Algebraic Grid Generation, Block Structured Meshes, Multiblock-Adaptive Meshes, and Unstructured Meshes. It was amply demonstrated that the viability of a numerical solution depends directly on the quality of the mesh and surface representation as measured by its spacing and resolution. Results indicate that geometry discretization and generation of meshes for complex 3-D configurations in aerospace will continue to be time- and cost-consuming operations for some time to come. For individual titles, see N90-21976 through N90-21997.

N90-21976# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Aerothermodynamics Section.
RECENT DEVELOPMENTS IN GRID GENERATION
J. HAEUSER and A. VINCKIER In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 15 p (SEE N90-21975 15-34) Mar. 1990
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An overview is given on recent developments in grid generation with emphasis on the results presented in the proceedings of the Second International Conference in Numerical Grid Generation in Computational Fluid Mechanics '88. Grid generation is essential for the solution of all kinds of fluid physics problems. It also reports briefly about the grid generation activities mainly to be used for Hermes. It is particularly important in cases where very different length scales are present, as, for example, in the case of turbulence, which can be considered as the pacing item in present day fluid physics. The main issue deals with multi-block grids in 3-D, but unstructured grids are also briefly mentioned. The important topics in multi-block grid generation are outlined and various approaches to their solution are discussed. The following main building blocks were identified: topology of the grid, that is how neighboring blocks are identified and what their relative orientation is to each other; patched (nonoverlapping grid that has grid line continuity only) or matched grids (grids with slope continuity, i.e., continuous tangent vector); block decomposition, which has to be automated if hundreds or thousands of blocks are being used; surface grid generation and analytical description of smooth surfaces to avoid the generation of shocks or expansion fans; grid point clustering (static grids); grid adaptation (dynamic grids) according to specified gradients or function values performed either by redistribution or by local enrichment; and postprocessing of grids to visualize and to achieve a specified grid quality at certain points or along certain lines or planes (interactive process). Author

N90-21977# Mississippi State Univ., Mississippi State. Dept. of Aerospace Engineering.
GENERAL STRUCTURED GRID GENERATION SYSTEMS
JOE F. THOMPSON In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 8 p (SEE N90-21975 15-34) Mar. 1990
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Current techniques for the generation of composite-block structured grids for general 3D configurations are discussed. The various aspects of grid generation involved are noted, and their incorporation in general codes is cited. Current techniques for adaptive grids for general configurations are also discussed. Author

N90-21978# Volvo Flygmotor A.B., Trollhaettan (Sweden).
ALGEBRAIC BLOCK-STRUCTURED GRID GENERATION BASED ON A MACRO-BLOCK CONCEPT
LARS-ERIK ERIKSSON and ERLAND ORBEKK (Norges Tekniske Hoegskole, Trondheim.) In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 11 p (SEE N90-21975 15-34) Mar. 1990
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An algebraic technique for generating block-structured grids of arbitrary topology is described. The method is based on a macro-block concept which allows the usage of large blocks with partial block boundary interfacing. Various spline procedures are used for curve generation and for constrained surface grids whereas all unconstrained surfaces and volumes are gridded by transfinite interpolation. Instead of using derivative information to control the grid in each block the present method is based on the idea of generating as many interior guiding surfaces as required for grid control and gridding each resulting sub-block independently of other sub-blocks. The resulting metric discontinuities, both inside blocks and between blocks, are smoothed either by a local algebraic smoothing procedure or by a global elliptic type smoothing procedure or combinations of both. The complete method was coded in a highly modular way and includes all graphics routines. Several 3-D multi-block grid examples are presented and discussed. Author

N90-21979*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
APPLICATIONS OF ALGEBRAIC GRID GENERATION
PETER R. EISEMAN (Columbia Univ., New York, NY.) and ROBERT E. SMITH In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 12 p (SEE N90-21975 15-34) Mar. 1990
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Techniques and applications of algebraic grid generation are described. The techniques are univariate interpolations and transfinite assemblies of univariate interpolations. Because algebraic grid generation is computationally efficient, the use of interactive graphics in conjunction with the techniques is advocated. A flexible approach, which works extremely well in an interactive environment, called the control point form of algebraic grid generation is described. The applications discussed are three-dimensional grids constructed about airplane and submarine configurations. Author

N90-21983# General Dynamics/Fort Worth, TX. Computational Fluid Dynamics Group.
A STRUCTURED APPROACH TO INTERACTIVE MULTIPLE BLOCK GRID GENERATION
J. P. STEINBRENNER, J. R. CHAWNER, and C. L. FOUTS In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 12 p (SEE N90-21975 15-34) Mar. 1990
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The sheer variety of problems found in Computational Fluid Dynamics (CFD) has dictated a need for grid generation methods of the utmost generality. Experience has shown that user interaction and graphical feedback are two necessary features of a successful

method as well. Employing these ideas, a structured method of grid generation was developed, allowing a grid system to be constructed through the use of four specialized codes, accessed on two machines. These codes are based on the multiple block concept, whereby the flowfield domain is decomposed into a number of contiguous subdomains, allowing for efficient grid generation and flowfield solution. The first of these codes aids the user in inspecting the flow domain and in developing a suitable blocking strategy for the block system. A second code is then used to establish the exact connections between abutting blocks and to set flow boundary conditions on all surfaces of the block system. This connectivity and boundary condition data is accessed in the final two codes to construct the grid itself. The third code generates the surfaces of each block in the system, and the final code distributes grid points on the block interiors. The intricacies of these codes are explained along with an example, conclusions and projections for further work.   Author

N90-21988# Royal Aerospace Establishment, Farnborough (England).
FEATURE-ASSOCIATED MESH EMBEDDING FOR COMPLEX CONFIGURATIONS
C. M. ALBONE and GAYNOR JOYCE (City Univ., London, England) In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 12 p (SEE N90-21975 15-34) Mar. 1990
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The mesh-generation scheme described was designed to cope with complex geometric and flow features by employing many regular three-dimensional overlying meshes. Features are classified according to the number of geometric constraints to which they are subject, and each feature has its own purpose-built mesh. Four different mesh topologies are required to deal with all possible geometric and flow features. Progress to date is described and meshes for simple three-dimensional configurations are shown together with results of some Euler flow calculations.   Author

N90-21989# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Computational Fluid Dynamics Group.
ON THE WAY TO AN INTEGRATED MESH GENERATION SYSTEM FOR INDUSTRIAL APPLICATIONS
W. SEIBERT, W. FRITZ, and S. LEICHER In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 12 p (SEE N90-21975 15-34) Mar. 1990
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The main features of some specialized batch modules, which were developed recently to meet the requirements of a grid generation for complex configurations, are described. One module is a combination of an algebraic grid generator for the determination of a surface grid and the far field boundary, and an hyperbolic grid generator for the sectionwise calculation of the corresponding orthogonal internal grid lines. Two other modules are concentrated on solution adaptive grids - either using algebraic redistribution proportional to the curvature of a typical flow filed describing function, or by solving elliptical partial differential equations resulting from the transformation of the Poisson equation from the physical space into the computational space. Adaption of the grid to pressure gradients and to the total pressure loss is done by replacing the source terms. The first part, however, is the description of the graphic-interactive program-system INGRID, which already comprises several standard techniques to generate composite volume grids around arbitrary complex configurations, and which has the potential to become an integrated system to match the demands for a general productive mesh generation method. As application examples several grids are shown, illustrating actual problems of external aircraft aerodynamics, ground-vehicle aerodynamics and of internal pipe flow.   Author

N90-21990# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Direction de l'Aerodynamique.
GENERATION, OPTIMIZATION, AND ADAPTATION OF MULTIDOMAIN MESHES AROUND COMPLEX CONFIGURATIONS [GENERATION, OPTIMISATION, ET ADAPTATION DE MAILLAGES MULTIDOMAINES AUTOUR DE CONFIGURATIONS COMPLEXES]
OLIVIER-PIERRE JACQUOTTE In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 11 p (SEE N90-21975 15-34) Mar. 1990 In FRENCH Original language document was announced in IAA as A89-48756
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A method for the construction, optimization, and adaptation of three-dimensional structured meshes around complex configurations is presented. The first step consists of the algebraic generation of a multidomain mesh by dividing the calculation domain into structured hexahedral subdomains. A variational method is then developed to improve the qualities of the mesh (in particular its metrical properties) and to adapt it to the physical solution to be calculated on the mesh. The method has been used to obtain results for such configurations as a turbine blade, a hollow nacelle, and the Aster missile.   Author

N90-21991# Aircraft Research Association Ltd., Bedford (England).
A DISCUSSION ON ISSUES RELATING TO MULTIBLOCK GRID GENERATION
J. M. GEORGALA and J. A. SHAW In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 13 p (SEE N90-21975 15-34) Mar. 1990 Sponsored in part by Ministry of Defence, England
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Efforts aimed at bringing a multiblock grid generation system to the state of maturity necessary for practical use are discussed. Attention is focused upon the interrelated areas of topology generation and grid control. An algorithm for automatically decomposing a flow domain about an aircraft configuration into a component-adaptive topology is given. Two techniques for controlling the resulting grid topology are described. The first automatically produces default grids, which will generally be of an acceptable quality. The second is a user-friendly interactive grid editor which allows any deficiencies in the default grids to be rapidly identified and modified. Examples of the multiblock approach are applied to a range of aircraft geometries.   Author

N90-21992# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France). Departement des Etudes Theoriques Aerodynamiques.
AUTOMATIC GRID GENERATION IN COMPLEX THREE-DIMENSIONAL CONFIGURATIONS USING A FRONTAL SYSTEM [GENERATION DE MAILLAGE AUTOMATIQUE DANS DES CONFIGURATIONS TRIDIMENSIONNELLES COMPLEXES UTILISATION D'UNE METHODE DE FRONT]
F. HUET In AGARD, Applications of Mesh Generation to Complex 3-D Configurations 12 p (SEE N90-21975 15-34) Mar. 1990 In FRENCH
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Among the types of grid generation, the frontal construction method, starting from the limiting preset parameters, seems to be the most promising with respect to complex configurations within the framework of the finite element method. Its flexibility and its great adaptability makes it a tool with a very large area of application. The algorithm presented functions for the grids of complex configurations encounterd in aeronautics: engine nozzles with multiflow, Hermes shuttle, and Falcon.   Transl. by E.R.

N90-21993*# University Coll. of Swansea (Wales). Dept. of Civil Engineering.
UNSTRUCTURED FINITE ELEMENT MESH GENERATION AND ADAPTIVE PROCEDURES FOR CFD
J. PERAIRE, K. MORGAN, and J. PEIRO *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 12 p (SEE N90-21975 15-34) Mar. 1990 Sponsored by NASA; Avions Marcel Dassault; and Civil and Military Aircraft Div., British Aerospace Public Ltd. Co.
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 20/4
A method is described for generating unstructured meshes of triangles or tetrahedra for computational domains of complex geometrical shape. To illustrate the power of the approach, it is applied to the solution of flows past several complete aircraft configurations. The advocated approach allows for the natural incorporation of mesh adaptivity and this is demonstrated for both inviscid and viscous computations in two and three dimensions.
Author

N90-21994*# George Washington Univ., Washington, DC. School of Engineering and Applied Science.
GENERATION AND ADAPTATION OF 3-D UNSTRUCTURED GRIDS FOR TRANSIENT PROBLEMS
RAINALD LOEHNER *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 17 p (SEE N90-21975 15-34) Mar. 1990 Sponsored in part by DNA; Air Force Ballistic Missile Office; and NRL
(Contract NAS1-18419; NAS1-18670)
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 20/4
Grid generation and adaptive refinement techniques suitable for the simulation of strongly unsteady flows past geometrically complex bodies in 3-D are described. The grids are generated using the advancing front technique. Emphasis is placed not to generate elements that are too small, as this would severely increase the cost of simulations with explicit flow solvers. The grids are adapted to an evolving flowfield using simple h-refinement. A grid change is performed every 5 to 10 timesteps, and only one level of refinement/coarsening is allowed per mesh change.
Author

N90-26280# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
REPORT OF THE FLUID DYNAMICS PANEL WORKING GROUP 10 ON CALCULATION OF 3D SEPARATE TURBULENT FLOWS IN BOUNDARY LAYER LIMIT
May 1990 145 p
(AGARD-AR-255; ISBN-92-835-0560-3; AD-A223936) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The results of a study conducted by Working Group 10 of the AGARD Fluid Dynamics Panel to investigate the limits of boundary layer methods, both the integral and field type formulations, for calculating three-dimensional turbulent separated flow are presented. Test cases used to assess the boundary layer calculations included the DFLVR prolate spheroid at angle of attack and the NASA-Ames Wing C. Comparisons between boundary layer calculations and experimental data are presented for these test cases along with observations, conclusions, and recommendations.
Author

N91-21464# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
APPLICATION OF MESH GENERATION TO COMPLEX 3-D CONFIGURATIONS
JOSEPH L. STEGER and W. SCHMIDT, ed.
(Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Germany, F.R.) 1991 18 p Presented at the AGARD Fluid Dynamics Panel Specialists Meeting, Loen, Norway, 24-25 May 1989
(AGARD-AR-268; ISBN-92-835-0608-1; AD-A235117) Copyright Avail: NTIS HC/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The papers presented at the AGARD Fluid Dynamics Panel Specialists' Meeting are summarized and evaluated. Some general comments regarding progress in mesh generation are provided

and the important role of grid generation in providing accurate aerodynamic simulations is underscored. Recommendations and opinions are offered regarding the use of both structured and unstructured grids for CFD applications. Author

N91-32443# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
APPRAISAL OF THE SUITABILITY OF TURBULENCE MODELS IN FLOW CALCULATIONS
Jul. 1991 100 p Review held in Friedrichshafen, Fed. Republic of Germany, 26 Apr. 1990
(AGARD-AR-291; ISBN-92-835-0625-1; AD-A242221) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A status review is presented of the activities in several NATO nations which is aimed at assessing the use and suitability of existing, and emerging, turbulence models in flow field calculations. Assessments are presented for both steady and unsteady flow fields associated with a variety of problems. These problems included forced convection flow fields for both attached and separated shear layers, two phase flow, and turbulent reacting flows in addition to flow fields driven by free convection. These assessments indicate that there is presently no universal turbulence model which provides acceptable results for a broad spectrum of flow problems and some doubt is expressed concerning the possibility of ever being able to develop such a model. However, some success is noted for turbulence models which were developed for and applied to problems with similar flow field characteristics. For individual titles, see N91-32444 through N91-32451.

N91-32444# National Aerospace Lab., Amsterdam (Netherlands).
TURBULENCE MODELLING: SURVEY OF ACTIVITIES IN BELGIUM AND THE NETHERLANDS, AN APPRAISAL OF THE STATUS AND A VIEW ON THE PROSPECTS
B. VANDENBERG *In* AGARD, Appraisal of the Suitability of Turbulence Models in Flow Calculations 7 p (SEE N91-32443 24-34) Jul. 1991
(AGARD-AR-291) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Turbulence research proceeding presently at various places in the Netherlands and Belgium is briefly reviewed. Subsequently some experimental results obtained in turbulent boundary layers, as occur on airplane wings, are considered in relation to the usual turbulence model assumptions. The status of turbulence modelling is found not to be satisfactory. To support the development of semiempirical models of acceptable accuracy, a more extensive base of reliable turbulence data would be desirable. Author

N91-32445# Centre d'Etudes et de Recherches, Toulouse (France). Complexe Scientifique de Rangueil.
CALCULATION OF TURBULENT COMPRESSIBLE FLOWS
J. COUSTEIX *In* AGARD, Appraisal of the Suitability of Turbulence Models in Flow Calculations 20 p (SEE N91-32443 24-34) Jul. 1991
(AGARD-AR-291) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The use and the suitability is discussed of turbulence models for calculating compressible flows in aerodynamics. As the compressible form of turbulence models is generally extended from a basic incompressible form, the emphasis is placed on the pertinence of these extensions and on the peculiarities of compressible flows. Author

N91-32446# Karlsruhe Univ. (Germany, F.R.). Inst. for Hydromechanics.
SOME CURRENT APPROACHES IN TURBULENCE MODELLING
W. RODI *In* AGARD, Appraisal of the Suitability of Turbulence Models in Flow Calculations 10 p (SEE N91-32443 24-34) Jul. 1991 Sponsored in part by DFG
(AGARD-AR-291) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Some recent work is reviewed in the area of modeling turbulence in near wall regions and by Reynolds stress equation models. Various low Reynolds number versions of the kappa-epsilon model and damping functions are examined with the aid of results from direct numerical simulations and they are compared with respect to their performance in calculating boundary layers under adverse and favorable pressure gradients. A two layer model is presented in which near wall regions are resolved with a one equation model and the core region with the standard kappa-epsilon model. Various applications of this model are shown. The ability of various models to simulate laminar-turbulent transition in boundary layers is discussed. Recent applications of a fairly simple, standard Reynolds stress equation model to two complex flow of practical interest are presented. Finally, some recent proposals for improved Reynolds stress equation models are presented and an outlook is provided on possible future turbulence model developments.
Author

N91-32447# Patras Univ. (Greece). Lab. of Applied Thermodynamics.
TURBULENCE MODELS FOR NATURAL CONVECTION FLOWS ALONG A VERTICAL HEATED PLANE
D. D. PAPAILIOU *In* AGARD, Appraisal of the Suitability of Turbulence Models in Flow Calculations 8 p (SEE N91-32443 24-34) Jul. 1991
(AGARD-AR-291) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The state of development of turbulent models is reviewed which are currently used in the computation of turbulent free convection flows along heated plane surfaces. Some experimental results recently obtained are also compared with corresponding computations in which existing turbulence models were also used. There is a lack of sufficient knowledge regarding the effects of buoyancy on the turbulence structure of flows such as plumes, buoyant jets, and thermal flow, and also buoyancy's participation and role in the corresponding transport processes. The reasons causing this inadequacy of necessary information is discussed. As a consequence, in computing buoyancy induced flows, turbulent transport models are adopted from forced convection or ordinary flows, mostly in modified forms.
Author

N91-32448# Zaragoza Univ. (Spain). Fluid Mechanics Group.
TURBULENT FLOW MODELLING IN SPAIN: OVERVIEW AND DEVELOPMENTS
C. DOPAZO, R. ALIOD, and L. VALINO *In* AGARD, Appraisal of the Suitability of Turbulence Models in Flow Calculations 13 p (SEE N91-32443 24-34) Jul. 1991
(AGARD-AR-291) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A brief overview of ongoing flow modelling activities in the fields of turbulent boundary layers, two phase flows, and turbulent reactive flows is presented. Turbulent shear flows laden with small solid particles and the turbulent isothermal mixing of two chemical species undergoing a second order irreversible chemical reaction are discussed. An Eulerian approach is followed in the former, using a phase indicator function conditioning technique for the continuous phase and a Boltzmann type velocity distribution function for the dispersed phase. The latter is treated via a probability density function (pdf) formalism where the joint statistics of concentrations and concentration gradients is studied. Predictions are compared with available experimental results in both cases.
Author

N91-32449# Turkish Aerospace Industries, Ankara.
COMPUTATIONAL TURBULENCE STUDIES IN TURKEY
UNVER KAYNAK *In* AGARD, Appraisal of the Suitability of Turbulence Models in Flow Calculations 8 p (SEE N91-32443 24-34) Jul. 1991
(AGARD-AR-291) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Applications of various turbulence models to different flow problems that were recently carried out in Turkey are presented. Navier-Stokes, boundary layer, and vorticity stream function methods are used to solve 2-D or 3-D steady and/or unsteady flow problems. Examples are given in low speed and transonic flow regimes for axisymmetric bodies, airfoils, rigid ripples, and jet flows. Different turbulence models are used such as algebraic, half equation, and k-epsilon models. It is shown that improved accuracies can be obtained by using the so-called half equation (nonequilibrium) turbulence model for some 3-D configurations. Suitability of different turbulence models is explored for a variety of flow cases such as dynamic stall, jets in crossflow, and oscillatory boundary layers.
Author

N91-32450# Southampton Univ. (England). Dept. of Aeronautics and Astronautics.
APPRAISAL OF THE SUITABILITY OF TURBULENCE MODELS IN FLOW CALCULATIONS: A UK VIEW ON TURBULENCE MODELS FOR TURBULENT SHEAR FLOW CALCULATIONS
G. M. LILLEY *In* AGARD, Appraisal of the Suitability of Turbulence Models in Flow Calculations 15 p (SEE N91-32443 24-34) Jul. 1991
(AGARD-AR-291) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The background and basis is examined for the different models of turbulence as currently used for solutions to the Reynolds averaged Navier-Stokes equations. It is concluded that no model of turbulence as currently used is fully satisfactory, although many computer codes may legitimately claim to give results to engineering accuracy. The need is stressed to provide means for calibrating all CFD computer codes against good, reliable, independently assessed experimental data. Attention is drawn to a need for a reassessment of the central role claimed in turbulence modeling for the six independent components of the Reynolds Stress Tensor. There is also a need to replace the term eddy viscosity by a term that more accurately expresses the large scale turbulent mixing process in a turbulent flow.
Author

N91-32451# Stanford Univ., CA. Dept. of Mechanical Engineering.
COLLABORATIVE TESTING OF TURBULENCE MODELS
PETER BRADSHAW *In* AGARD, Appraisal of the Suitability of Turbulence Models in Flow Calculations 5 p (SEE N91-32443 24-34) Jul. 1991
(AGARD-AR-291) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A review is given of an ongoing international project, in which data from experiments on, and simulations of, turbulent flows are distributed to developers of (time averaged) engineering turbulence models. The predictions of each model are sent to the organizers and redistributed to all the modellers, plus some experimentalists and other experts. The organizers' inspection of the results has identified several discrepancies which were traced to numerical errors.
Author

N92-21685# Aerospatiale, Toulouse (France). Div. Avions.
METHOD FOR CALCULATING THE THREE-DIMENSIONAL WATER CONCENTRATION COEFFICIENTS AND ITS INDUSTRIAL APPLICATIONS [METHODE DE CALCUL DE COEFFICIENTS DE CONCENTRATION D'EAU EN TRIDIMENSIONNEL ET SES APPLICATIONS INDUSTRIELLES]
P. PREL *In* AGARD, Effects of Adverse Weather on Aerodynamics 12 p (SEE N92-21679 12-03) Dec. 1991 In FRENCH
(AGARD-CP-496) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A three dimensional method for calculating the concentration coefficients of water droplets, its general principles, as well as

the details of the calculating computer programs that were used, are described. The applications are presented for locating probes on the Airbus 340 and ATR 72 airplanes, mainly showing the effect of the drop diameter on the measured concentration.

<div align="right">Author</div>

N92-21953# Naval Postgraduate School, Monterey, CA. Dept. of Aeronautics and Astronautics.
THE AERODYNAMICS OF SHIP SUPERSTRUCTURES
J. V. HEALEY *In* AGARD, Aircraft Ship Operations 14 p (SEE N92-21951 12-05) Nov. 1991
(AGARD-CP-509) Copyright Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

After 70 years of naval aviation, a belated understanding of the aerodynamics of ships is slowly emerging. The lack of understanding, and undoubtedly other reasons, has led to superstructure configurations that are unsuited to adjacent helicopter flight. This has resulted in severely limited safe operating envelopes, danger to pilots and ship personnel and blade strikes that occasionally result in the complete loss of a helicopter. The air flows around ships abound with recirculating zones, bounded by shear layers that emanate from the sharp edges of the superstructures. These zones vary enormously in size in an intermittent manner, giving rise to flows with extreme velocity gradients and turbulence intensity levels that are too high to be measured with hot wire anemometers. This complicates the situation because, at the present time, a data base for simulation can be established only via measurement. The essential ingredients for the aerodynamic design of new ships are proposed and some suggestions for the improvement of the aerodynamics of existing ships are made. Correcting an aerodynamically poor ship is no substitute for the incorporation of aerodynamics into the ship design process.

<div align="right">Author</div>

N92-21954# Naval Air Test Center, Patuxent River, MD. Rotary Wing Aircraft Test Directorate.
SHIP AIRWAKE MEASUREMENT AND MODELING OPTIONS FOR ROTORCRAFT APPLICATIONS
DEAN CARICO, BILL REDDY, and CHARLES DIMARZIO (Northeastern Univ., Boston, MA.) *In* AGARD, Aircraft Ship Operations 24 p (SEE N92-21951 12-05) Nov. 1991
(AGARD-CP-509) Copyright Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Ship airwake is important in defining rotorcraft ship operational limitations and in predicting those limitations using analysis and simulation. Accurate real time ship airwake models are required to support pilot shipboard landing training in aviation training devices. Increased emphasis must be placed on obtaining quantitative full scale airwake data and in quantitatively evaluating ship airwake simulation models. Quantitative ship airwake data measurement equipment ranges from hand held mechanical sensors, to propeller anemometers mounted on a mast, to possible laser velocimeter and other options in the near future. Wind tunnel and computational fluid dynamics options are also possible candidates for ship airwake data generation. It is important to compare the different techniques for obtaining ship airwake data and evaluate the utility and strengths and weaknesses of each technique. Many activities in the U.S. and in other countries are involved in rotorcraft shipboard landing flight test, analysis, and simulation.

<div align="right">Author</div>

N92-21955# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain).
MEASUREMENT OF THE FLOW DISTRIBUTION OVER THE FLIGHT DECK OF AN AIRCRAFT CARRIER
M. MULERO and F. GOMEZ PORTABELLA *In* AGARD, Aircraft Ship Operations 12 p (SEE N92-21951 12-05) Nov. 1991
(AGARD-CP-509) Copyright Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A study was conducted on the general configuration of the air flow over the flight deck of a Spanish aircraft carrier. The level was determined of fluctuations of the wind vector in certain points of the deck where operations of VSTOL planes and helicopters take place. It was decided to study the possibility of making wind tunnel testing over a reduced scale model of the ship and later

take some limited data over the actual ship. Preliminary tests to assess the validity of the simulation of the main flow features in the wind tunnel were performed over a simple square cube and they showed a systematic constancy in the shape of the cavity and the wake as a function of the Reynolds numbers studied. Tests were then performed on a reduced scale model of the ship and data were gathered by means of hot film probes and by photographing wool tufts attached to the surface of the model. Results show separation past the leading edge of the ramp, which produces vortices that trail along and over the deck to distances that depend on the direction of the approach wind. Limited data of local velocities and direction in the horizontal plane were obtained over the real ship, which show the highly disturbed flow.

<div align="right">Author</div>

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INSTRUMENTATION AND PHOTOGRAPHY

Includes remote sensors; measuring instruments and gages; detectors; cameras and photographic supplies; and holography.

N89-29310# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
AEROTHERMODYNAMIC INSTRUMENTATION
RICHARD D. NEUMANN *In* AGARD, Special Course on Aerothermodynamics of Hypersonic Vehicles 40 p (SEE N89-29306 24-02) Jun. 1989
(AGARD-R-761) Copyright Avail: NTIS HC A15/MF A02

The features of thermal instrumentation, thermal model simplifications implicit in thermal instrumentations, thermal gage definition, thermal gages, and the products of simplifications are discussed.

<div align="right">Author</div>

N90-21359# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
THE ANATOMY OF THE GYROSCOPE, PART 3
FRANK W. COUSINS and JOHN L. HOLLINGTON, ed. (Smiths Industries Aerospace and Defence Systems Ltd., Cheltenham, England) 1990 298 p
(AGARD-AG-313-PT-3; AD-A221595) Copyright Avail: NTIS HC A13/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The gyroscope and its applications are collated with the technical information to be found in the patent literature, augmented by that found in textbooks and technical journals. A detailed consideration is given to early mechanical gyroscopes. Included is a discussion of gyroscopic gears, vibratory gyroscopes, interferometric gyroscopes, and the use of the gyroscope in optical and related devices and deals finally with the difficult problem of gyroscopic inertial drives.

<div align="right">Author</div>

N91-14042# Honeywell, Inc., Minneapolis, MN.
APPLICATION OF HIGH-TEMPERATURE SUPERCONDUCTORS TO HIGH-PRECISION ACCELEROMETERS
JAMES LENZ, QUARK CHEN, JAMES MCARDLE, TOM WERNER, and WAYNE CASTLEMAN *In* AGARD, Applications of Superconductivity to Avionics 7 p (SEE N91-14030 05-76) Oct. 1990 Sponsored by DARPA, Washington, DC and ONR, Washington, DC
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Superconducting materials offer unique capabilities to high-precision acceleration sensing. Two specific aspects are shielding of magnetic fields and magnetic levitation due to the Meissner Effect. The basic configuration and operation of accelerometers using superconducting materials are reviewed. Physical properties such as conductivity, permeability, trapped magnetic flux, and material uniformity are correlated to shielding and levitation performance. Measurements of these properties for the YBaCuO superconductors are included.

<div align="right">Author</div>

N91-14043# Naval Air Development Center, Warminster, PA.
SUPERCONDUCTING JOSEPHSON JUNCTION GYROSCOPE (JJG)
FRANCIS A. KARWACKI   *in* AGARD, Applications of
Superconductivity to Avionics 4 p (SEE N91-14030 05-76)   Oct.
1990
(AGARD-CP-481)   Copyright   Avail: NTIS HC/MF A08;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
A multi-year effort to develop a Josephson Junction Gyroscope
(JJG) is described. The goal is to develop a small solid-state
gyroscope that utilizes the phase coherence of Cooper-paired
electrons to measure applied rotation. The research is divided
into a low temperature proof of concept, high temperature material
research, Josephson junction development, and the development
of an experimental test facility.   Author

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LASERS AND MASERS

Includes parametric amplifiers.

N90-21924#   Yale Univ., New Haven, CT.   Dept. of Applied
Physics.
HIGH INTENSITY LASER BEAM INTERACTIONS WITH SINGLE DROPLETS
RICHARD K. CHANG and ALFRED S. KWOK   *In* AGARD,
Atmospheric Propagation in the UV, Visible, IR, and MM-Wave
Region and Related Systems Aspects 12 p (SEE N90-21907
15-32)   Mar. 1990
(Contract DAAL03-88-K-0040; AF-AFOSR-0100-88)
(AGARD-CP-454)   Copyright   Avail: NTIS HC A16/MF A03;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
High density laser beam propagation in the atmosphere requires
knowledge of the linear and nonlinear optical interactions of the
UV, visible, and IR radiation with individual water droplets. The
spherical water-air interface of droplets (with radii larger than the
wavelength) can enhance the incident laser intensity inside the
droplet and in the air, provide optical feedback which can lower
the threshold for stimulated nonlinear emission when the
wavelength is in the transparent range of water, and modify the
internal intensity distribution and, thereby, distort the droplet shape
when the incident radiation is in the transparent or absorbing range
of water. Nonlinear optical research with single micrometer-size
water droplets irradiated by high intensity laser radiation in the
transparent and absorbing regions of water is reviewed.   Author

N91-15170#   Raytheon Co., Sudbury, MA.
INFRARED LASER RADAR SYSTEMS
A. V. JELALIAN and D. R. BATES   *In* AGARD, Advances in
Components for Active and Passive Airborne Sensors 20 p (SEE
N91-15154 07-06)   Sep. 1990
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Infrared laser radars constitute a direct extension of
conventional radar techniques to very short wavelengths. Whether
they are called lidar or ladar, they operate on the same basic
principles as microwave radars. Because they operate at much
shorter wavelengths, ladars are capable of higher accuracy and
more precise resolution than microwave radars. On the other hand,
ladars are subject to the vagaries of the atmosphere and are
thus generally restricted to shorter ranges. CO2 lasers operate at
wavelengths between 9 and 11.5 microns spanning much of the
8 to 12 micron atmospheric window. Atmospheric attenuation is
discussed throughout the electromagnetic spectrum and the impact
is assessed that weather has on system selection, with a view
toward complementary use of active radar and active and passive
optical systems. CO2 laser radar field test results are presented
to indicate the performance potential for moving target detection
and range detection and imaging of targets. Simultaneous
measurements from a common aperture active and passive system
test are also presented.   Author

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MECHANICAL ENGINEERING

Includes auxiliary systems (nonpower); machine elements and
processes; and mechanical equipment.

N91-14045#   International Research and Development Co. Ltd.,
Fossway (England).
THE WORLD OF SUPERCONDUCTIVE MACHINERY
A. D. APPLETON   *In* AGARD, Applications of Superconductivity
to Avionics 10 p (SEE N91-14030 05-76)   Oct. 1990
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The development of superconducting machinery has been in
progress since the early 1960's. A summary of the progress which
was made to date together with a view on the likely developments
in the future is presented. The bulk of the work in respect of
rotating machinery was on dc homopolar motors and generators,
and ac generators; the superconducting components are the
stationary field windings of the dc machines and the rotating dc
field windings of the ac machines. The bulk of the work on
superconducting ac generators was directed towards the
requirements of large central power stations. However some of
the earliest investigations were in respect to aircraft generators
and this application continues to be of interest. Although some
work was undertaken on inside out generators in which the dc
field winding was stationary, all of the current activity is in respect
to the more conventional geometry. In the early 1980s it was
discovered that by producing ultra fine wires of niobium titanium,
these liquid helium cooled superconductors could carry current at
power frequencies without prohibitive losses which had previously
been the case. This discovery and the subsequent production of
these wires in France and later in Japan enabled work to proceed
on superconducting transformers and on totally superconducting
ac generators. The next events in this rapidly evolving technology
were the discoveries in late 1986 and early 1987 that a non
metallic material was superconducting at temperatures in excess
of 90 K. The great significance of this development is that these
ceramic materials could be cooled with liquid nitrogen instead of
liquid helium and the ramifications of this upon design and cost
are immense. The likely impact of this discovery on electrical
power equipment is discussed.   Author

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QUALITY ASSURANCE AND RELIABILITY

Includes product sampling procedures and techniques; and quality
control.

N90-28068#   Advisory Group for Aerospace Research and
Development, Neuilly-Sur-Seine (France).   Structures and Materials
Panel.
IMPACT OF EMERGING NDE-NDI METHODS ON AIRCRAFT DESIGN, MANUFACTURE, AND MAINTENANCE
May 1990   232 p   In ENGLISH and FRENCH   The 69th
meeting held in Brussels, Belgium, 1-6 Oct. 1989
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Developments in NDE-NDI (nondestructive evaluation-
nondestructive inspection) applicable to the major
components and assemblies in airframes, engines, and their
sub-assemblies were reviewed. Users' needs and priorities were
discussed with emphasis on identification of the constraints that
present day NDE-NDI methods impose on the activities of aircraft
designers/manufacturers, airworthiness authorities, and aircraft
operators. The methods available for the characterization and
control of materials and processes were examined and current
developments in techniques for improved reliability and in-service
inspection were assessed. In a final session, research studies in

both physical and analytical methods were reviewed. For individual titles, see N90-28069 through N90-28093.

N90-28071# Martin Marietta Aerospace, Denver, CO. Astronautics Group.
ASSESSMENT AND DEMONSTRATION OF THE CAPABILITIES OF NDI PROCESSES, EQUIPMENT, AND PERSONNEL.
WARD D. RUMMEL *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 19 p (SEE N90-28068 22-38) May 1990
(AGARD-CP-462) Copyright Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The application of modern materials and structural analysis methods and the use of fatigue and fracture analysis in life prediction and life cycle modeling has focused attention on the need for quantitative nondestructive inspection (NDI) methods to quantify materials integrity and life limited component integrity. Advances in both life prediction methods and in quantitative NDI technology have enabled implementation of retirement for cause/life cycle management methods. The combined application of life prediction methods and the application of advanced NDI methods have resulted in improvements in engineering system reliability predictions and in quantification of both systems operating levels and systems life cycle operating margins. The principles of quantitative NDI process characterization, the development of analytical tools for NDI process characterization, and some typical results achieved by quantitative NDI process analysis and characterization are discussed. Author

N90-28072# Royal Aerospace Establishment, Farnborough (England). Dept. of Materials and Structures.
INSPECTION RELIABILITY
DAVID A. BRUCE *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 10 p (SEE N90-28068 22-38) May 1990
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The current methods for estimating the reliability of nondestructive evaluation (NDE) procedures are briefly reviewed. As an example, their application to the results of a recent UK-led baseline study of the reliability of rotating probe eddy current inspection, is described. After introducing definitions of the terminology, the proposed parametric and non-parametric statistical methodologies are described. The result of applying these methodologies to the actual results of the baseline program is shown, while the implications of the findings are examined in terms of their impact on airworthiness calculations, and the improvements which may be necessary if more reliance is to be placed on estimates of NDE reliability. Author

N90-28075# Construcciones Aeronauticas S.A., Madrid (Spain). Project Div.
ULTRASONIC INSPECTION OF ADVANCED CFRP STRUCTURES BY COMPUTER-CONTROLLED, PULSE-ECHO TECHNIQUE
B. SAINZ, J. M. BERNARDO, V. CORTES, and C. VALDECANTOS *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 6 p (SEE N90-28068 22-38) May 1990
(AGARD-CP-462) Copyright Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A complete system for NDE-NDI (nondestructive evaluation-nondestructive inspection) of a primary carbon fiber reinforced plastic (CFRP) structure was developed. Both internal and external damages were considered and monitored in order to document its behavior along the fatigue test for certification purposes. For external defect, i.e., those accessible from the outside, a portable, computer controlled ultrasonic system was designed and proved successful. The pulse-echo water squirter technique was used. The mechanical X-Y frame is able to scan up to 600(X) by 400(Y) mm. Data acquisition is performed for the amplitude signal so that C image can be drawn. Internal damages are controlled by a series of ultrasonic transducers bonded surrounding the damage so that a fixed signal is drawn from each transducer unless the defect limit extends and crosses the

ultrasonic beam giving a new echo growing from the time base. All the 80 transducers can be checked sequentially by means of a multiplexer. A major trouble is that the whole structure is aged by 3 months at 70 C and 70 percent humidity. This environment affects both bonding line integrity and piezoelectric parameters of the ceramic. Some design improvements were introduced to reduce these effects. Author

N90-28076# Aeritalia S.p.A., Turin (Italy). Defence Aircrafts Group.
AN ULTRASONIC SYSTEM FOR IN-SERVICE NON-DESTRUCTIVE INSPECTION OF COMPOSITE STRUCTURES
F BOSCHETTI, F. CIPRI, L. PUGLIESE, and M. SCOLARIS *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 6 p (SEE N90-28068 22-38) May 1990
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In order to perform, directly on the airfield, the nondestructive inspection (NDI) of aerospace composite structures by means of equipment similar to that already in use in the manufacturing workshop, a new ultrasonic system was developed by Aeritalia. The system includes an ultrasonic telemetry device for the geometrical location of the U.S. transducer position on the structure to be scanned and an instrumentation for the acquisition and processing of the ultrasonic data by B or C scan representation. The system operates in pulse-echo mode and provides in real-time a bidimensional representation of the intensity of the U.S. signals as well as the depth of the reflecting surface. Some typical examples of inspection performed on composite primary structures during fatigue tests simulating service life are presented. Author

N90-28078# Universal Technology Corp., Dayton, OH.
IN-SERVICE INSPECTION OF COMPOSITE COMPONENTS ON AIRCRAFT AT DEPOT AND FIELD LEVELS
NOEL A. TRACY, GROVER L. HARDY, and FRANK J. FECHEK (Wright Research Development Center, Wright-Patterson AFB, OH.) *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 11 p (SEE N90-28068 22-38) May 1990
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ARIS (Automated Real-Time Imaging System) is a modular, easily transportable, field-ready, ultrasonic system that provides automated, simultaneous recording and real-time display of ultrasonic data and search-unit position during routine manual inspections of laminar and sandwich aircraft structures. The Materials Laboratory of the U.S. Air Force Wright Research and Development Center sponsored the development of ARIS and subsequently evaluated the system in both laboratory and field environments with the aid of an independent contractor. During the evaluation ARIS was used on many aircraft structural components to determine if the system operated according to specifications and to discover ways of improving its applicability and usefulness. Suggested modifications addressed new applications of ARIS, the convenience and comfort of using ARIS, and the appropriateness and logicality of the software. Apart from its use on aircraft parts, ARIS was evaluated for transportability, ease of set-up, operational defects, and hardware reliability. Pictorial examples of ARIS in use are included and all aspects of the field evaluation are discussed. The versatility of ARIS is evident through the many features in the original design and the seemingly minor modifications in hardware and software that enhanced the features so that ARIS turned out to be more widely applicable than originally planned. ARIS has a definite place in the portable C-scan arena. Author

N90-28079# Defence Research Establishment Pacific, Victoria (British Columbia).
DEVELOPMENT OF AN AUTOMATED ULTRASONIC INSPECTION SYSTEM FOR COMPOSITE STRUCTURE ON IN-SERVICE AIRCRAFT
W. R. STURROCK, R. W. RAMSBOTTOM, and W. J. MILLER (National Defence Headquarters, Ottawa, Ontario)   *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 13 p (SEE N90-28068 22-38)   May 1990
(AGARD-CP-462)   Copyright   Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Composite honeycomb (carbon/epoxy facesheets bonded to aluminum honeycomb) control surfaces for the CF-18 are inspected at the time of manufacturing using (among other methods) ultrasonic through-transmission, but there is no automated ultrasonic inspection system to verify structural integrity of the honeycomb on in-service aircraft. Manual methods of ultrasonic contact scanning or even local through-transmission can be performed over small areas, but it is impossible to reliably inspect a complete control surface, such as a trailing edge flap on the wing or a horizontal stabilizer, with hand-held transducers. A description is given of the development and characteristics of an automated scanner and ultrasonic system to perform through-transmission inspections of honeycomb structure on the CF-18 without removal of the part from the aircraft. The prototype system, including a mobile lift table/platform, was demonstrated on an aircraft at CFB Cold Lake, Alberta, and examples of C-scan images obtained are shown. Recommendations are made for further improvements.   Author

N90-28080# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
NEUTRON RADIOGRAPHY: APPLICATIONS AND SYSTEMS
H.-U. MAST and R. SCHUETZ   *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 11 p (SEE N90-28068 22-38)   May 1990   Sponsored by Federal Ministry of Research and Development, Fed. Republic of Germany
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In accordance with previous results obtained in the U.S., a recent research project showed neutron radiography to be a nondestructive testing (NDI) method of potential value in aerospace maintenance and quality assurance, complementing conventional inspection methods. Applications include the detection of corrosion products, entrapped moisture, adhesive defects as well as some defects in carbon fiber composites. For years the large-scale use of neutron radiography was delayed due to the lack of small and inexpensive but powerful neutron sources. Recent progress in this area led to the present development of a new generation of small neutron sources, such as compact cyclotrons and powerful neutron generators.   Author

N90-28081# Royal Aerospace Establishment, Farnborough (England). Dept. of Materials and Structures.
PROGRESS IN THE DETECTION OF CRACKS UNDER INSTALLED FASTENERS USING EDDY CURRENTS
D. J. HARRISON   *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 8 p (SEE N90-28068 22-38)   May 1990
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The detection and characterization of fatigue cracks growing radially from fastener holes continues to be a major problem in the nondestructive inspection of aircraft. In general, it is highly desirable to be able to detect cracks in the skin and substructure without the need to remove the fasteners. Eddy-current methods are in principle well-suited to the detection of cracks in metals but, in this case, difficulties of interpretation can arise as a consequence of the relatively complicated geometry. For example, the effect of the fastener itself or a nearby edge can easily mask the effect of a crack. If the effects of irrelevant geometric features can be identified and removed then the ability of the eddy-current systems to detect cracks reliably under these circumstances can

be considerably enhanced. An intelligent eddy-current instrument was developed specifically for this problem. The Eddiscan uses a rotating transducer to map precisely any variations in the induced electromagnetic field around the circumference of the fastener. By using pattern recognition and other analysis techniques, the presence and positions of cracks can then be inferred. Using this method, cracks in the skin and subsurface layers can be detected with either ferrous or nonferrous fasteners installed.   Author

N90-28082# Royal Military Coll. of Canada, Kingston (Ontario). Dept. of Physics.
ACOUSTIC EMISSION DETECTION OF CRACK PRESENCE AND CRACK ADVANCE DURING FLIGHT
S. L. MCBRIDE, M. D. POLLARD, J. D. MACPHAIL, P. S. BOWMAN, and D. T. PETERS   *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 5 p (SEE N90-28068 22-38)   May 1990   Sponsored by Department of National Defence, Ottawa, Ontario
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Results are presented which show that it is possible to detect crack growth and crack presence in airframe composites during flight. To accomplish this, a data acquisition system was developed specifically for in-flight applications. It is shown that crack advance of less than 1 sq mm was readily detected during flight and the fracture-related acoustic emission signals.   Author

N90-28083#   Wright Research Development Center, Wright-Patterson AFB, OH. Materials Lab.
DEVELOPMENT AND APPLICATION OF COMPUTED TOMOGRAPHY (CT) FOR INSPECTION OF AEROSPACE COMPONENTS
THOMAS J. MORAN   *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 7 p (SEE N90-28068 22-38)   May 1990
(AGARD-CP-462)   Copyright   Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The requirement for quantitative characterization of flaws and material properties in advanced aerospace system components has led to extensive DOD efforts in the area of x ray computed tomography (CT). This technology, which was originally developed for medical applications, generates quantitative cross-sectional images of the density of the component being inspected. After an in-house Materials Laboratory team provided an initial demonstration of its industrial and aerospace applications potential ten year ago, the Air Force initiated several contract programs to construct military inspection CT systems and demonstrate their potential. From the time the first small (XIM) and large (AFACTS-1) CT systems began operation, the quantitative potential of this methodology is demonstrated for a wide range of applications. A representative sampling of these applications is discussed in order to provide a balanced picture of which applications are suitable for CT and which are not suitable, either as a result of technical deficiencies or economic limitations.   Author

N90-28084#   Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
THE APPLICATION OF INFRARED THERMOGRAPHY TO THE NONDESTRUCTIVE TESTING OF COMPOSITE MATERIALS [APPLICATION DE LA THERMOGRAPHIE INFAROUGE AU CONTROLE NON DESTRUCTIF DES MATERIAUX COMPOSITES]
HERVE TRETOU'i', JEAN-YVES MARIN, and RENE DEMOL   *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 8 p (SEE N90-28068 22-38)   May 1990   In FRENCH
(AGARD-CP-462)   Copyright   Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The construction of the structural parts in composite materials for aircraft necessitated the development of some way to test more, in order to assure the quality of the finished product. This testing must take place before assembly of the aircraft and in ground time or upon disassembly at the factory. Different methods of nondestructive tests, as well as testing by ultrasound and by x radioscopy are already widely used. However, the need for a faster

and easier test, stimulates the development of infrared thermography. Transl. by E.R.

N90-28085# Institut Foerster G.m.b.H. und Co. K.G., Reutlingen (Germany, F.R.).
NEW ASPECTS IN AIRCRAFT INSPECTION USING EDDY CURRENT METHODS
MANFRED TIETZE *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 8 p (SEE N90-28068 22-38) May 1990
(AGARD-CP-462) Copyright Avail: NTIS HC A11/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

High demands in safety at the highest possible load of aircraft structures cause increasing expenditure in the development of testing procedures for production, maintenance, and overhaul. Aircraft structural parts which are generally designed to achieve minimum weight as well as high mechanical stability unfortunately very often have the disadvantages of low corrosion resistance and high susceptibility to crack formation and propagation. Consequently the latitude for tolerable flaw sizes is very small. Therefore, reliable, documented inspection is of increasingly vital importance. Eddy current testing is one of the most effective tools to detect open or concealed corrosion and to assess damage caused by fatigue or corrosion cracking. In respect of the different sources of corrosion and possible crack formation, to enable identification, evaluation, and location it is necessary to have appropriate eddy current units and sensors optimized to the expected inspection program. The following describes the use of a meter type instrument for inspection of surface defects and a new impedance plane instrument that allows static and dynamic applications for detection of metal thinning due to corrosion, metal spacing, subsurface cracks, etc. and for very quick fastener hole inspection. Finally, new signal processing techniques for displaying flaw dimensions through imaging procedures are discussed. All units described are portable and battery operated. Author

N90-28086# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain). Structures and Materials Div.
STENOPIC RADIOGRAPHY: A NON-DESTRUCTIVE TEST WITHOUT CONTACT
GABRIEL DELOJO, JOSE M. DELOSRIOS, and JOSE MIGUEL *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 7 p (SEE N90-28068 22-38) May 1990
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The Nondestructive Testing Laboratory of INTA, is working now on experiences about the practical applications of the Stenope principle to obtain radiographic images from diffuse Compton radiation. The experiments have shown that it is possible to have a photographic register from an object by its difunded radiation when it it illuminated with a very intense 400 KV, x ray beam. Information can be obtained about nature differences and/or subsurfacial discontinuities from only one side of the sample. The first experiences were made with a fine grain radiographic film and high velocity salt screens. Next experiences were made with a fine grain radiographic film and high velocity salt screens. Next experience will be carried out with a high sensibility electron image intensifier assembled with a TV circuit, and, different energies radiation. Results obtained are exposed and discussed. Author

N90-28087# United Technologies Research Center, East Hartford, CT. Nondestructive Evaluation and Diagnostics Research.
NONCONTACT LASER THERMOMECHANICAL NONDESTRUCTIVE EVALUATION FOR ADVANCED COATINGS
H. I. RINGERMACHER *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 4 p (SEE N90-28068 22-38) May 1990
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Photoacoustic microscopy techniques were developed that permit the evaluation and visualization of thermomechanical properties of advanced coating systems including evaluation of attachment to various substrates, coating in-plane modulus,

thickness variation as well as variation in thermal properties. The technique involves scanning a component surface with a modulated laser beam while monitoring the induced vibration with a laser Doppler heterodyne interferometer. The induced vibration level is strongly dependent on the near surface thermomechanical coupling, thus making coatings an ideal application. Thermomechanical images of coatings along with physical modeling are described. Applications include silicon nitride and zirconia coatings for thermal barrier and oxide protection. Author

N90-28088*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCED NDE TECHNIQUES FOR QUANTITATIVE CHARACTERIZATION OF AIRCRAFT
JOSEPH S. HEYMAN and WILLIAM P. WINFREE *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 13 p (SEE N90-28068 22-38) May 1990
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Recent advances in nondestructive evaluation (NDE) at NASA Langley Research Center and their applications that have resulted in quantitative assessment of material properties based on thermal and ultrasonic measurements are reviewed. Specific applications include ultrasonic determination of bolt tension, ultrasonic and thermal characterization of bonded layered structures, characterization of composite materials, and disbonds in aircraft skins. Author

N90-28089# Naval Air Development Center, Warminster, PA. Advanced Metallic and Ceramic Materials Branch.
ACOUSTIC EMISSION FROM A GROWING CRACK
L. J. JACOBS (Georgia Inst. of Tech., Atlanta.), W. R. SCOTT, D. M. GRANATA, and M. J. RYAN *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 7 p (SEE N90-28068 22-38) May 1990
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A dynamic crack growth event is modeled using an integral equation method to develop an analytical expression for an acoustic emission waveform at any point of a crack propagation source. An experimental procedure is under development for investigating the important characteristics using a simple precracked compact tension specimen. A laser interferometric apparatus is used to measure displacement and velocity normal to the specimen surface. Crack propagation gages are used to determine the crack velocity. These experimental results are then used to verify the analytical model. Author

N90-28090# Sherbrooke Univ. (Quebec). Dept. of Mechanical Engineering.
STUDY OF FAILURE PROCESSES IN FIBER REINFORCED COMPOSITES USING ACOUSTIC EMISSION TECHNIQUES
C. ROY, A. MASLOUHI, and M. EL GHORBA *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 14 p (SEE N90-28068 22-38) May 1990 Sponsored in part by Natural Sciences and Engineering Research Council of Canada; National Research Council of Canada; and Canadian Space Agency, Ottawa
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Static and fatigue failures of composite materials are dominated by the initiation, growth, and propagation of typical damages, up to some catastrophic condition. Nondestructive evaluation (NDE) techniques are used to detect and monitor the progressive development of damage and therefore they contribute profoundly to furthering the understanding of damage growth and its effect on the material response. With few exceptions, most of the presently used nondestructive evaluation do not possess a real-time, in-situ capability. Fortunately, acoustic emission (AE) techniques show promise for monitoring structures in service and to assess damage at various stages in the life of a composite structure. New directions are described in the study of damage growth in composite specimens subjected to cyclic loading. Changes are assessed in the rate of damage accumulation in the

graphite fiber reinforced plastics (GFRP) during cycle mode 2 loading using tradition AE techniques. Typical damage growth patterns are identified and represented on a S-N fatigue curve. The microfailures in carbon fiber reinforced plastic (CFRP) during uniaxial fatigue testing are identified by applying advanced signal processing techniques on the actual event waveforms coupled with pattern recognition analysis. The data analysis procedure has evolved from earlier work analyzing acoustic emissions from the discrete components of a CFRP laminate. Pattern recognition analysis using the reduced waveform features and training sets resulted in discriminating between AE and noise signals and in distinguishing signal classes from damage related sources.   Author

N90-28091# Aerospatiale, Suresnes (France). Central Lab.
INSPECTION SYSTEM FOR IN-SITU INSPECTION OF AIRCRAFT COMPOSITE STRUCTURES
P. BLONDET and I. MOLINERO *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 8 p (SEE N90-28068 22-38) May 1990
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The intensive use of composite materials in aircraft primary structures has led to the setting up of special inspection systems for the detection of any defects which may be produced during the life of the aircraft. The main defects which are investigated during maintenance are, in general, delamination defects produced by various types of impact (stones, lightning, effects of maintenance tools being dropped). Until more global techniques (thermography, holography) are developed, the most suitable method for this type of inspection is ultrasonics. The problem involves application of these inspection procedures to an aircraft under maintenance conditions while scanning the areas to be inspected and obtaining a real time diagnosis. The SIAM R-theta system was especially designed to meet the requirements of this type of inspection. It is capable of both assessing the damage after detection of the defect (visually, for example), and detecting defects within the framework of general inspection.   Author

N90-28092# Manitoba Univ., Winnipeg.
USE OF ACOUSTIC EMISSION FOR CONTINUOUS SURVEILLANCE OF AIRCRAFT STRUCTURES
M. NABIL BASSIM *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 6 p (SEE N90-28068 22-38) May 1990   Sponsored in part by Petro-Canada Ltd., Calgary, Alberta; Ontario Hydro; Viatex Resources; Canadian Natural Sciences and Engineering Research Council; and National Research Council of Canada
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Since its inception as a technique of nondestructive evaluation, acoustic emission (AE) has held great promise for its ability to provide monitoring of structures on a continuing basis. Equipment development, however, has emphasized periodic testing and a lack of adaptation to the specific conditions of a given structure, such as aircraft, in terms of operating conditions, noise, vibration, etc. Because of these factors, the use of acoustic emission for continuous monitoring of aircraft structures has been lacking. Recently, the problem was approached from two angles. Firstly, a predictive approach was developed for using acoustic emission to monitor fracture and fatigue of materials. In this approach, the relationship between acoustic emission and fatigue life (expressed as stress intensity factor or the number of cycles to failure) is defined both theoretically and experimentally. It is then possible, using techniques of dynamic pattern recognition, to obtain the status of a structure with respect to its remaining life. Acoustic emission maps for different materials failing by fatigue are produced. Secondly, a new acoustic emission system was patented which relies on using intelligent and expert systems software, as well as rule for defining fatigue damage. The combination of these two approaches produces a significant development in using acoustic emission for continuous monitoring of aircraft and other structures and fulfills the promise held by AE in that direction.
                    Author

N90-28093# University Coll., London (England). Dept. of Mechanical Engineering.
IMPACT OF NDE-NDI METHODS ON AIRCRAFT DESIGN, MANUFACTURE, AND MAINTENANCE, FROM THE FUNDAMENTAL POINT OF VIEW
LEONARD J. BOND *In* AGARD, Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture, and Maintenance 5 p (SEE N90-28068 22-38) May 1990
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Comments are presented on the impact of emerging NDE-NDI (nondestructive evaluation-nondestructive inspection) methods on aircraft design, manufacture, and maintenance. In particular, fundamental aspects of recent developments are considered, together with current trends and future prospects. The meeting presentations and discussion are reviewed in terms of the philosophy, physics, and technology involved. NDE-NDI is shown to require consideration as an integral part of the design, manufacturing, and operational condition monitoring process, for all parts of an aircraft. Various areas of NDE are highlighted and these include the importance of high performance quantitative NDE, the impact of new materials (e.g., composites), changes in manufacturing processes (e.g., diffusion bonding), and the importance of mathematical modeling for inspection optimization and also for the identification of NDE inspection techniques. Automation of the implementation of NDT and both the recording and the display of the resulting data is seen to be necessary in many cases to achieve the required sensitivity and level of reliability of inspection. Global inspection techniques are being sought which highlight suspect zones that can then be investigated using other techniques, to provide detailed local examinations.   Author

N92-19004# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AGARD/SMP REVIEW: DAMAGE TOLERANCE FOR ENGINE STRUCTURES. 4: RELIABILITY AND QUALITY ASSURANCE
Dec. 1991   42 p In ENGLISH and FRENCH The 69th meeting was held in Brussels, Belgium, 1-6 Oct. 1989
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The workshop reviewed the areas critical to the acceptance of an approach based on damage tolerance concepts as an alternative service life philosophy to that of 'safe life' for the design of engine components. Also addressed was the need for, and the approaches to, ensuring component reliability and quality assurance. The current procedures were surveyed for materials and component specifications, standard process control, quality assurance, and systems design. For individual titles, see N92-19005 through N92-19007.

N92-19005# Rolls-Royce Ltd., Derby (England).
INTRODUCTION: NEEDS AND APPROACHES TO RELIABILITY AND QUALITY ASSURANCE IN DESIGN AND MANUFACTURE
A. C. PICKARD *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 4: Reliability and Quality Assurance 4 p (SEE N92-19004 09-38) Dec. 1991 Previously announced as N91-10297
(AGARD-R-773) Copyright Avail: NTIS HC/MF A03;
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AGARD/Scientific Publications Executive
In the damage tolerance approach for improving the integrity of aircraft engines, reliability and quality assurance issues are discussed. The implications of the following aspects on the damage tolerance concept are studied: component material specifications and standards; controls on manufacturing processes and procedures; and design systems and quality assurance. The subjects reviewed in the workshop on reliability and quality assurance are given.   Author

N92-19006# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France).
MANUFACTURING PROCESS CONTROL AS A DAMAGE TOLERANCE CONCEPT
JEAN-PAUL HERTEMAN *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 4: Reliability and Quality Assurance 7 p (SEE N92-19004 09-38) Dec. 1991
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Manufacturing process control means a search for the lowest possible variability of the manufacturing part characteristics. Process control is as necessary for damage tolerance as for a conventional 'safe service life' design, or even more, for reasons relating to the engine reliability and operation safety on the one hand and to the life cycle costs on the other hand. These reasons are reviewed. Furthermore, damage tolerance contains several concepts which can be used profitably to modify, reorientate, and improve the procedures giving access to the required process control. Some of these concepts are discussed. Author

N92-19007# Fiat Aviazione S.p.A., Turin (Italy).
QUALITY ASSURANCE AND DESIGN SYSTEMS
L. CARONI and E. CAMPO *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 4: Reliability and Quality Assurance 9 p (SEE N92-19004 09-38) Dec. 1991
(AGARD-R-773) Copyright Avail: NTIS HC/MF A03;
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Inside the company quality system as outlined by NATO AQAP-1, a major role is given to engineering quality. This is the branch which is responsible for assurance that a design and development program is set, codes of design practice are established and maintained, and that drawings and specifications include all practical experience gained by the company. The engineering quality manual and the design manual are the reference for such activities. The engineering quality manual, in fact, sets the methodology to be used in the project development. The design manual, on the other hand, documents the technical data and information to support material choice, structural analysis, and life prediction. An example is given to show the type of content of the design manual within the subject of damage tolerance criteria of rotating critical parts. Author

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STRUCTURAL MECHANICS

Includes structural element design and weight analysis; fatigue; and thermal stress.

N90-18401# La Sapienza Univ., Rome (Italy). Dipartimento Aerospaziale.
CRACK PROPAGATION FROM ARTIFICIAL DEFECTS IN TYPICAL ENGINE DISK MATERIALS; INTERPRETATION OF EXPERIMENTAL RESULTS BY MEANS OF 3D J INTEGRAL
ALDO FREDIANI and ROBERTO GALATOLO (Pisa Univ., Italy)
In AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 2: Defects and Quantitative Materials Behaviour 10 p (SEE N90-18396 11-07) Aug. 1989
(AGARD-R-769) Copyright Avail: NTIS HC A06/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

The results are shown for crack propagation tests performed on corner cracked specimens built in Powder Metals, AP1 and AF115, at high temperatures and different values of the stress ratio R. Analysis of the final crack shapes shows that discrepancies exist between the crack shapes expected on the basis of the behavior of the stress intensity factor and actual crackshapes; similar conclusions are obtained in other significant examples. The three-dimensional J-Integral (or GJ) is, then, introduced; the GJ values are computed along the crack fronts of circular shaped cracks and the actual cracks. It transpires that the values of GJ are virtually constant along the fronts of the actual cracks. Finally, future possibilities or application are outlined. Author

N90-18424# Ecole Polytechnique Federale de Lausanne (Switzerland).
TIME-DEPENDENT MEASUREMENTS ON VIBRATING ANNULAR TURBINE CASCADES UNDER VARIOUS STEADY STATE CONDITIONS
A. BOELCS, T. H. FRANSSON, and D. SCHLAEFLI *In* AGARD, Unsteady Aerodynamic Phenomena in Turbomachines 14 p (SEE N90-18405 11-07) Feb. 1990
(AGARD-CP-468) Copyright Avail: NTIS HC A14/MF A02;
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Two-dimensional sections of three turbine blades were investigated experimentally in a non-rotating annular cascade facility with respect to its steady-state and unsteady aerodynamic characteristics. The sections are representative for the near tip sections of the blades where the nominal flow conditions are subsonic at the inlet and near sonic or supersonic at the outlet. Emphasis was put on the time dependent aerodynamic coupling effects between the neighbor blades. Unsteady experimental data were obtained with the blades vibrating both in the traveling wave mode as well as with single blade excitation. Decomposition of the experimental data, obtained in the traveling wave mode, into local (along the blade surfaces) and integrated unsteady aerodynamic influence coefficients indicates that the largest aerodynamic excitation comes from the suction surface leading edge region and, in some cases, from the pressure surface trailing edge region for all three cascades. The unsteady aerodynamic influence coefficients indicate that for sub- and supersonic outlet flow velocities, all three blade-geometries are self-damped (i.e., a single vibrating blade has a damping influence on itself), but an instability may arise because of the aerodynamic coupling effects between, essentially, the reference blade and its immediate suction side neighbor and, to a lesser extent, its pressure side neighbor. For transonic outlet flow velocities however, a clear destabilizing effect of the (for this flow regime) almost normal shock on the blade itself appears, constituting an excitation mechanism leading eventually to single blade flutter. Author

N91-11240# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
SHORT-CRACK GROWTH BEHAVIOUR IN VARIOUS AIRCRAFT MATERIALS
P. R. EDWARDS, comp. and JAMES C. NEWMAN, JR., comp. (National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.) Aug. 1990 198 p
(AGARD-R-767; ISBN-92-835-0577-8; AD-A227422) Copyright
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The results of the first phase of an AGARD Cooperative Test Program on the behavior and growth of short fatigue cracks are reviewed. The establishment of a common test method, means of data collection/analysis and crack growth modeling in an aircraft alloy AA 2024-T3 are described. The second phase allowed testing of various materials and loading conditions. The results of this second phase are described. All materials exhibited a short-crack effect to some extent. The effect was much less evident in 4340 steel than in the other materials. For the aluminum, aluminum-lithium, and titanium alloys, short cracks grew at stress-intensity factor ranges lower, in some cases much lower, than the thresholds obtained from long crack tests. Several laboratories used the same crack growth model to analyze the growth of short cracks. Reasonable agreement was found between measured and predicted short-crack growth rates and fatigue lives. For individual titles, see N91-11241 through N91-11251.

N91-11241*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN AGARD SUPPLEMENTAL TEST PROGRAMME ON THE BEHAVIOUR OF SHORT CRACKS UNDER CONSTANT AMPLITUDE AND AIRCRAFT SPECTRUM LOADING
P. R. EDWARDS (P. P. Data Ltd., Fleet, England) and JAMES C. NEWMAN, JR.   *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 43 p (SEE N91-11240 02-39)   Aug. 1990
(AGARD-R-767)   Copyright   Avail: NTIS HC/MF A09;
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AGARD/Scientific Publications Executive   CSCL 20/11
    An AGARD Supplemental Test Program on the growth of short fatigue cracks was conducted to allow testing of various materials and loading conditions that were of interest. Twenty-two participants from ten laboratories in eight countries contributed to the supplemental test program. The objective is to review the supplemental test program and to summarize the results obtained from all laboratories. The materials tested in the supplemental program were: 2024-T3 and 7075-T6 aluminum alloys, 2090-T8E41 aluminum-lithium alloy, Ti6Al4V titanium alloy, and 4340 steel. Tests on single-edge-notch-tension specimens were conducted under several constant-amplitude loading conditions and spectrum loading conditions (FALSTAFF, Inverted FALSTAFF, GAUSSIAN, TWIST, Felix, and the Fokker 100 spectra). The plastic-replica method was used to measure the growth of short cracks at the notch root. The results from the supplemental test program show good agreement among the several laboratories who measured short-crack growth rates on the aluminum-lithium alloy.   Author

N91-11242# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Structural Integrity.
DETERMINATION OF THE SHORT CRACK EFFECT IN 2090-T8E41 ALUMINUM LITHIUM
CHRISTOPHER J. MAZUR and JAMES L. RUDD   *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 11 p (SEE N91-11240 02-39)   Aug. 1990
(AGARD-R-767)   Copyright   Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The United States Air Force developed two primary sets of design requirements to ensure the structural integrity of aircraft: damage tolerance and durability. The purposes of these design requirements are to ensure structural safety and preclude the occurrence of expensive maintenance and repair costs, respectively. These requirements are generally satisfied through the use of linear elastic fracture mechanics and crack growth rate data experimentally generated for long cracks. Recently, various investigators have indicated that short cracks may grow significantly faster than long cracks for the same crack-driving force. The end result may be unconservative life predictions when situations arise where short crack lengths are included in the analysis. To accurately predict the growth of these short cracks, the short crack phenomenon must be understood. The objective is to describe the work of the Flight Dynamics Laboratory as a participating agency in the AGARD Supplement Test Program on Short Cracks. The manufacturing and testing of 2090-T8E41 aluminum-lithium short and long crack specimens were performed under this effort. Constant amplitude and spectrum fatigue tests were conducted at various stress ratios and stress levels. The short and long crack results were compared to verify the existence of any short crack effect. As a result of the unusual fracture patterns in the aluminum-lithium short crack tests, an analytical approach considering combined Mode 1 and Mode 2 type fracture was considered and compared to the standard Mode 1 analysis used in the previous AGARD Core Test Program.   Author

N91-11243# Laboratorio Nacional de Engenharia e Tecnologia Industrial, Lisbon (Portugal).
SHORT CRACK BEHAVIOUR IN AL-LI ALLOY 2090
M. HELENA CARVALHO and M. DEFREITAS (Lisbon Univ., Portugal)   *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 17 p (SEE N91-11240 02-39)   Aug. 1990
(AGARD-R-767)   Copyright   Avail: NTIS HC/MF A09;
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    Within the AGARD Cooperative Test Program on the behavior of short cracks, a common airframe aluminium alloy (2024-T3)

was investigated and the significance of the short crack effect analyzed from tests conducted on a single edge notched fatigue specimens of sheet material. The follow up Supplemental Test Program dealt with other alloys such a Ti6Al4V, steel 4340, Al 7075 and Al-Li 2090, all of them of interest Al-Li alloy at LNETI/CEMUL are described.   Author

N91-11244# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).   Inst. for Materials Research.
CRACK BEHAVIOUR OF 2024-T3, 2090-T8E41 AND 7075-T6 UNDER CONSTANT AMPLITUDE AND DIFFERENT TYPES OF VARIABLE AMPLITUDE LOADING, ESPECIALLY GAUSSIAN LOADING
H. NOWACK, K. H. TRAUTMANN, and J. STRUNCK   *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 14 p (SEE N91-11240 02-39)   Aug. 1990
(AGARD-R-767)   Copyright   Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The contribution of the DFVLR (DLR) to the AGARD cooperative test program on short and long cracks is described. Within the core program tests on 2024-T3 single edge notch (SENT) specimens were performed with constant amplitude, FALSTAFF, and Gaussian loading. Within the supplemental program short and long crack tests on the aluminum-lithium alloy 2090-T8E41 were carried out with Gaussian loading and some further exploratory long crack tests with the conventional high strength aluminum alloy 7075-T6 were added. The long crack tests were performed on center crack (CCT-) specimens. From the investigations it came out that 2024-T3 and 2090-T8E41 showed the so-called short crack effect. This effect is mainly attributed to the influence of crack closure. The microscopical behavior of 2024-T3 and 2090-T8E41 was different. At 2024-T3 several cracks initiated, normally as center cracks, whereas at 2090-T8E41 corner cracks were the predominant cracks. In the long crack stage 2090-T8E41 turned out to be not such damage tolerant as expected.   Author

N91-11245# Royal Aircraft Establishment, Farnborough (England).
THE GROWTH OF SHORT FATIGUE CRACKS IN 2024 AND 2090 ALUMINIUM ALLOYS UNDER VARIABLE AMPLITUDE LOADING
R. COOK   *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 11 p (SEE N91-11240 02-39)   Aug. 1990
(AGARD-R-767)   Copyright   Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    Fatigue crack growth measurements were made on 2024-T3 and 2090-T8E41 aluminum alloys subjected to FALSTAFF, Inverted FALSTAFF, and FELIX standard loading sequences. Crack growth rates at short crack lengths under FALSTAFF and Inverted FALSTAFF in 2024-T3 were found to be similar at each of three applied stress levels. This result is explained in terms of crack opening stress levels and is qualitatively predicted by a closure based crack growth model. Short fatigue cracks were shown to grow at stress intensity factors well below the long crack growth threshold in 2090-T8E41 alloy under FELIX loading. The short cracks, however grew initially perpendicular to the applied loading direction and then abruptly changed direction and grew at 60 deg to the initial crack direction. Short crack growth rates in 2024-T3 and 2090-T8E41 were compared and found to be similar if the length of the short cracks in the 2090 alloy were taken to be the length of the crack projected onto the axis perpendicular to the loading direction. This work represents the United Kingdom contribution to the supplemental program of the AGARD coordinated short fatigue crack growth investigation.   Author

N91-11246# Aeronautical Research Inst. of Sweden, Bromma. Dept. of Structures.
SHORT CRACK GROWTH UNDER REALISTIC FLIGHT LOADING: MODEL PREDICTIONS AND EXPERIMENTAL RESULTS FOR AL 2024 AND AL-LI 2090
A. F. BLOM *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 15 p (SEE N91-11240 02-39)   Aug. 1990   Sponsored by Defense Materials Administration
(AGARD-R-767) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The swedish contribution to the AGARD effort on short fatigue crack growth includes various experimental investigations on the aluminum alloys Al 2024-T3 and Al-Li 2090-T8E41. These two materials were subjected both to constant amplitude loading, at stress ratios R = -2, -1, 0, and 0.5 and also to spectrum loading with the standardized load sequences FALSTAFF and TWIST, representative for the lower wing surface of fighter and civil aircraft, respectively. The TWIST sequence was also used to generate long crack growth data for the two alloys. The experimental results are summarized and numerical predictions by means of a modified Dugdale-Barenblatt model originally proposed by Newman are also included. Numerical results correspond well to the observed experimental behavior for most of the performed tests.   Author

N91-11247*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE GROWTH OF SHORT CRACKS IN 4340 STEEL AND ALUMINUM-LITHIUM 2090
M. H. SWAIN, R. A. EVERETT (Army Aviation Systems Command, Hampton, VA.), JAMES C. NEWMAN, JR., and E. P. PHILLIPS *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 30 p (SEE N91-11240 02-39)   Aug. 1990   Sponsored by NASA
(AGARD-R-767) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive   CSCL 20/11
    The objectives were to investigate crack initiation characteristics and short crack growth behavior for Al-Li 2090 and for 4340 steel and to evaluate the ability of a closure-based crack-growth model to predict fatigue crack growth rates and total fatigue lives for the steel. Single-edge-notched tension specimens of each alloy were used to obtain the short crack growth rate information via an acetate replica technique. In addition to constant amplitude loading, tests on the steel were conducted using the Felix/28 variable amplitude spectrum (a shortened form of a standard loading sequence for fixed or semi-rigid helicopter rotors). The short crack growth rates were compared to those for long cracks grown under similar loading conditions. Metallurgical features associated with crack initiation are discussed. For Al-Li 2090 under R = -1 loading, the short cracks grew well below the long crack threshold and grew at acute angles to the loading axis. For 4340 steel under constant amplitude loading at R = 0.5 and 0 and for the Felix/28 spectrum loading, short-crack growth rates agreed well with long-crack growth rates, even near the long-crack threshold. A slight short-crack effect, growth below the long-crack threshold, was observed at R = -1. Fatigue lives were found to depend on the size and type of initiation site, especially for the Felix/28 loading sequence. A semi-empirical crack-growth model incorporating crack-closure effects was used to predict crack growth rates and total fatigue lives of notched 4340 steel specimens. An initial defect size and shape typical of those identified in this steel was assumed for the life predictions. For all loading conditions, reasonable agreement was found between measured and predicted values for both crack growth rates and fatigue lives.   Author

N91-11248# National Aerospace Lab., Amsterdam (Netherlands).
SHORT AND LONG FATIGUE CRACK GROWTH IN 2024-T3 UNDER FOKKER 100 SPECTRUM LOADING
R. J. H. WANHILL and L. SCHRA *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 26 p (SEE N91-11240 02-39)   Aug. 1990   Sponsored by Netherlands Agency for Aerospace Programs
(AGARD-R-767) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The behavior of short and long fatigue cracks in the widely used damage tolerant aluminum alloy 2024-T3 was compared using flight simulation loading representatives for the Fokker 100 wing/fuselage structure. The results showed that the apparently anomalous behavior of short cracks is not significant for durability analysis of the current wing/fuselage structure. Also the data provide a reference for evaluating new, candidate materials for durable wing/fuselage structures in transport aircraft.   Author

N91-11249# Middle East Technical Univ., Ankara (Turkey). Dept. of Metallurgical Engineering.
GROWTH OF SHORT FATIGUE CRACKS IN 7075-T6 ALUMINUM ALLOY
CEVDET KAYNAK and ALPAY ANKARA *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 8 p (SEE N91-11240 02-39)   Aug. 1990
(AGARD-R-767) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The growth of short fatigue cracks was monitored using a plastic replica method for cracks propagating on the specimen notch from the initial length of 40 to 50 microns up to the specimen thickness of 2.3 mm. Single-edge-notched tension (SENT) Al 7075-T6 specimens were tested under R-ratios of 0.5, 0, and -1 and at two different stress levels of each R-ratio. The general conclusion is that the growth rates of short cracks seem to be faster than the growth rates of long cracks for an R-ratio of -1. No significant differences were observed for R = 0, and the short cracks actually grew more slowly at R = 0.5.   Author

N91-11250# Pisa Univ. (Italy). Dept. of Aerospace Engineering.
SHORT CRACK OBSERVATIONS IN TI-6AL-4V UNDER CONSTANT AMPLITUDE LOADING
A. LANCIOTTI and R. GALATOLO *In* AGARD, Short-Crack Growth Behaviour in Various Aircraft Materials 7 p (SEE N91-11240 02-39)   Aug. 1990
(AGARD-R-767) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The Italian contribution to the AGARD supplementary test program on the growth of short fatigue cracks is described. Constant amplitude loading fatigue tests (zero-to-tension and fully reversed loading) were carried out on annealed Ti6Al4V titanium alloy, to establish the behavior of short and long cracks in this material. The results indicate that short cracks grow faster than long cracks at the same stress intensity factor range and they can also grow below the long crack threshold stress intensity factor range.   Author

N91-24638# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
ANALYTICAL QUALIFICATION OF AIRCRAFT STRUCTURES
Apr. 1991   171 p   In ENGLISH and FRENCH   The 70th Meeting was held in Sorrento, Italy, 1-6 Apr. 1990
(AGARD-R-772; ISBN-92-835-0603-0; AD-A237927) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The role of structural analysis in relation to aircraft qualification procedures was addressed in order to establish guidelines for the future and to seek out those areas where there exists a commonality of approach between nations. Topics covered include: quality assurance of software tools for structural analysis, comparison of analysis and test results, and trends in analysis for certification/certification only by analysis. For individual titles, see N91-24639 through N91-24652.

N92-18573# Centre d'Essais Aeronautique Toulouse (France). Div. Materiaux et Structures.
FATIGUE SAFETY FACTOR: ASSESSMENT OF ASSOCIATED SAFETY LEVEL
V. DEHAYE *In* AGARD, Fatigue Management 5 p (SEE N92-18571 09-05) Dec. 1991 In FRENCH
(AGARD-CP-506) Copyright Avail: NTIS HC/MF A12;
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AGARD/Scientific Publications Executive

Techniques related to the determination of fatigue reliability factors for aircraft structures are discussed. Particular attention is given to methods for the estimation of corresponding safety levels. Of central concern are those combat aircraft that have been reviewed according to the 'safe life' concept. The parameters affecting structural fatigue behavior are outlined. Approaches to fatigue reliability analysis used for the principle french combat fleet are addressed.   Transl. by M.G.

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GEOSCIENCES (GENERAL)

N90-14406# Naval Research Advisory Committee, Washington, DC.
THE IMPORTANCE OF ENVIRONMENTAL DATA
GERALD CANN and ROBERT P. PORTER *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 6 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03

A top level analysis of the significance of quantitative knowledge of environmental parameters to naval weapons and naval warfare was conducted. It was concluded that the impact of the environment needs to be considered more thoroughly during the research, development, and acquisition process. This requires a central environmental top level requirement or master plan and a more formalized connection between the organizations involved in various aspects of environmental science.   Author

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EARTH RESOURCES AND REMOTE SENSING

Includes remote sensing of earth resources by aircraft and spacecraft; photogrammetry; and aerial photography.

N90-14409# Space and Naval Warfare Systems Command, Washington, DC. Environmental Systems Program Office.
THE TACTICAL ENVIRONMENTAL SUPPORT SYSTEM (TESS(3))
JACK J. JENSEN *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 3 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03

The U.S. Navy has taken an aggressive step toward the analysis and prediction of the performance of tactical sensors and systems at sea. The TESS(3) is one of three key components now under development which will form the basis for state of the art on-scene tactical support. Along with a high resolution satellite receiver/recorder and the automated Shipboard Meteorological and Oceanographic Observing System (SMOOS), TESS(3) is expected to significantly improve the ability of the tactical commander to exploit potential advantages which accrue from a quantitative knowledge of the surrounding environment.   Author

N90-14416# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
AIRBORNE FLIR DETECTION OF SURFACE TARGETS
HERBERT G. HUGHES *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 12 p (SEE N90-14405 06-32) Sep. 1989 Sponsored by Office of Navy Technology
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03

An algorithm is presented for predicting the detection ranges of a surface target by an airborne Forward Looking Infrared (FLIR) system. The total infrared background radiance scene under cloud-free skies is modeled to include the atmospheric path emissions between the target and sensor and the effects of a wind ruffled sea on the surface emissions and sky radiance reflections. A model is also introduced of the average temperature of a ship based upon the solar heating effects throughout a specified course, the ambient meteorological conditions, and the viewing angle. Together, these two models allow the range to be determined where the difference between the apparent ship's temperature (i.e., the actual ship temperature degraded by the atmospheric transmittance and the effective background temperature of the sea surface as viewed from the sensor altitude is equal to the minimum detectable temperature difference of the FLIR. A case study is presented to demonstrate the vulnerability of a Frigate class ship to detection by an airborne common module FLIR during a five hour period where the ship's course changed allowing solar heating of different sides of the ship. The results show considerable increases in predicted detection ranges with altitude using the present algorithm over those based on a fixed temperature difference between a target and its background.
                                                              Author

N90-14436# German Military Geophysical Office, Traben-Trarbach (Germany, F.R.).
THE THERMAL BEHAVIOR OF NATURAL BACKGROUNDS AND ITS PREDICTION BY MEANS OF NUMERICAL MODELS
FRITZ G. WOLLENWEBER *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 12 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03

The Federal Office for Military Technology and Procurement together with the German Military Geophysical Office (GMGO) are conducting a research effort to establish procedures to describe and to predict thermal behavior of natural backgrounds under varying meteorological conditions. The experimental phase of this effort started in 1988 with measurements of surface temperatures of different backgrounds like trees, crops, pasture, roads and buildings together with meteorological measurements. These measurements are conducted in two geographical locations, the Meppen proving ground in Northern Germany and Oberjettenberg proving ground in the Alps. The measurement campaign has a time frame of at least one year with measurements taking place during three days each month. It is anticipated to gather a data set that reflects the full range of thermal backgrounds for tactically important locations in Central Europe. One objective of this effort is to compare and evaluate thermal background models that are under development as a companion task. The results of the Meppen '85 experiment, a pilot study to this campaign, are presented. The results are compared with predictions of the current version of the U.S. Air Force Tactical Decision Aid (USAF TDA) and with the thermal background model CANOPY developed by GMGO. The GMGO model determines energy exchange within canopies with a multi-layer approach for energy, moisture, and momentum fluxes. In comparison with measurements the GMGO model performs much better than the USAF IR-TDA model. Differences between model results can be explained by the neglect of latent heat flux in the USAF TDA model for vegetation backgrounds and its semi-statistical approach.   Author

N90-14437# Defence Research Establishment Valcartier (Quebec).
REMOTE SENSING OF THE AEROSOL SCATTERING COEFFICIENT WITH A MULTI-FIELD-OF VIEW LIDAR
LUC R. BISSONNETTE and DANIEL L. HUTT   *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 13 p (SEE N90-14405 06-32) Sep. 1989
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A new lidar technique is proposed for the remote determination of the obscuration effects of natural and man-made aerosols. It is based on the simultaneous measurement of the lidar returns at different fields of view. By ratioing these returns, the need is eliminated for a backscatter-to-extinction relation which makes the inversion of the single-scattering lidar-measurements subject to uncertainties. A system operating at 1.054 micrometers and fields of view of 5, 25, 50, and 75 mrad is described. Preliminary results are discussed.   Author

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ENVIRONMENT POLLUTION

Includes atmospheric, noise, thermal, and water pollution.

N90-21908# Admiralty Research Establishment, Portsdown (England).
A SURVEY OF THE MARITIME-AEROSOL DATA COLLECTED AT SOUTH UIST AND THE IMPLICATIONS FOR THE LOWTRAN MARITIME AEROSOL MODEL
N. P. TOLLIDAY, M. H. SMITH, P. M. PARK, and I. E. CONSTERDINE (Manchester Univ., England)   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 11 p (SEE N90-21907 15-32) Mar. 1990
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Over the period 1979 until 1988, a Maritime Aerosol Study was performed. A survey of the results obtained and some comments on how well the data conforms to the LOWTRAN maritime aerosol model are presented. Aerosol loadings and spectral distributions were measured, over numerous 2 to 4 week periods since 1979, at a coastal site on the island of South Uist, situated off north-west Scotland. Aerosol size distributions, covering the radius range 0.08 to 23.5 microns, were measured by Particle Measuring Systems optical particle counters, together with basic meteorological observations. Two further field projects were conducted at this site during the spring and summer of 1986. The spring project was characterized by an intense cyclone which gave rise to local wind speeds exceeding 40 m/s while, during the summer, much calmer conditions prevailed with an extended period of very low wind speeds. These observations demonstrated that volumetric loadings of marine aerosol continue increasing for all measured wind speeds, contrary to earlier speculation suggesting a limit beyond 12 to 15 m/s. The low wind speed period permitted the relaxation response of the atmosphere to be investigated, and the decay of the aerosol loadings, for various size categories, over this period was found to be consistent with a simple turbulent deposition model. Variations in aerosol spectral shape with wind speed will be presented, and demonstrate that particulate volume and surface area are dominated by the larger particles for moderate and high wind speeds. The consequences of these findings for the LOWTRAN Maritime Aerosol Model and for atmospheric propagation at visible and infrared wavelengths are discussed.
                                                              Author

N90-21909# Centre National de la Recherche Scientifique, Paris (France).
THE MEDITERRANEAN MARINE ENVIRONMENT AND ITS EFFECTS ON AEROSOLS AND INFRARED TRANSMISSION Thesis
MIREILLE TANGUY   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 13 p (SEE N90-21907 15-32) Mar. 1990 In FRENCH
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A series of experiments conducted depend on the validation of the LOWTRAN 6 code by the computation of the atmospheric transmission of infrared rays through the marine boundary layer in the Mediterranean region. The opto-electronic device implanted in the coast is made up of a transmissometer, which aids in the measurement of transmission in the 3 to 5 and 8 to 12 micron frequencies, along a horizontal path at 8 km and an altitude 40 m above sea level. In order to compare data from different readings, an automatic weather station and an optical sonde (CSASP-100-HV) work in parallel. Also, a study was made of the behavior of aerosol density as a localization function of the measurement along with weather conditions during the summer on board national French navy ships.   Transl. by E.R.

N90-21910*#   National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NEW SPECTRAL FEATURES OF STRATOSPHERIC TRACE GASES
A. GOLDMAN, F. J. MURCRAY, R. D. BLATHERWICK, J. J. KOSTERS, F. H. MURCRAY, D. G. MURCRAY (Denver Univ., CO.), and C. P. RINSLAND   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 13 p (SEE N90-21907 15-32) Mar. 1990
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A new Michelson-type interferometer system operating in the infrared at very high resolution (0.002 to 0.003 wavenumber FWHM) was used to record numerous balloon-borne solar absorption spectra of the stratosphere, ground-based solar absorption spectra, and laboratory spectra of molecules of atmospheric interest. Results obtained are reported for several important stratospheric trace gases, HNO_3, $ClONO_2$, HO_2NO_2, NO_2, and COF_2, in the 8 to 12 micron spectral region. Many features of these gases were identified in the stratospheric spectra. Comparison of the spectra with line-by-line simulations shows previous spectral parameters are often inadequate. New analysis of high resolution laboratory and atmospheric spectra and improved theoretical calculations will be required for all bands. Preliminary versions of several sets of improved line parameters are presented.   Author

N90-21911# Science Applications International Corp., Billerica, MA.
MINIMIZING THE EFFECTS OF THE ATMOSPHERE IN THE OBSERVATION OF ULTRAVIOLET RADIATION
A. V. DENTAMARO, C. G. STERGIS, and V. C. BAISLEY (Air Force Geophysics Lab., Hanscom AFB, MA.)   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 11 p (SEE N90-21907 15-32) Mar. 1990
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Ground measurements were performed which provide an accurate method of measuring ultra-violet radiation sources propagating through the atmosphere. This method of measurement effectively minimizes the influence of the atmosphere in the detection of UV sources at equal or greater altitude at the specific time the measurements are being made, allowing evaluation of propagation losses. Radiation of wavelength 3000 to 3700 A was collected and recorded by a UV imager mounted onto an 18 inch Cassegrain telescope situated on Santa Ynez Mountain, California at an altitude of 1.26 km above sea level. Various meteorological and topographical conditions determine the transmittance of the incident starlight through the atmosphere. Measurements were taken under optimum conditions (little or no cloud cover, visibility greater than 20 km). The atmospheric transmittance code

LOWTRAN 6 was used to generate transmittance as a function of observation angle and meteorological range (quantitative measurement of visibility). Comparing the measured intensity of one star to its known absolute intensity above the atmosphere determines the transmittance for any point in the sky. In addition, extinction coefficients were measured at the observation point and at ground level using a photometer and a standard UV source. Both the stellar and photometer data indicate that the meteorological range during the ten day period of observation varied from 20 to 30 km. Therefore, the method was useful in accounting for changes in the atmosphere. Under these optimum viewing conditions, ground-based measurements of various high altitude sources of radiation such as rocket plumes or vehicle glow with a maximum error due to transmission losses of 10 percent should be possible. Author

N90-21912# National Oceanic and Atmospheric Administration, Boulder, CO. Wave Propagation Lab.
SCINTILLATION OF MILLIMETER-WAVE INTENSITY AND PHASE CAUSED BY TURBULENCE AND PRECIPITATION
R. J. HILL, S. F. CLIFFORD, R. J. LATAITIS, and A. D. SARMA
In AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 6 p (SEE N90-21907 15-32) Mar. 1990 Sponsored in part by National Research Council
(Contract MIPR-125-88)
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A propagation experiment over exceptionally flat farm land was performed near Flatville, Illinois. Extensive micrometeorological (abbreviated as micromet) measurements were made simultaneously. Because of the excellent horizontal homogeneity of the site, these micromet data determine the turbulence statistics along the entire propagation path. Instrumentation for measurements of rain as well as fog and snow were deployed. There were five experiment sessions, each about one month long. Several millimeter-wave frequencies between 116 and 230 GHz were used. Results for data during inclement weather were reported. Some results of these studies are reviewed and new results are presented for temporal spectra of intensity and phase difference obtained during precipitation. Author

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GEOPHYSICS

Includes aeronomy; upper and lower atmosphere studies; ionospheric and magnetospheric physics; and geomagnetism.

N90-11361# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
IONOSPHERIC STRUCTURE AND VARIABILITY ON A GLOBAL SCALE AND INTERACTIONS WITH ATMOSPHERE AND MAGNETOSPHERE
Apr. 1989 468 p In ENGLISH and FRENCH Symposium held in Munich, Fed. Republic of Germany, 16-20 May 1988
(AGARD-CP-441; ISBN-92-835-0500-X) Copyright Avail: NTIS HC A20/MF A03
Communications, Navigation and Surveillance Systems operating in/through the aerospace EM propagation environment are affected by the state/variability of the propagation media. The range of phenomena need for their elucidation, observations and analysis on a global scale since only an understanding of the complex global interaction can improve the means of predictability and assessment of localized phenomena suggesting methods for mitigating adverse propagation conditions. With this goal, ionospheric dynamics, ionosphere/magnetosphere and ionosphere/atmosphere interactions were analyzed and discussed. For individual titles, see N90-11362 through N90-11404.

N90-11363# Alberta Univ., Edmonton. Inst. of Earth and Planetary Physics.
MAGNETOSPHERIC SUBSTORMS AS A SIGNATURE OF THE SOLAR TERRESTRIAL INTERACTION
GORDON ROSTOKER In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 14 p (SEE N90-11361 02-46) Apr. 1989 Sponsored by Natural Sciences and Engineering Research Council of Canada
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
It is now well known that perturbations of the high latitude ionosphere are regulated by the properties of the solar wind and the interplanetary magnetic field. Variations in the direction of the interplanetary magnetic field lead to episodes normally lasting for a few minutes to a few hours in which large amounts of solar wind energy penetrate into the distant magnetosphere. This energy is stored in an intermediary form in the magnetotail magnetic field and in the kinetic drift energy of the Earth's boundary layers and plasma sheet before it is ultimately degraded to heat through the action of electric current systems which couple the magnetosphere to the ionosphere. The physical processes through which the solar wind energy, once it has entered the magnetosphere, is redistributed and dissipated through the process known as the magnetospheric substorm are discussed. Based on the nature of the physical processes involved, the possibility is discussed for being able to predict the locale and level of the high latitude ionospheric perturbations which result from the action of the precipitation of energetic particles into the upper atmosphere as part of the electromagnetic coupling of the outer magnetosphere to the ionosphere. Author

N90-11364# Duesseldorf Univ. (Germany, F.R.). Inst. for Theoretical Physics.
BALANCE EQUATIONS FOR IONOSPHERIC PLASMAS WITH DIFFERENT PARTIAL TEMPERATURES
K. SUCHY In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 11 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
Different expressions for pressure tensors in multispecies plasmas are investigated for their physical meaning. Partial temperatures are introduced proportional to the partial translational energies (per particle). This leads to the definitions of translational energy tensors and temperature tensors proportional to the pressure tensors. Stress tensors are defined as differences of the corresponding pressure tensors and their values in local thermodynamic equilibrium. Heat flux vectors are defined as quantities with vanishing divergence under adiabatic constraints. Balance equations are established for masses, momenta, pressures, temperatures, energies, enthalpy, stresses and heat fluxes. Author

N90-11365# Technische Hogeschool, Eindhoven (Netherlands). Dept. of Physics.
NON-LINEAR WAVE-EQUATIONS FOR LOW-FREQUENCY ACOUSTIC GRAVITY WAVES
R. H. M. MIESEN, L. P. J. KAMP, and F. W. SLUIJTER In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 9 p (SEE N90-11361 02-46) Apr. 1989 Previously announced in IAA as A89-16729
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
It is shown that low-frequency (LF) acoustic gravity waves propagating parallel to the Earth's surface satisfy the Korteweg-DeVries (KdV) equation or the Kadomtsev-Petviashvili equation and have a discrete spectrum of group velocities. The nonlinear wave equations are obtained using the reductive perturbation technique, and changes for a compressible atmosphere are discussed. IAA

N90-11366# Freiburg Univ. (Germany, F.R.).
GLOBAL IONOSPHERIC DYNAMICS
E. RAWER In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 21 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
Plasma (a minor constituent in planetary atmospheres) motion is narrowly linked with that of the neutrals as long as collisional

coupling between neutral and charged particles is strong. At greater heights, both constituents are more and more decoupled and may move separately whenever forces are present which do only act upon charged particles. The most important difference between known planetary ionospheres is the absence or presence of a general magnetic field. While in the first condition the plasma moves freely, a magnetic field cannot provoke plasma motions of its own but restricts the motions provoked by other forces to one in either the direction parallel to the magnetic field or perpendicular to it. So, the motion patterns depend largely on the prevailing forces. Largely different conditions are found in the terrestrial ionosphere according to magnetic latitude. While at mid-latitudes mechanical forces mainly provoked by neutral winds are most important, electric forces cannot be neglected at low and high magnetic latitudes. Apart from such large scale motions, many small scale motions of more or less wave-like character are observed, in particular, internal gravity waves due to different causes. It is not always easy in local measurements to separate these localized motions from the large scale patterns. Different methods exist for observing plasma motions in the terrestrial ionosphere. Unfortunately, all of these can only be applied with caution. The spatial and temporal density of such local observations is unsatisfactory.   Author

N90-11367# Southampton Univ. (England). Dept. of Physics.
GLOBAL IONOSPHERIC DYNAMICS: A REVIEW
H. RISHBETH   *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 13 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
    The ionosphere is a highly dynamic region of the Earth's environment, and its spatial and temporal variations are extremely complex. Practical needs call for a good description of the ionosphere and reliable predictions of its behavior. Some of the scientific problems and the principles behind them are reviewed. For practical and scientific purposes, the ionosphere is often modeled. The most important parameter for modeling is the electron density distribution N(h,t) which, at any one place, is primarily a function of height (h) and local time (t), but varies also with time of year, magnetic disturbance and solar activity. Thus time-scales ranging from minutes up to a solar cycle need to be considered. Many other parameters (such as temperature, composition and velocity) can be modeled and are needed for a physical understanding of the ionosphere. Aspects of ionospheric structure and behavior that are considered include the thermospheric wind system and its effects; sporadic E; the low latitude ionosphere; the high latitude ionosphere; and ionospheric storms. The references are illustrative rather than comprehensive.   Author

N90-11368# Air Force Geophysics Lab., Hanscom AFB, MA.
A FULLY ANALYTIC, LOW AND MIDDLE LATITUDE IONOSPHERIC MODEL
D. N. ANDERSON and J. M. FORBES   *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 7 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
    The well-known Chiu ionospheric model is a global empirical model which calculates electron density profiles as a function of latitude, local time, season and solar cycle. It is extensively used by thermospheric dynamicists because its analytic formulation can quickly provide global electron density values. The model, however has serious shortcomings. Recently, a fully analytic ionospheric model based on the Chiu formulation, was developed which provides much more realistic, low and mid-latitude electron density distributions. This is accomplished by redefining the latitude and local time dependence of parameters such as hmF2, nmF2, and the topside and bottomside scale heights. The modifications are based on a recently-developed Semi-empirical, Low-latitude Ionospheric Model (SLIM) and involves decomposing hmF2, nmF2 and plasma density scale heights into harmonic terms to describe the local time variations and then applying Hermite polynomials to obtain latitude variations. The analytic model generates electron density profiles under solar cycle minimum, moderate and maximum conditions for winter, summer and equinox periods. Differences between this model and the Chiu model are discussed and comparisons with observed, low-latitude electron density distributions are presented.   Author

N90-11369# Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau (Germany, F.R.).
GLOBAL MORPHOLOGY OF PLASMA BUBBLES IN THE LOW LATITUDE IONOSPHERE
K. SCHLEGEL, K. OYAMA, and T. TAKAHASHI (Tohoku Univ., Sendai, Japan)   *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 6 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
    The electron density and electron temperature structure in and around plasma bubbles in the low latitude ionosphere was studied with instruments on the Japanese satellite HINOTORI. Histograms are presented about the number of occurrence of certain types of bubbles in a latitude range of + or - 30 degrees around the equator. Particularly the temperature within the plasma bubbles which can be higher or lower than the temperature of the ambient plasma will be discussed and explanations will be proposed. A particular class of bubbles seem to occur over the South Atlantic magnetic anomaly and over the Hawaiian anomaly.   Author

N90-11370# Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux (France).
SIMULATION OF THE POLAR CAP F REGION IONIZATION USING AN EXPERIMENTAL CONVECTION ELECTRIC FIELD Abstract Only
C. TAIEB   *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 1 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
    The electrons and ions concentration over the polar cap F region was calculated with a code running on a vectorial computer. Four coupled continuity equations, one for each ion specie, are solved together with the momentum equation, assuming that the in velocities and temperatures are the same for all species. The transportation of the ionization is due to neutral wind drag, the electric field and the ambipolar diffusion velocity which includes a stress tensor for taking account of the anisotropy created by the intense electric field encountered in the polar cap. The horizontal ion transportation is due to the planetary convection electric field which is deduced from 24 hours EISCAT observations during a quiet day. Because the observations are limited northward in latitude it is necessary to interpolate the equipotential lines providing reasonable physical assumption. Then the experimental convection electric field is replaced by a theoretical one. Results from the simulation of the ions concentration with the two convection models are compared. These results are compared also with the EISCAT electron density measurements.   Author

N90-11371# Royal Aerospace Establishment, Farnborough (England). Space Dept.
AVERAGE DIURNAL AND SEASONAL PROFILES OF IONOSPHERIC STORMS
G. L. WRENN, A. S. RODGER, and H. RISHBETH (Southampton Univ., England)   *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 9 p (SEE N90-11361 02-46) Apr. 1989
(Contract NERC-GST.02.112)
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
    The reduction of Maximum Usable Frequency (MUF) during a geomagnetic storm represents a serious hindrance to the efficient operation of HF transmission links. Possible improvements in forecasting services are discussed. Statistical analyses of ionosonde data from Slough, U.K. (52 N) are used to define patterns for the main phase effects of ionospheric storms and these are compared with similar patterns derived for other midlatitude stations. The storm induced changes in foF2 are primarily dependent upon local time, season and the strength of the geomagnetic disturbance, as quantified by the geomagnetic index ap (tau). The phase of the solar cycle controls average ionization levels whilst short-term variations in solar activity have little effect. The computed mean patterns can be used to forecast foF2 for a few hours ahead, given the required geomagnetic input. Data from a complete solar cycle, 1971 through 1981, are used to determine the errors in the forecasts and to demonstrate that a useful advantage can be attained by this method. The root mean square error in foF2 for 89139 samples is 14.4 percent which compares favorably with the 17.0 percent that is obtained using forecasts based upon either quiet-time values or the previous day's

measurements. Studies of error distributions highlight various limitations in the technique and indicate avenues to further improvement. Author

N90-11372# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
MEDIUM SCALE STRUCTURE OF THE F-REGION
ADOLF K. PAUL In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 8 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03

The standard picture of the F-region is based on hourly observations by ionosondes. More frequent recordings with advanced digital instruments show that very often F-region variations take place with periods of less than half an hour. This means that even if ionograms are taken in 15 minute intervals the actual variations of the ionosphere are still undersampled. Assuming that the effects of propagating acoustic gravity waves are observed, the undersampling of the oscillations results in an overestimation of the periods and the wavelengths. This in turn means that distances between existing and planned ionospheric stations are too large for correct spatial sampling of the waves. Therefore, at this time the observed temporal variations in combination with an assumed propagation velocity provide the only means to obtain first order information about the medium scale spatial structure of the F-region on a routine basis. Digital ionograms recorded during 1980 to 1981 at Brighton, Colorado show characteristics (e.g. virtual height variations and Doppler profiles) supporting the hypothesis that short term F-region variations are caused by acoustic gravity waves which seem to be present all the time with varying amplitudes. In addition, some direct evidence for the spatial structure can be obtained from the angle of arrival observations and their frequency or height dependence. Comparisons of foF2 and MUF (3000) indicate that the main effect of gravity waves on the F-region structure is the variation of the height of the layer and to a lesser degree a variation of the maximum electron density. Author

N90-11373# Air Force Geophysics Lab., Hanscom AFB, MA. Ionospheric Physics Div.
VLF/LF RADIO WAVE STUDIES OF THE STRUCTURE AND VARIABILITY OF THE EQUATORIAL, MID-LATITUDE AND POLAR IONOSPHERE BELOW 100 KM
P. A. KOSSEY, J. E. RASMUSSEN, and W. L. KLEMETTI In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 14 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03

The VLF/LF radio wave observations of structure and variability in the lower ionosphere are described. Emphasis is on data relating to the ionosphere below 100 km, obtained at equatorial, mid-latitude and polar locations, with a VLF/LF pulse ionosounder. The use of the data to help characterize the short- and long-term variability of the lower ionosphere is considered, in addition to its use to infer specific structural features of the ionosphere, such as the C-layer below 70 km altitude. Data obtained within the polar cap during a number of solar proton events (SPEs) are also described. Author

N90-11374# Technical Univ. of Istanbul (Turkey).
THE MIDDLE AND HIGH LATITUDE IONOSPHERE AT APPROXIMATELY 550 KM ALTITUDE
Y. K. TULUNAY In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 5 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03

Ambient electron density measurements made by the radio frequency capacitance probe on Ariel 4 satellite were analyzed in order to study the structures present at the satellite altitudes, i.e. between approximately 470 and 600 km, at latitudes poleward of + or - 50 degrees Lambda both during winter and equinox; data obtained on 94 days centered on the solstices, and March 1972 were used. The general morphology of and the extreme densities, the mid-latitude electron density trough, the polar cap depletions and the electron density enhancements associated with the cusp auroral zone were determined statistically. Analyses of the solstice and the equinox data acquired during quiet magnetic conditions show that the Northern and Southern Hemisphere ionospheres

were significantly different. The global characteristics of the winter solstice and the equinox electron densities were similar although they differ from each other in fine details. Author

N90-11375*# Utah State Univ., Logan. Center for Atmospheric and Space Sciences.
MODELLING IONOSPHERIC DENSITY STRUCTURES
R. W. SCHUNK and J. J. SOJKA In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 12 p (SEE N90-11361 02-46) Apr. 1989
(Contract NAGW-77; F49620-86-C-0109)
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03 CSCL 04/1

Large-scale density structures are a common feature in the high-latitude ionsphere. The structures were observed in the dayside cusp, polar cap, and nocturnal auroral region over a range of altitudes, including the E-region, F-region and topside ionosphere. The origins, lifetimes and transport characteristics of large-scale density structures were studied with the aid of a three-dimensional, time-dependent ionospheric model. Blob creation due to particle precipitation, the effect that structured electric fields have on the ionosphere, and the lifetimes and transport characteristics of density structures for different seasonal, solar cycle, and interplanetary magnetic field (IMF) conditions were studied. The main conclusions drawn are: (1) the observed precipitation energy fluxes are sufficient for blob creation if the plasma is exposed to the precipitation for 5 to 10 minutes; (2) structured electric fields produce structured electron densities, ion temperatures, and ion composition; (3) the lifetime of an F-region density structure depends on several factors, including the initial location where it was formed, the magnitude of the perturbation, season, solar cycle and IMF; and (4) depending on the IMF, horizontal plasma convection can cause an initial structure to break up into multiple structures of various sizes, remain as a single distorted structure, or become stretched into elongated segments. Author

N90-11376*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
OBSERVATIONS OF IONOSPHERE/MAGNETOSPHERE INTERACTIONS FROM THE DYNAMICS EXPLORER SATELLITES
R. A. HOFFMAN In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 17 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03 CSCL 04/1

The Dynamics Explorer program was a dual spacecraft mission designed to study the interactions between the upper atmosphere, ionosphere and magnetosphere. The global auroral images acquired from the high altitude spacecraft have provided a revolutionary new time-dependent frame of reference for the interpretation of data acquired in situ. Using data especially from the low altitude spacecraft, interrelationships are developed between the various electrodynamic parameters measured. Ionospheric irregularities are found to be especially intense in regions of electric field convection shears, which are closely related to the dusk hemisphere field-aligned currents. These region 1 currents are spatially connected to the boundary plasma sheet electron precipitation. At all local times, there appears to be a universal relationship between regions where div E is less than 0 and electron precipitation structures. Depending upon the characteristics of the electrons bombarding the atmosphere, the atmosphere will radiate various spectral optical emissions, which can be imaged from high above the polar caps, with temporal resolution sufficient to follow the time-dependent evolution of a substorm. It is concluded that with further detailed analyses of the electrodynamic parameters obtained from in situ measurements, analyses of auroral images will yield specific information on many of the important ionospheric parameters over an entire auroral oval and polar cap, including regions of intense ionospheric irregularities. Author

N90-11377# Centre de Recherches en Physique de l'Environnement, Saint Maur des Fosses (France).
EMPIRICAL MODELS OF CONVECTION ELECTRIC FIELDS AND ELECTROSTATIC POTENTIAL AT HIGH LATITUDE FROM EISCAT OBSERVATIONS: PRELIMINARY RESULTS
Abstract Only
CATHERINE SENIOR, DOMINIQUE FONTAINE, and GERARD CAUDAL *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Mangetosphere 1 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
Convection electric fields are observed with the EISCAT European Incoherent Scatter Common Program CP-3, which probes the F2 region of the aurorial ionosphere between 61 and 70 degrees invariant latitude for 24-hour runs. Average convection patterns were calculated from ion drift data gathered in several tens of these 24-hour experiments conducted between January 1982 and June 1987, for various levels of magnetospheric activity and orientation of the interplanetary magnetic field. The averaging technique is presented and the physical meaning of our criteria for selecting the data samples are discussed. Electrostatic potential distributions are computed from these statistical electric field models, using the method developed by Alcayde et al. These electrostatic potential patterns are compared to earlier models obtained from incoherent scatter radar or satellite data. Results are consistent with the well-known two-cell convection pattern with antisunward flow over the polar cap, and sunward flow in the auroral zone. The characteristics and variability of these two cells are discussed in the light of indices of magnetospheric activity and orientation of the interplanetary magnetic field. Particular emphasis is placed on the shape and position of the two cells, and on the intensity of the dawn to dusk potential drop applied to the ionospheric auroral zone probed by the radar. Author

N90-11378# Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau (Germany, F.R.).
LOW FREQUENCY ELECTROSTATIC WAVES OBSERVED IN THE VICINITY OF AN AURORAL ARC
K. RINNERT *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 7 p (SEE N90-11361 02-46) Apr. 1989
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Measurements of the electric field vector from d.c. to about 150 Hz were performed on board the CAESAR-2 payload. The payload flew over a faint localized auroral arc associated with an inverted-V precipitation event. Equatorward of this auroral disturbance intense electrostatic low frequency signals were observed with fundamental frequency below the ion cyclotron frequency These signals had properties of wave fields of ion-beam-driven electrostatic ion cyclotron waves (EIC) described by Yamada et al. The spatially or temporarily limited occurrence of these signals may give an indication of the distribution of ion beams or field-aligned currents. Author

N90-11379# Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux (France).
POLAR F LAYER LACUNA IRREGULARITIES AT DUMONT D'URVILLE
PAUL VILA *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 8 p (SEE N90-11361 02-46) Apr. 1989
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Polar F lacunae, a loss of F-region echoes by the vertical-incidence ionosondes are re-investigated. The Dumont D'Urville series including rapid-run sequences suggest the existence of three distinct classes of lacuna. Combining these morphological descriptions with some specific observations by backscatter radar, incoherent scatter meridian scans, angle-or-arrival ionosonde measurements and VIKING satellite, a dual mechanism was suggested for the propagation loss causing lacunae. This consists in a fine E-F sporadic screen structure sometimes identical to the Olesen Sec phenomenon, and of F-region fronts about 300 km wide which tilt the scattered ionosonde waves away from the captation cone of the ionosonde receiving antenna. The scant physical measurements available for this study allow a unifying model to be proposed for the front and screen formation, which needs checking up with more co-ordinated data. Author

N90-11380# University Coll., London (England). Dept. of Physics and Astronomy.
SEASONAL AND GEOMAGNETIC RESPONSE OF THE THERMOSPHERE AND IONOSPHERE
D. REES and T. J. FULLER-ROWELL *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions witn Atmosphere and Magnetosphere 27 p (SEE N90-11361 02-46) Apr. 1989 Sponsored in part by United Kingdom Science and Engineering Research Council
(Contract AF-AFOSR-0341-86)
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A self-consistent coupled thermospheric/ionospheric model, a valuable diagnostic tool for examining thermospheric/ionospheric interactions was produced. The neutral thermospheric wind velocity, composition, density, and energy budget are computed, including their full interactions with the high-latitude ion drift and the evolution of the plasma density. A series of simulations was performed at high solar activity, for a level of moderate geomagnetic activity, for each of the June and December solstices, and positive and negative values of the IMF-BY component. In the winter polar region, ion transport and the dirunal migration of the polar convection pattern into and out of sunlight play a major role in the plasma density structure at F-region altitudes. In the summer polar region, an increase in the proportion of molecular to atomic species, created by the global seasonal thermospheric circulation and augmented by the geomagnetic forcing, controls the plasma densities at all Universal Times. The increased destruction of F-region ions in the summer polar region reduces the mean level of solar insolation. In the winter polar region at 300 km the dominant ion is O(+); in summer molecular and O(+) ions are of similar number densities. The summer ion temperature at 300 km exceeds the winter values by 500 K, due to change in neutral temperature. In the lower thermosphere auroral oval the ion density is dominated by auroral precipitation in both seasons, resulting in only a small seasonal dependence in the height-integrated Joule heating rate and field-aligned currents (FAC). Within the polar cap, solar ionization generates a large seasonal variation of conductivity, producing a threefold increase in peak Joule heating rates, changing the balance of FAC. Neglect of neutral winds increases dusk sector Joule heating. Most of the neutral and electrodynamic parameters considered also have strong IMF-BY dependence. Author

N90-11381# Bonn Univ. (Germany, F.R.). Inst. fuer Astrophysik und Extraterrestrische Forschung.
STORMTIME COUPLING OF THE NEUTRAL AND IONIZED UPPER ATMOSPHERE AT MIDDLE LATITUDES
G. W. PROELSS *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 13 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
Present knowledge about the interaction between magnetic storm associated changes in the neutral gas composition and ionospheric storms is reviewed. After a brief description of ionospheric disturbance effects, it is shown that the negative phase is caused by a decrease of the atomic oxygen to molecular nitrogen (oxygen) density ratio. Local time variations are discussed as an example of systematic changes common to both disturbance phenomena. It is shown that negative ionospheric storms may be confused with ionospheric trough effects which are not produced by neutral composition changes. There is also no association between composition perturbations and positive ionospheric storm effects which again are attributed to the transport of ionization. Author

N90-11382# Science Research Council, Chilton (England).
IONOSPHERE-THERMOSPHERE COUPLING AT HIGH LATITUDES: ASPECT ANGLE DEPENDENCE OF NON-THERMAL PLASMAS Abstract Only
K. J. WINSER, M. LOCKWOOD, A. D. FARMER, G. O. L. JONES, D. REES, and A. ARULIAH (University Coll., London, England)
In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 1 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
Recent observations with the EISCAT incoherent scatter radar have shown large, relatively short lived (approximately 1 hour), enhancements in the dayside, auroral convection flows over a

side range of latitude. These are larger than the neutral thermal speed and represent the first experimental observations of non-thermal plasma over a range of observing angles, indicating a clear angular dependance. The observed ion temperature anisotropy, deduced by assuming a Maxwellian line-of-sight ion velocity distribution, exceeds the theoretical value for a bi-Maxwellian based on a realistic ion-neutral collision model. One of the main problems was that the neutral temperature and wind velocity had to be estimated from either the radar data or models, which may introduce a large source of error into the calculations described above. This problem is discussed and the possible consequences are illustrated by comparing the meridional and zonal components of the neutral wind derived from EISCAT observations with those measured simultaneously in the same volume, using a Fabry-Perot interferometer (FPI). A new experiment is planned which will combine low elevation EISCAT observations of the auroral zone/polar cap ionosphere with simultaneous FPI measurements of the neutral wind and temperature, which will address some previously unsolved problems on the collisional and plasma processes that occur in the high-latitude ionosphere/thermosphere system. Author

N90-11383# Auroral Observatory, Tromso (Norway).
QUIET TIME CONDUCTIVITIES OF THE AURORAL IONOSPHERE
ASGEIR BREKKE and CHRIS HALL *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 17 p (SEE N90-11361 02-46) Apr. 1989 Sponsored in part by Norges Almenvitenskapelige Forskningsrad
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EISCAT incoherent scatter data of the E- and F-region raw electron density profiles for 7 quiet days were used to derive the auroral ionosphere conductivities and conductances. Empirical formulas for the solar zenith angle dependence were obtained which are compared with earlier models and results. In particular, the Hall- to Pedersen-conductance ratio was found to be lower during quiet periods than usually reported from similar work on incoherent scatter data and model studies. For disturbed days, however, when the data are corrected for background ionization, this conductance ratio is much higher than models predict. Author

N90-11384# Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau (Germany, F.R.).
CALCULATION OF THE TEMPERATURE AND VELOCITY VECTOR OF THE NEUTRAL GAS USING EISCAT CP3-DATA
D. FIGUEROA and H. KOHL *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 4 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03

The CP3-mode of EISCAT is particularly appropriate for three-dimensional studies of the interaction between ionosphere and thermosphere, because of its good latitude, height and time coverage. Using mainly CP3-data of EISCAT as input, parameters of the neutral gas in the middle thermosphere in the latitudes of EISCAT, was calculated by solving the coupled transport equations for the neutral and ion gases for the heights between 150 and 500 km and latitudes between 66 and 72 degrees. By numerically solving the energy equation of the ions and the momentum equation of the neutral gas we obtained the temperature and the horizontal velocity of the neutral gas. This, used in combination with the energy equation of the neutral gas, allowed us to estimate the vertical neutral gas velocity. The calculated neutral gas temperatures sometimes deviate from those obtained by empirical models, which rather represent average conditions, and cannot be expected to described individual periods in the strong varying auroral thermosphere. Calculated neutral gas velocities show clearly the effect of the convection pattern of the ion gas, and little vertical variation. Estimated vertical neutral gas velocities look fairly reasonable, although they are subject to several sources of error. Author

N90-11385# Leicester Univ. (England). Ionospheric Physics Group.
ION HEATING EVENTS OBSERVED AT THE EISCAT RADAR
I. W. MCCREA, T. R. ROBINSON, M. LESTER, and T. B. JONES *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 10 p (SEE N90-11361 02-46) Apr. 1989
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According to simple theory, a quadratic relationship should exist between ion temperature and ion velocity during frictional heating of the high-latitude ionosphere. A method of fitting the form of this relationship for a selection of EISCAT Common Program data is demonstrated, and the observed behavior is consistent with theoretical predictions. From the equation obtained, estimates are made of the neutral mass and one component of the neutral wind. These appear to be physically realistic. The validity and sensitivity of the technique is briefly discussed, and an attempt is made to account for possible errors due to changes in the ion composition and the presence of anistropic plasma velocity distributions. Author

N90-11386# Technische Hogeschool, Eindhoven (Netherlands). Dept. of Physics.
ON THE INFLUENCE OF IONOSPHERIC CONDUCTIVITY ON DISPERSION OF ACOUSTIC GRAVITY WAVES
L. P. J. KAMP, R. H. M. MIESEN, P. C. DEJAGHER, and F. W. SLUIJTER *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 8 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03

The influence of ionization and conduction on the dispersion of acoustic gravity waves in the upper atmosphere was investigated by means of a numerical analysis of the corresponding dispersion relation in which the Hall frequency is assumed to be much smaller than the Brunt-Vaisala frequency. It is shown that a significant consequence of the incorporation of ionospheric conduction is a relatively strong damping of gravity waves, unless propagating parallel to the Earth's magnet field with frequencies smaller than the Brunt-Vaisala frequency. Typically this damping takes place with a characteristic damping rate that scales with the Pedersen conductivity. Furthermore it turns out that waves that belong to the acoustic branch of the double-branch dispersion relation are also damped with a camping rate of the same order in magnitude when ionospheric conduction is taken into account. This is the case for waves propagating perpendicular to the Earth's magnetic field and for waves propagating parallel to the Earth's magnetic field but then with frequencies that are of the order of the acoustic cut-off frequency. Author

N90-11387# Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau (Germany, F.R.).
ATMOSPHERIC GRAVITY WAVES IN THE AURORAL SOURCE REGION OF TIDS, STUDIED WITH THE EISCAT CP2-DATA
H.-P. MAUELSHAGEN and K. SCHLEGEL *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 14 p (SEE N90-11361 02-46) Apr. 1989
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Atmospheric gravity waves and travelling ionospheric disturbances (TIDs) with the data where the methods of estimating different TID-events, their direction and further aims of study presented, were studied. The time was confined more or less to a magnetically very quiet 38 hour period, 5 to 6 May 1987. Contrary to more active days it is possible in this period to show not only different TID-events but also to resolve a frequency-time evolution of sudden events. For this very weak magnetic activity it is unlikely that the present TIDs originate in auroral effects. Thereby the criteria were worked out to distinguish events of propagating waves and of waves which are just beginning. Summing up this work shows that it is possible to estimate the whole complex wave number as a function of time of every resolvable wave-like structure. This offers a possibility to test the theories of the generation, the propagation, and the dissipation of TIDs. Author

N90-11388# Bari Univ. (Italy). Dept. of Physics.
ON THE POSSIBILITY OF PRODUCING ARTIFICIAL IONIZATION AND POLAR AURORA IN THE IONOSPHERE BY RADIO-WAVES EMITTED FROM THE GROUND
MARIO CUTOLO and ANGELA ARGENZIANO *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 4 p (SEE N90-11361 02-46)   Apr. 1989   Prepared in cooperation with Naples Univ., Italy
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    in 1938 Prof. V. A. Bailey demonstrated by calculations that some resonance may occur between electrons and a wave as the frequency of this wave varies around the local gyrofrequency, fh. A radio-wave having a frequency equal to the gyrofrequency is called a, gyro-wave. The resonance increases the collision frequency in the low ionosphere by an appreciable amount (i). There are two principal consequencies of the resonance: If a second wave unmodulated passes through the ionosphere region where the gyro-wave acts, an interaction is found between these two waves. This phenomenon is called gyrointeraction and was demonstrated experimentally. If the radiowave is a gyro-wave, with a carrier frequency varying around the local gyrofrequency and is powerful it could produce in the ionosphere an artificial aurora or airglow. The powerful gyro-wave would reduce strongly the electric voltage of the region illuminated by the gyro-wave as to generate an electrical discharge. Moreover with a suitable system of 800 aerial and with a power of 500 kW or of 1,000,000 kW it would be possible to generate an artificial aurora between 60 and 88 km in the ionosphere. Starting form the experiments of H. A. Wilson and D. M. Myers with high-frequency discharges on the lines developed by J. S Towsend and his associates, Bailey developed his theory. These experiments, made by Wilson and Myers, showed that the electric discharges can occur in the air when in the uniform column z/p the ratio of the electric force z to the gas pressure p is approximately 16. It is possible therefore to conclude that two of the necessary conditions for producing electrons and light, are satisfied when E/p 16. An investigation was made in 1959 of the possible increases of both the collision frequencies and the electron density N caused by a powerful extraordinary circular gyrowave in the nocturnal lower-E-region and in the daytime D-region. The principal process then freshly introduced was the attachment of the electrons to molecules in some collisions. According to this new thory the power density requirement for the excitations of an artificial airglow by means of gyrowaves were reconsidered.   Author

N90-11389# California Univ., San Diego. Dept. of Electrical and Computer Engineering.
IONOSPHERIC IRREGULARITIES DUE TO POWERFUL HF RADIO TRANSMISSIONS
J. A. FEJER *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 10 p (SEE N90-11361 02-46)   Apr. 1989
(Contract F19628-86-K-0031)
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    It was known for some time that sufficiently powerful HF radio transmissions produce a great variety of ionospheric irregularities. Ionospheric modification facilities with effective radiated powers of the order of 100 MW directed toward the ionosphere were used for the study of such irregularities since 1970. Such man-made irregularities were employed to establish experimental scatter communications links. Very powerful short wave broadcast transmitters must also produce man-made irregularities which affect the ionospheric propagation of short waves. All aspects of the physical phenomena which play a role in the production of ionospheric irregularities by powerful HF transmissions, are discussed. These include thermal self-focusing of radio waves, formation of short-scale field-aligned irregularities by a thermal parametric instability in which the scattering of the HF pump wave by the irregularities into Langmuir waves plays an important role, and those parametric instabilities in which the ponderomotive force dominates over thermal forces. The latter two parametric instabilities can lead to the acceleration of electrons to energies of tens of electron volts. Such accelerated electrons can produce artificial airglow and also additional ionization which under certain conditions could be significant. In their strongly nonlinear stage parametric instabilities can lead to the formation

of localized electron density depletions (cavitons) maintained by the ponderomotive force of Langmuir waves trapped in them.
                        Author

N90-11390# Crete Univ., Iraklion (Greece). Dept. of Physics.
A REVIEW ON RADIO STUDIES OF AURORAL E-REGION IONOSPHERIC IRREGULARITIES
C. HALDOUPIS *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 20 p (SEE N90-11361 02-46)   Apr. 1989
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    The physical significance of recent radar studies of auroral irregularities at different frequency bands in the VHF and UHF range is discussed, with emphasis on Doppler spectral studies. The results suggest that important differences exist between the 50 MHz equatorial and auroral backscatter processes, and that the role of altitude and of electron density in the generation and saturation of instabilities is much more important in the auroral than in the equatorial E region. The need for a general unified theory of radio aurora incorporating wave energy propagation characteristics and new nonlinear saturation mechanisms is emphasized.   IAA

N90-11391# Illinois Univ., Urbana. Dept. of Electrical and Computer Engineering.
IONOSPHERIC IRREGULARITIES AND THEIR EFFECTS ON ELECTROMAGNETIC WAVES PROPAGATING THROUGH THEM
K. C. YEH *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 7 p (SEE N90-11361 02-46)   Apr. 1989
(Contract NSF ATM-84-14134)
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
    Global sounding and probing of the ionosphere have revealed the frequent presence of irregularities throughout various ionospheric regions. Using the collected data, many comprehensive studies were made and reviewed. Models were constructed and continuously inmproved with additional data. Extensive morphological studies clearly indicate a strong dependence on the phase of solar cycle, the geomagnetic latitude, and the local time. Data were also collected that enable the characterization of the electron density fluctuations statistically in their space-time behavior. Such characterizations are necessary in connecting medium properties to wave properties. The ionosphere is known to be a dispersive medium. In the presence of irregularities, severe scattering may additionally take place. A radio wave propagating through such an environment may therefore experience fading and scintillation. The strength of a scintillating signal is usually measured by its scintillation index S4, defined as the normalized root-mean-square intensity fluctuations above the mean. The dependence of S4 on radio frequency was investigated by using multifrequency data. The results are shown to agree with theory. The higher-order statistics that are used to describe the space-time signal were measured. Using spaced antennas, a cross correlation function can be calculated in addition to S4 and self spectrum. Several methods exist that connect the cross correlation function the ionospheric drift velocity and the velocity fluctuations. Several days of data obtained at an equatorial station will be shown as examples.   Author

N90-11392# Centre de Recherches en Physique de l'Environnement, Saint Maur des Fosses (France).
ELECTROSTATIC TURBULENCE IN THE HIGH LATITUDE IONOSPHERE Abstract Only
J.-C. CERISIER, H. MOUNIR, and J.-J. BERTHELIER *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 1 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
    Two components of the Extremely Low Frequency (ELF) electric field are measured on board the low altitude (400 to 2000 km) polar orbiting satellite Aureol-3. At high latitude, the main wave-field component observed in the frequency range up to a few hundred Hertz is the electrostatic turbulence. The frequency spectrum measured in the satellite reference frame usually follows a power lay (E squared alpha $E(sub 0)$ f sup $-alpha$), thus allowing to describe the turbulence with two parameters (amplitude and

spectral index). These characteristic parameters will be discussed in relation with the possible free energy sources: field-aligned current, particle precipitation, electron density gradient. The relation between the frequency spectrum and the wave number spectrum is not unambiguous. However, under the hypothesis of time-independent turbulence, it is possible to deduce, from the measurement of two different components of the electric field, the anisotropy of the wave number spectrum of the turbulence. The method used for this determination will be described and applied to physical situations observed in the polar cap, in the auroral zone, and in sub-auroral regions. Author

N90-11393# Boston Univ., MA.
AURORAL AND SUB-AURORAL F-LAYER IRREGULARITY STUDIES IN THE NORTHERN AND SOUTHERN HEMISPHERE DURING THE EQUINOX TRANSITION STUDY SEPTEMBER 16-26, 1984
J. AARONS, J. C. FOSTER, L. KERSLEY, and A. S. RODGER (British Antarctic Survey, Cambridge, England) *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 14 p (SEE N90-11361 02-46) Apr. 1989 Sponsored in part by ONR, Washington, DC
(Contract NSF ATM-84-19117)
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A preliminary model detailing the auroral and sub-auroral nightly behavior of F-layer irregularities during the injection and recovery phases of magnetic storms is outlined. Initially the irregularities spread equatorwards from the auroral region. On subsequent nights in those storms where Dst slowly returns to its zero level there is activity at auroral latitudes at the end of the magnetic storm and finally, relatively high irregularity intensity primarily at sub-auroral latitudes. The model was tested with observations of the irregularities observed during the September 1984 Equinox Transition Study. Observations of irregularities and incoherent scatter were examined for the injection phase of the magnetic storm of Sep. 22 to 23. The concept was to determine what parameters are most important in indicating whether irregularities are present over a range of latitudes from 53 to 78 degrees CGL. The data set indicates distinct correlation with convection velocities in the early portion of the storm when a sub-storm was shown on magnetograms. In the latter half of the night with the magnetic storm fully developed, the data show good correlation with an electron density trough, high electron temperatures, and high velocities. For the recovery phase of a magnetic storm another period in the ETS is examined with sub-auroral irregularities observed during the recovery of Dst when quiet magnetic conditions prevailed. The general form of the model appears to be valid but many aspects of the timing and the magnitude of the irregularity intensity are to be determined. Author

N90-11394# Universite de Toulon et du Var (France).
SMALL-SCALE IRREGULARITIES AND GLOBAL PLASMA DYNAMICS IN THE HIGH-LATITUDE IONOSPHERE
C. HANUISE, R. A. GREENWALD, K. B. BAKER, J. M. RUOHONIEMI, J. C. CERISIER, and CATHERINE SENIOR (Centre de Recherches en Physique de l'Environnement, Saint Maur des Fosses, France) *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 14 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
New sophisticated HF coherent radars were installed in the past few years at very high latitudes. The APL Goose Bay radar and the French SHERPA radar in Schefferville are the two components of the Polar Region Ionospheric Structrure Monitor (PRISM) operating in Canada. These instruments detect irregularities within the three-dimensional volume covering much of northeastern Canada and Greenland. The instruments are capable of following the temporal variability of these irregularities as well as determining unambiguously the Doppler shift and spectral broadening of radar signals scattered by them. The scientific goals of the program concern both the physics of the small-scale structures and the mapping of large-scale plasma convection. Several case studies of plasma mechanisms generating the small-scale density structures were already published. The temporal and spatial variability of the large-scale irregularity structures, as seen by the radars, is also investigated. The relationship between the radar Doppler velocity and the plasma drift velocity were

confirmed. The potential of the system for studying global ionospheric dynamics is emphasized. When combining the two radial velocities measured by each radar, a two-dimensional map of plasma convection and electric field is derived over a region as large as 2 million square kilometers, with a fine temporal and spatial resolution in the auroral region and over the polar cap. Author

N90-11395# Lowell Univ., MA. Center for Atmospheric Research.
EXAMPLES OF METEOROLOGICAL BEHAVIOR OF THE IONOSPHERE
K. BIBL *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 6 p (SEE N90-11361 02-46) Apr. 1989
(Contract CRL-61(052)-623)
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
For some time the network of ionosonde stations in Europe were dense enough to study the meteorological behavior of the ionosphere. Because the electron recombination near the maximum of the F-region ionization is sufficiently small, the maximum electron density and the profile are controlled substantially by dynamic processes. Gravity waves and vertical plasma drift and its vertical gradients change the F-layer ionization significantly. In fixed frequency ionosonde recordings the author has discovered direct oblique echoes from a hole in the ionosphere over the Alps. Maps were drawn to show the meteorological properties of this European Anomaly either as a time development of a cross-section of Europe from northern Germany to Rome, Italy using six stations, or as a sequence of a contour maps of the ionosphere over Europe using ten stations. A short animated movie was produced demonstrating the development of the hole in the ionosphere and its recovery with a curl developing. Even the average behavior of the F-region ionization shows substantial differences with location. In Europe the variations of the local gradients in ionization can be different by a factor of two over two locations separated by 1000 km. This behavior, important for understanding the meteorology of the ionosphere and for precise ionspheric radio predictions, certainly requires intense studies with digital sounders in Europe and at other locations. Author

N90-11396# Lowell Univ., MA. Center for Atmospheric Research.
MULTISTATION/MULTIPARAMETER OBSERVATIONS WITH A NETWORK OF DIGITAL IONOSONDES
B. W. REINISCH, J. BUCHAU (Air Force Geophysics Lab., Hanscom AFB, MA.), K. BIBL, and G. S. SALES *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 9 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
The global network of modern ionosondes generates a data set of ionospheric characteristics that can serve as test bed for the developing ionospheric models. Remote access to each station make it possible to use real time data for project planning and radio communication tasks. New ionospheric parameters like ionospheric roughness, tilt angles and drift are now available for each Digisonde location. Author

N90-11397# Science Applications International Corp., McLean, VA. Lab. for Atmospheric and Space Sciences.
COORDINATED MULTI-PARAMETER MEASUREMENTS AND PREDICTIONS OF THE GLOBAL-SCALE IONOSPHERE
EDWARD P. SZUSZCZEWICZ, R. A. WOLF, B. G. FEJER, R. W. SCHUNK, and E. ROELOF (Johns Hopkins Univ., Laurel, MD.) *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 16 p (SEE N90-11361 02-46) Apr. 1989
(Contract NSF ATM-85-13362)
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The solar-terrestrial system involves a myriad of macro and microphysical processes that challenge the development of a unified physical description of solar, magnetrospheric, interplanetary, and thermospheric controls of the global-scale ionosphere. A well-planned interdisciplinary effort combining theoretical modelling with a coordinated measurement program should lead to significant advances in understanding of the solar-terrestrial system as a whole and the development of real-time

predictive capability for a world-wide specification of ionospheric conditions as they are dictated by the controlling subsystem inputs. The SUNDIAL program has such a focus, with a combined modelling and measurement program that includes solar, solar wind, interplanetary and geomagnetic data, and nearly 70 ionospheric monitoring stations at high-, middle- and low-latitudes in the American, European/African, and Asian/Australian sectors. The program operates in an 8 to 14 day campaign mode with around-the-clock measurements. Campaigns were initiated in October 1984, and since September 1986 were conducted at 9-month intervals to study each of the four ionospheric seasons twice within the ascending phase of the current solar cycle. The measurement and modeling elements in the program were reviewed perspectives on global-scale ionospheric predictability discussed and some of the accumulating results which address magnetospheric substorms and the triggering of equatorial spread-F highlighted. Author

N90-11398# Centre National d'Etudes des Telecommunications, Lannion (France).
NORTH-SOUTH TROPICAL F2 LAYER ASYMMETRY AT WEST AFRICAN AND PACIFIC LONGITUDES
COLETTE DAVY, ROLAND FLEURY, PIERRE GOURVEZ, RUDI HANBABA, and PAUL VILA (Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux, France) In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 6 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
Because in September to October 1986 the a sub p magnetic activity nearly changed with 24-hour steps, this period presents rather simple F2 layer day-to-day changes in the intertropical zone. Along the ten days selected for the equinox Sundial study, the CNET stations: Dakar (17.7 N, 17.2 W, northern subtropic, Ouagadougou (12.4 N, 1.6 W, magnetic eauator), Tahiti (17.4 S, 149.2 E, southern tropic) provide a sufficient latitude diversity to characterize the magnetic season asymmetry of generally dominant anti-solar tropical peak densities. On the basis of previous ground-based and satellite meridian-aligned surveys the F2 layer peak true height and foF2 evolution were investigated, here estimated from the Dakar variations of September 27, September 28 and October 4 1986. The evolution on the (moderately) disturbed day when the average kp values jumped from 1 plus the day before to 4 plus show everywhere the same single weaker maximum around 15 LT. The 1966 complete data along the Tamanrasset median help investigate the main processes of these two different types of evolutuion; the intertropical fountain and neutral drag mechanisms are investigated: the respective effects of the E X B dynamo, neutral wind from sub-solar atmospheric heating and from sub-auroral disturbance dynamo are deduced. Couplings between these processes and the conjugate photo-electron forced diffusion are discussed. Author

N90-11399# Royal Aerospace Establishment, Farnborough (England). Radio and Navigation Dept.
JOINT VHF COHERENT RADAR AND OBLIQUE SOUNDER OBSERVATIONS FOR SHORT TERM IONOSPHERE FORECASTING
P. S. CANNON, M. LESTER, E. C. THOMAS, A. H. DICKSON, T. B. JONES, R. MAUDE, P. J. RYLAH (Leicester Univ., England), and A. K. SHUKLA In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 13 p (SEE N90-11361 02-46) Apr. 1989
(Contract SERC-SGD/10696)
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03
An experiment which utilizes two VHF coherent radars located in northern Scotland together with an oblique chirp sounder, operating over a path from Norway to northern Scotland is described. The expected sounder path falls within the radars field-of-view. Some initial results are described from the first in a series of experiments. A statistical correlation is found between the occurrence of radar backscatter and the occurrence of sporadic-E. On some occasions a positive correlation also exists between the backscatter signal to noise ratio and the highest frequency measured from the sporadic-E trace on the ionogram. On other occasions the correlation is poor. An initial interpretation of these data is presented which suggests that propagation of

the HF sporadic-E signals via a simple plane ionosphere is inadequate to explain the observations. Author

N90-11404# Laboratoire d'Etude des Transmissions Ionospheriques, Cachan (France).
INFLUENCE OF IONOSPHERIC VARIATIONS ON HIGH-RELIABILITY HF SYSTEMS UTILIZING LARGE BASES [INFLUENCE DES VARIATIONS IONOSPHERIQUES SUR LES SYSTEMES HF A HAUTE FIABILITE UTILISANT DE GRANDES BASES]
C. GOUTELARD and J. P. VANUFFELEN (Telecommunications Radioelectriques et Telephoniques, Le Plessis-Robinson, France) In AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 12 p (SEE N90-11361 02-46) Apr. 1989 In FRENCH
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A0
Transmission reliability is dependent on propagation parameters and interference. The use of wide bases provides a solution to this problem. The minimal base dimensions are determined by the interference. Management of the established network requires large scale modeling of the propagation medium and evaluation of interference. Optimal reception conditions are established for the case of bases composed of two to four receiving stations. Optimal coverage limits are determined and three hierarchical systems are defined for real-time network management. Author

N90-15043# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
DESCRIPTION OF ATMOSPHERIC TURBULENCE [DESCRIPTION DE LA TURBULENCE ATMOSPHERIQUE]
PIERRE-MARIE HUTIN In AGARD, Flight in Adverse Environmental Conditions 14 p (SEE N90-15041 07-01) Sep. 1989 In FRENCH Previously announced in IAA as A89-48750
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Over one million hours of aircraft flight test data for loading factors in excess of 0.5 g were analyzed using three different methods in order to model coherent atmospheric turbulence. The Houbolt method (using a rigid body with two degrees of freedom for the aircraft flight mechanics) is found to provide a better description of the atmosphere than either the Pratt method (in which turbulence values are obtained from the vertical acceleration of the aircraft) or the Hall method (using only a single degree of freedom for the aircraft motion). The Houbolt method is improved by a calibration using exact calculations for a small number of different aircraft configurations. IAA

N90-21919# Air Force Geophysics Lab., Hanscom AFB, MA.
MODELS OF AEROSOLS, CLOUDS, AND PRECIPITATION FOR ATMOSPHERIC PROPAGATION STUDIES
ERIC P. SHETTLE In AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 14 p (SEE N90-21907 15-32) Mar. 1990
(AGARD-CP-454) Copyright Avail: NTIS HC A16/MF A03;
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A number of models are reviewed for the atmospheric aerosols, clouds, and precipitation and their effects on the propagation of electromagnetic radiation at wavelengths from the ultraviolet through the microwave spectral regions. The focus is on the models developed at AFGL and elsewhere primarily for use in the atmospheric propagation models LOWTRAN (Kneizys et al., 1983 and 1988) and FASCODE (Clough et al., 1986), but also examines other particulate models. The scattering and absorption properties of the different particulate models are presented. Applications of the various models are discussed with recommendations on when it is most appropriate to use which aerosol or cloud model. Sensitivities of calculated transmittances and background radiances to the different types of particulate models are examined for a range of wavelengths. Author

N90-21921# Naval Research Lab., Washington, DC.
THE NAVAL OCEANIC VERTICAL AEROSOL MODEL Progress Report
STUART G. GATHMAN, GERRIT DELEEUW, KENNETH L. DAVIDSON, and DOUGLAS R. JENSEN (Naval Ocean Systems Center, San Diego, CA.) *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 11 p (SEE N90-21907 15-32) Mar. 1990 Sponsored in part by National Research Council
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The Naval Oceanic Vertical Aerosol Model (NOVAM) was formulated to estimate the vertical structure of the optical and infrared extinction coefficients in the marine atmospheric boundary layer (MABL). NOVAM was designed to predict the non-uniform and non-logarithmic extinction profiles which are often observed. It is based on a combination of empirical and physical models which describe the aerosol dynamical behavior. The extinction properties are calculated from the aerosol profiles using the Mie theory. For the initial evaluation of NOVAM, data from the July 1987 FIRE experiment (conducted off the coast of southern California) was used. Aerosol particle size distributions, aerosol scattering, and required meteorological parameters throughout the MABL were obtained from both airborne and surface-based platforms (aircraft, ship and balloon instrumentation packages). The aerosol-derived extinction properties throughout the MABL are compared with the NOVAM estimates. Author

N91-18506# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Panel.
IONOSPHERIC MODIFICATION AND ITS POTENTIAL TO ENHANCE OR DEGRADE THE PERFORMANCE OF MILITARY SYSTEMS
Oct. 1990 483 p In ENGLISH and FRENCH Symposium held in Bergen, Norway, 28-31 May 1990
(AGARD-CP-485; ISBN-92-835-0590-5; AD-A239823) Copyright Avail: NTIS HC/MF A21; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The propagation medium is, in effect, an integral part of many military systems. For the most part, interest in the propagation medium was focused on identifying and quantifying the limitations it imposes on systems. The results of on-going theoretical and experimental research show potential for modifying selected regions of the ionosphere in order to affect radio wave propagation. A variety of modification techniques are being investigated, both ground- and space-based, to increase or decrease existing ionization or to create independent artificial plasmas. These techniques include high power radio waves, lasers, particle beams, and chemical releases. In addition, recent development in high power RF sources raise concerns over system limitations, due to self induced anomalous absorption, ray path deviation and clutter. These proceedings present the current state of ionospheric modification technology. For individual titles, see N91-18507 through N91-18549.

N91-18507# Leicester Univ. (England). Dept. of Physics and Astronomy.
THE PHYSICS OF GROUND BASED HEATING
TUDOR B. JONES *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 9 p (SEE N91-18506 10-46) Oct. 1990
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The first indication that powerful radiowaves could modify the earth's ionosphere was the discovery of the Luxembourg Effect in 1933, (Tellegen, 1933). The transfer of the modulation of the high power Luxembourg broadcasts on to weaker signals propagating through the same region of the ionosphere could only be explained in terms of ionospheric 'cross modulation' (Bailey and Martyn, 1934). The ionospheric electron temperature and hence its electron density, were changed by the high power wave and these subsequently influenced other radio signals propagated through the modified region. In the early 1970s, it was realized that high power radio wave could produce many instabilities in the ionosphere

in addition to the collision phenomena associated with the Luxembourg effect. Author

N91-18508# Air Force Geophysics Lab., Hanscom AFB, MA. Ionospheric Physics Div.
HIGH POWER HF MODIFICATION: GEOPHYSICS
HERBERT C. CARLSON, JR. *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 13 p (SEE N91-18506 10-46) Oct. 1990
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As the electric field and power density of radio frequency (RF) radiation increases continuously in a plasma, the response of the plasma to the incident energy changes discontinuously. This follows from a complex of competing physical processes, each generally with its own power dependent threshold, and plasma instabilities each with its own growth and decay rate. Nonlinear power dependencies, boundary condition dependencies on past histories of the plasma conditions, dependence on proximity to plasma resonances, and nonlinear mixing in the plasma to up and down convert with respect to resonances, all conspire to make experimental guidance invaluable to theoretical development. The experiment ahs demonstrated that with increasing HF power one passes the threshold of detectability sequentially from: passive transmission, to cross-modulation, to thermal bulk heating, to parametric and other instabilities with plasma structuring and stimulated electromagnetic radiation, to electron acceleration and airglow, to reported stimulated ionization. The RF propagation and emission environment is affected through the VLF to GHz range by lensing, scattering, modulation, and simulated emission. The optical background and emission character is affected over a very wide spectrum by electron impact and temperature enhancement altering translational, rotational and vibrational temperatures (as well as raising fine structure population distribution questions). A set of geophysical effects are address over this range, and participation is invited in anticipation of what effects lie beyond the next threshold (of ionospheric response to higher HF illumination). The exciting upgrade of the Heater at Tromso and emerging new HF modifier plans in the U.S. are partial motivation for such conjecture. Author

N91-18509# Clemson Univ., SC.
REVIEW OF SOVIET IONOSPHERIC MODIFICATION RESEARCH
LEWIS M. DUNCAN and ROBERT L. SHOWEN (SRI International Corp., Menlo Park, CA.) *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 9 p (SEE N91-18506 10-46) Oct. 1990 Sponsored in part by AFGL and LANL
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A technical assessment of Soviet research of the past five to tens years in ionospheric modification by high-power radio waves was reviewed and provided. This review includes a comprehensive survey of Soviet published literature, conference proceedings, and direct discussions with the involved Soviet researchers. The current state of the art for Soviet research in this field is evaluated, identifying areas of potential breakthrough discoveries, and discussing implications of this work for emerging technologies and future applications. This assessment is divided into the categories of basic research, advanced research, and applications. Basic research is further subdivided into studies of the modified natural geophysical environment, nonlinear plasma physics, and polar geophysical studies. Advanced research topics include the generation of artificial ionization mirrors and high-power oblique propagation effects. A separate comparative assessment of Soviet theoretical work is also included. The evaluation of practical and potential applications of this research discusses the utility of ionospheric modification in creating disturbed radio wave propagation environments, and its role in current and future remote-sensing and telecommunication systems. The Soviet effort in ionospheric modification sustains theoretical and experimental research at activity levels considerably greater than that found in comparable programs in the West. Notable strengths of the Soviet programs are its breadth of coverage, large numbers of scientific participation, theoretical creativity and insight, and its powerful radio

wave transmitting facilities. Weakness in the Soviet effort include ccomputational limits in numerical analysis of nonlinear processes, inferior experimental diagnostic capabilities, and an apparent tendency of experimental program to validate theoretical predictions as opposed to exploring new phenomena. A recent review of Soviet ionospheric modification research is given by Migulin and Gurevich. Author

N91-18510# Rice Univ., Houston, TX.
HISTORICAL OVERVIEW OF HF IONOSPHERIC MODIFICATION RESEARCH
WILLIAM E. GORDON and LEWIS M. DUNCAN (Clemson Univ., SC.) *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 13 p (SEE N91-18506 10-46) Oct. 1990
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Radio waves have inadvertently modified the Earth's ionospher since the Luxembourg observations of Tellegen in 1933 and perhaps since Marconi in 1901. The history of ionospheric modification by radio waves is reviewed, beginning with Marconi, describing the Luxembourg effect and its explanations, and its early use to deduce the properties of the lower ionosphere in the 1930s. The measurements became more sophisticated in the 1950s, leading to the call for high-power high-frequency modification experiments in the upper ionosphere. Beginning in 1970, radio facilities became available of sufficient powers to induce changes in the ionospheric plasma detectable by a wide array of diagnostic instruments and techniques. A summary of these effect is presented based upon work up to 1990. These studies were originally motivated as a means of better understanding the natural ionosphere using a weak perturbational approach. However, a rich spectrum of nonlinear wave-plasma interactions was quickly discovered and ionospheric modifications research became strongly motivated by issues in basic plasma physics. The ionosphere and near-Earth space are now exploited as an exceptional plasma laboratory-without-walls for the study of fundamental plasma processes requiring large spatial or temporal scales. A brief overview of these processes and phenomena is presented, illustrated using results obtained from the Arecibo ionospheric modification facilities. The lessons learned and phenomena explored thus far offer many opportunities for controlling the ionospheric environment critical to many civilian and military telecommunications systems, both to disrupt systems normally operational and to create new propagation paths otherwise unavailable. Author

N91-18511# Office of Naval Research, Arlington, VA.
IONOSPHERIC MODIFICATION RESEARCH AT HIPAS
RICHARD G. BRANDT *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 10 p (SEE N91-18506 10-46) Oct. 1990
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The High Power Auroral Simulation (HIPAS) ionospheric heating facility radiates a total power of 1.2 MW with a effective radiated power (ERP) of 84 MW. It presently operates at an HF frequency of 2.85 MHz but is tunable to about 5 MHz. Electrojet modulation experiments were conducted at frequencies from 5 Hz to 5 MHz. The magnetic field amplitudes, measured close to the heater, can be 1 pT or larger under very strong electrojet conditions. Even under much weaker conditions when the amplitudes are highly variable, the phase of the ELF signal is relatively stable. The efficiency of converting HF to ELF is presently too low for a practical communication system. Beam painting was proposed as a method for improving the conversion efficiency in D region heating by causing a much larger area of the ionosphere to radiate coherently; this concept will be tested using microsecond beam steering. Use of shorter heating pulses (lower duty cycle) already seems promising. Even larger gains are expected for E region heating as compared to D region heating. Author

N91-18512# EISCAT Scientific Association, Ramfjordbotn (Norway).
VLF, ELF, AND ULF WAVE RESEARCH USING THE TROMSO HEATING FACILITY
MICHAEL T. RIETVELD, R. BARR, P. STUBBE, A. MAUL, H. KOPKA (Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau, Germany, F.R.), and R. L. DOWDEN *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 10 p (SEE N91-18506 10-46) Oct. 1990 Sponsored in part by DFG
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Results from the Tromso Heating Facility in the areas of wave generation from ULF (mHz) to VLF (kHz) frequencies, as well as VLF wave propagation under heated ionospheres are presented. Results from similar facilities in the USSR and USE are not included. Author

N91-18513# Leicester Univ. (England). Dept. of Physics.
OBSERVATIONS OF THE ANOMALOUS ABSORPTION OF DIAGNOSTIC RADIO WAVES DURING IONOSPHERIC MODIFICATION AT ARECIBO
A. J. STOCKER, T. R. ROBINSON, and TUDOR B. JONES *In* AGARD, Ionospheric Modification and its Potential to Enhance of Dograde the Performance of Military Systems 6 p (SEE N91-18506 10-46) Oct. 1990
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The theory indicates that the anomalous absorption produced during modification of the ionosphere by means of high power radio waves is a dependent on the magnetic dip angle. Recent measurements of the anomalous absorption at Arecibo, Puerto Rico, are found to be considerably smaller in magnitude than those previously reported for the high latitude site at Tromso, Norway. Author

N91-18514# Danish Meteorological Inst., Copenhagen. Dept. of Geophysics.
THEORY OF A THERMAL RESONANCE INSTABILITY IN THE E-REGION OF THE IONOSPHERE
P. HOEG *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 15 p (SEE N91-18506 10-46) Oct. 1990
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Auroral region modulation experiments have shown, that strong electromagnetic HF waves are generating short-scale field-aligned irregularities i the E region of the high latitude ionosphere. For overdense conditions the instabilities are excited close to the reflection altitude of the O-mode heating wave. The theory presented here for a thermal resonance instability are capable of explaining these observations for magnetically quiet to moderate disturbed conditions. The dispersion relation for a thermal resonance instability is considered, where differential heating by collisional dissipation is more important then the action of the ponderomotive force. Thus special attention is paid to the transport theory, when a constant ambient electric field is applied to the plasma. For irregularities with transverse scale lengths much smaller than the wavelength of the heating wave, thermal nonlinearity causes strongly enhanced electron density fluctuations in regions of excess heating wave intensity. In the region, where the upper hybrid frequency of the plasma matches the heating wave frequency, the initial growth of irregularities takes place. The dispersion relation for the electrostatic response of the heating wave together with the full theory of transport lead to criteria for the threshold electric heating wave field, growth rate and drift velocity of the instabilities. Numeric simulations of the theory demonstrate, the magnitude of the threshold electric field as the function of the altitude in the ionosphere, the magnitude and direction of the phase velocity of unstable waves and the influence of the constant ambient electric field on the threshold criteria. Author

N91-18515# Tromsoe Univ. (Norway).
ON THE VALIDITY OF THE WEAK TURBULENCE APPROXIMATION
ALFRED HANSSEN and E. MJOLHUS *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 12 p (SEE N91-18506 10-46) Oct. 1990 Sponsored in part by Norwegian Research Council (AGARD-CP-485) Copyright Avail: NTIS HC/MF A21; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The weak Langmuir turbulence approach to explain the artificial plasma line in ionospheric radio modification experiments, is examined. The mathematical model is a version of the one dimensional Zakharov equations, including damping and a nonlinear ac driving. Numerical full wave solutions to this set of equations are compared with the saturation spectrum determined by a wave kinetic equation derived from the same set of equations. It was found that a distance below the O-mode reflection level, omega - omega(sub p) is much greater than (m/M)omega(sub p) (omega is the applied frequency; omega(sub p) is the plasma frequency; m,M is the electron and ion masses), the full wave solution is in good qualitative agreement with the cascade theory. The number of cascades seen in the full wave solution is generally smaller than that of the saturation spectrum of the wave kinetic equation. On the other hand, in the reflection region omega - omega(sub p) is less than (m/M)omega(sub p), a qualitatively different process takes place, describable as many localized cycles of nucleation, (one dimensional driven) collapse, and burnout, similar to the results of Doolen et. al. These findings are discussed with respect the experiments performed in Arecibo and Tromso.   Author

N91-18516# Naval Research Lab., Washington, DC. Space Plasma Branch.
THEORY OF LARGE-SCALE HF HEATING PROCESSES IN THE UNSTRUCTURED AND STRUCTURED IONOSPHERE
M. J. KESKINEN, P. K. CHATURVEDI, and SIDNEY L. OSSAKOW *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 10 p (SEE N91-18506 10-46) Oct. 1990 (AGARD-CP-485) Copyright Avail: NTIS HC/MF A21; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Theoretical aspects of large-scale HF heating processes in the unstructured and structured ionosphere were studied. For the unstructured case, an analytical model is presented for the generation, convection, and steepening of HF-induced density cavities. The nonlinear propagation of high power HF in steepened cavities is discussed. Properties of thermal self-focusing instabilities in the presence of a convecting and steepened cavity is studied. For the structured ionosphere, parameteric coupling processes are discussed for a large amplitude HF pump wave with both F-region, i.e., interchange, current-convective, and ion cyclotron and E-region, i.e., two-stream and gradient-drift ionospheric instabilities which instabilities were proposed to account, in part, for naturally occurring ionospheric irregularities. It is shown that these instabilities may be stabilized or destabilized using high power HF heaters.   Author

N91-18517# Communications Research Centre, Ottawa (Ontario). Dept. of Communications.
DUCT MODEL FOR THE DUTY-CYCLE VARIATION OF THE PLASMA-LINE OVERSHOOT DURING CYCLIC HEATING AT ARECIBO
D. B. MULDREW *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 6 p (SEE N91-18506 10-46) Oct. 1990 (AGARD-CP-485) Copyright Avail: NTIS HC/MF A21; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

In a recent publication on ionospheric heating by Sulzer et al., (1989), the effects of suddenly changing the duty cycle, during on-off cycling of the HF transmitter, on the plasma-line (PL) overshoot are strikingly illustrated. When the duty cycle was suddenly decreased, the overshoot lifetime changed gradually over about 1 min from roughly 0.1 to most then 0.5 s. When the duty cycle was suddenly increased, the lifetime changed gradually from more than 0.5 to roughly 0.1 s. For a still higher duty cycle, the PL intensity began to pulsate dramatically. The Langmuir (L) waves

responsible for the PL grown by the parametric-decay instability and propagates in magnetic-field-aligned ionization ducts having a density decrement relative to the ambient density outside the duct. The change in the decrement depends both on the ponderomotive force of the trapped L waves and on heating due to damping of the L waves. When the HF is on, the decrement increases. When the HF is off, the decrement decreases. Rapid decay of the L waves (i.e., decay of the overshoot) by Landau damping begins when the decrement exceeds a certain level. The duty-cycle observations can be explained with this model.   Author

N91-18518*# Polytechnic Univ., Farmingdale, NY.
A THEORETICAL MODEL FOR THE TEMPORAL EVOLUTION OF HF-ENHANCED PLASMA LINES
S. P. KUO, A. Y. HO, M. C. LEE, and F. T. DJUTH (Aerospace Corp., Los Angeles, CA.) *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 9 p (SEE N91-18506 10-46) Oct. 1990 (Contract NAG5-1055; NSF ATM-88-16467; AF-AFOSR-0316-85; AF-AFOSR-0127-88) (AGARD-CP-485) Copyright Avail: NTIS HC/MF A21; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 04/1

The HF-enhanced plasma lines (HFPLs) observed in the Arecibo heating experiments refer to the radar returns at frequencies near the sum and difference of the radar frequency and the HF-heatear frequency. Those enhanced spectral lines are caused by backscatter of radar signals from parametrically excited plasma waves having a wavenumber of 18 n. A nonlinear theory was developed to describe the temporal evolution of those specified plasma waves and their originating altitude interval of HFPLs observed at Arecibo, Puerto Rico are explained. The theoretical resultsagree well with the observation (Djuth and Sulzer, 1989).
          Author

N91-18519# Leicester Univ. (England). Dept. of Physics and Astronomy.
ENHANCED FADING RATES PRODUCED DURING IONOSPHERIC MODIFICATION
TUDOR B. JONES and A. WILKINSON *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 7 p stems (SEE N91-18506 10-46) Oct. 1990 (AGARD-CP-485) Copyright Avail: NTIS HC/MF A21; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

When very high power radio waves are reflected from the ionosphere, modifications in the physical chareacteristics of the ambient plasma are produced. These include the production of field aligned plasma striations with scale size across the geomagnetic field lines ranging from a few meters to a few kilometers. The presence of these striations produces anomalous absorption of both the heater wave itself and of other HF signals propagation through the modified region. During experiments at Tromso, Norway, with the heating facility constructed by the Max Planck Institut fur Aeronomy, Lindau, West Germany, marked changes in the fading rate of HF signals reflected from the heated volume were noted. These rapid fluctuations in signal amplitudes are thought to be produced by medium scale striations generated during the heating process. An estimate of scale size of these striations is made from the experimental data.   Author

N91-18520# Naval Research Lab., Washington, DC. Space Plasma Branch.
LARGE SCALE PLASMA IRREGULARITIES AND AIRGLOW ENHANCEMENTS FROM IONOSPHERIC HEATING
PAUL A. BERNHARDT, HARVEY ROWLAND, LEWIS M. DUNCAN, and CRAIG A. TEPLEY (Arecibo Ionospheric Observatory, Puerto Rico.) *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 8 p (SEE N91-18506 10-46) Oct. 1990 (AGARD-CP-485) Copyright Avail: NTIS HC/MF A21; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Ionospheric modification with high power radio waves may generate plasma irregularities and airglow clouds. Large scale irregularities are produced in a convecting F-layer by a mechanism called the plasma relaxation oscillator. When a continuous beam

of powerful electromagnetic waves heats the ionosphere, a cavity is produced by thermal pressure gradients. The cavity drifts under the influence of ambient electric fields causing the vertically-incident, radio beam to be refracted from the zenith. At some point, the cavity can no longer 'capture' the beam and it returns to the zenith to form another cavity. This relaxation process repeats to yield irregularities on the scale of the heater beam diameter. Airglow enhancements are produced by energetic electrons accelerated out of the heated region. Large amplitude electrostatic waves may be excited by linear mode coupling, by parametric decay instabilities, and by strong plasma turbulence. This occurs near the point where the plasma frequency of the ionosphere matches wave frequency. The electrostatic waves accelerate ambient electrons to high enough energy to collisionally excite ambient oxygen atoms. Clouds of enhanced red-line (630.0 nm) and green-line (557.7 nm) emissions were recorded with low-light-level imaging systems located at Arecibo, Puerto Rico. Comparison of the imager data with data from the Arecibo incoherent scatter radar shows that artificial airglow clouds are physically tied to the density cavities and to regions of enhanced electrostatic waves by the earth's magnetic field lines. At currently available power levels (around 80 MW effective radiated power), HF modification yields 10-30 percent fluctuations in density and 10-100 Rayleigh enhancements in airglow intensity.   Author

N91-18521# Pacific-Sierra Research Corp., Los Angeles, CA.
IONOSPHERIC HEATING WITH OBLIQUE HF WAVES
EDWARD C. FIELD, JR. and RON M. BLOOM   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 13 p (SEE N91-18506 10-46)   Oct. 1990
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    Calculations of ionospheric electron density perturbations and ground-level signal changes produce by intense oblique high frequency (HF) transmitters are presented. This analysis considers radio field focusing at caustics, the consequent joule-heating of the surrounding plasma, heat conduction, diffusion, and recombination processes: these being the effects of a powerful oblique 'modifying' wave. It neglects whatever plasma instabilities might occur. Then effects on a secondary 'test' wave that is propagated along the same path as the first are investigated. Calculations predict ground-level field-strength reductions of several dB in the test wave for modifying waves having ERP in the 85 to 90 dBW range. These field-strength changes are similar in sign, magnitude, and location to ones measured in Soviet experiments. The results are sensitive to the model ionosphere assumed, so future experiments should employ the widest possible range of frequencies and propagation conditions. An effective power of 90 dBW seems to be a sort of threshold that, if exceeded, results in substantial rather than small signal changes. The conclusions are based solely on joule-heating and subsequent defocusing of waves passing through caustic regions.   Author

N91-18522# TRW Defense and Space Systems Group, Redondo Beach, CA. Space and Technology Group.
MODELING OF HF PROPAGATION AND HEATING IN THE IONOSPHERE
TIMOTHY M. SMITH, MERIT M. SHOUCRI, and THOMAS M. WAGNER   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 12 p (SEE N91-18506 10-46)   Oct. 1990   Sponsored in part by RADC, Hanscom AFB, MA
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    A comprehensive numerical implementation of plasma geometric optics is being enhanced and adapted to the problem of self-consistent ionospheric propagation of high power, high frequency (HF) radar signals. Emphasis is placed on realistic and rigorous description of the propagating waves so that geometric and spectral characteristics of nonlinear ionospheric effects can be predicted in detail. When improvements are complete, a plasma geometric optics code will be used in conjunction with an ionospheric transport code to determine self-consistently the HF radiation field and quasilinear modifications of ionospheric plasma properties due to ohmic dissipation of the HF radiation. This allows

detailed study of nonlinear phenomena such as beam self-focusing, formation of large-scale density cavities and striations, and induced wave ducting. An overview of the theory underlying the modeling of radiation propagation and ohmic power deposition is given and current results from the plasma geometric optics code together with associated ionospheric power deposition profiles are presented. Detailed structure of ordinary and extraordinary mode caustics formed in a manner consistent with a realistic antenna pattern and birefringence upon entrance into the ionosphere are evident.   Author

N91-18523# Lowell Univ., MA. Center for Atmospheric Research.
MODELING AND DESIGN FOR A NEW IONOSPHERIC MODIFICATION EXPERIMENT
GARY S. SALES, IAN G. PLATT, D. MARK HAINES, YUMING HUANG, and JOHN L. HECKSCHER (Air Force Geophysics Lab., Hanscom AFB, MA.)   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 11 p (SEE N91-18506 10-46)   Oct. 1990
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    Plans are now underway to carry out new high frequency oblique ionospheric modification experiments with increased radiated power using a new high gain antenna system and a 1 MW transmitter. The output of this large transmitting system will approach 90 dBW. An important part of this program is to determine the existence of threshold for nonlinear effects by varying the transmitter output. For these experiments, a high frequency probe system, a low power oblique sounder, is introduced to be used along the same propagation path as the high power disturbing transmitter. The concept was first used by soviet researchers to insure that this diagnostic signal always passes through the modified region of the ionosphere. The HF probe system will use a low power (150 W) CW signal shifted by approximately 40 kHz from the frequency used by the high power system. The transmitter for the probe system will be at the same location as the multiple antennas to measure the vertical and azimuthal angle of arrival as well as the Doppler frequency shift of the arriving probe signal. The three antenna array will be in an 'L' configuration to measure the phase differences between the antennas. At the midpath point a vertical sounder will provide the ionospheric information necessary for the frequency management of the experiment. Real-time processing will permit the site operators to evaluate the performance of the system and make adjustments during the experiment. A special ray tracing computer will be used to provide real-time frequencies and elevation beam steering during the experiment. A description of the system and the analysis used in the design of the experiment are presented.   Author

N91-18524# Royal Aerospace Establishment, Farnborough (England). Applied Ionospheric Physics Div.
OBLIQUE HEATING OF THE AURORAL IONOSPHERE BY LF/MF TRANSMITTERS
PAUL S. CANNON, M. J. RYCROFT, and T. TURUNEN (Geophysical Observatory, Sodankyla, Finland)   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 10 p (SEE N91-18506 10-46)   Oct. 1990
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    The generation of extremely low frequency (ELF) signals due to oblique heating of the auroral ionosphere by signals from ELF modulated LF/MF radio transmitters is described. A part from signals of natural origin, timing signals (six pips which occurred on the hour) were received. The pips of frequency 1 kHz, duration 105 ms and field strength of approximately 0.1 pT exhibit a favored source location of approximately 150 km south-south-east of Sodankyla. The pips are shown to occur only when there is significant local magnetic activity and when the auroral electrojet is enhanced. The originating signals are demonstrated to be of Soviet origin and due to LF/MF broadcast transmitters several hundred kilometers away from the ELF source location. Various mechanisms which could account for a localized generation region far from the transmitters are discussed. The favored mechanism

involves in-phase heating due to two or more transmitters.

Author

N91-18525# Air Force Geophysics Lab., Hanscom AFB, MA. Ionospheric Physics Div.
ARTIFICIAL IONOSPHERIC MIRRORS (AIM). A: CONCEPT AND ISSUES
PAUL A. KOSSEY, JOHN L. HECKSCHER, RAMY A. SHANNY, and EDWARD C. FIELD, JR. (Pacific-Sierra Research Corp., Los Angeles, CA.) *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 11 p (SEE N91-18506 10-46) Oct. 1990
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Theoretical and experimental research on the creation, maintenance, and control of artificial layers of ionization in the 50 to 90 km altitude range. The focus of the research is to assess the potential for exploiting such so-called 'artificial ionospheric mirrors' (AIM) as scatterers of radio waves to distances well beyond line-of-sight. The AIM concept is discussed in terms of a specific technical approach, the use of ground-based, very high power, RF waves to breakdown the atmosphere. The concept is described in terms of RF requirements to produce breakdown, electron production and losses, resultant ionization densities, and their lifetimes In addition, issues concerning the RF reflection properties of artificial patches of ionization in the atmosphere are considered, and the potential of exploiting the AIM concept for practical applications is introduced. Author

N91-18526# ARCO Power Technologies, Inc., Washington, DC.
PHYSICS OF RF BREAKDOWN FOR AIM APPLICATIONS
K. PAPADOPOULOS, TOM WALLACE, P. VITELLO, RAMY A. SHANNY, K. TSANG, and PIERRE LALLEMENT *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 13 p (SEE N91-18506 10-46) Oct. 1990
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Both a simple test particle approach and a complete kinetic calculation are used to predict the net electron production rate of an RF signal under conditions appropriate for an artificial ionospheric mirror (AIM) system. These predictions are compared with each other and with experimental data and are found to be in good agreement. The test particle based formula is incorporated into a model which calculates the one-dimensional vertical electron density profile created by a ground-based RF heater, and the performance of a baseline heater design is investigated, providing the foundation for the specification of a baseline AIM heater system. Author

N91-18527# Los Alamos National Lab., NM.
CROSSED-MICROWAVE-BEAM AIR IONIZATION LABORATORY EXPERIMENTS
W. T. ARMSTRONG, R. KARL, M. KELLY, R. ROUSSEL-DUPRE, M. BUCHWALD, C. D. SUTHERLAND, J. ZINN, R. ALVAREZ, P. BOLTON, G. SIEGER (Lawrence Livermore National Lab., CA.) et al. *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 13 p (SEE N91-18506 10-46) Oct. 1990 Sponsored in part by DOE and AF
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Detailed laboratory measurements and theoretical modeling relevant to the production, geometrical description and decay of microwave-induced air ionization for an upper atmospheric RF reflecting layer are reported. It is found that breakdown thresholds are adequately predicted by fluid models and simplified scaling models with refinement by kinetic models being important at lower pressures. Repetitive pulse sustainment was demonstrated to be straightforward with a commensurate reduction in sustainment power levels. However, establishment of a convenient breakdown geometry for specular RF reflections, other than a single layer in a crossed beam geometry, was not obtained. Detailed density decay measurements qualitatively support simple estimates of decay times and indicate ionization dwell times of tens of

milliseconds. Chemistry studies indicate three N(x)O(x) species will be produced. However, large N(x)O(x) production does not appear as a concern for relatively small, low repetition rate, proof of concept atmospheric experiments. A realizable proof of concept experiment is found with simple optimization criteria which is corroborated by laboratory measurements and theoretical simulations. Tail-erosion appears as a potentially severe limitation in atmospheric experiments beyond the proof of concept level, suggesting use of multiple-beam systems. Author

N91-18528*# Polytechnic Univ., Farmingdale, NY.
ON THE FEASIBILITY OF MICROWAVE PRODUCED BRAGG REFLECTOR: EXAMINED BY THE CHAMBER EXPERIMENT
S. P. KUO, Y. S. ZHANG, PAUL A. KOSSEY, and ROBERT J. BARKER (Air Force Office of Scientific Research, Bolling AFB, Washington, DC.) *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 12 p (SEE N91-18506 10-46) Oct. 1990
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A set of parallel plasma layers is generated by two intersecting microwave pulses in a chamber containing dry air at a pressure comparable to the upper atmosphere. The dependencies of breakdown conditions on the pressure and pulse length are examined. The results are shown to be consistent with the appearance of tail erosion of microwave pulse caused by air breakdown. A Bragg scattering experiment using the plasma layers as a Bragg reflector is then performed. Both time domain and frequency domain measurements of wave scattering are conducted. The results are found to agree very well with the theory. Moreover, the time domain measurement of wave scattering provides an unambiguous way for determining the temporal evolution of electron density during the first 100 microsec period. A Langmuir double probe is also used to determine the decay rate of electron density during a later time interval (1 to 1.1 ms). The propagation of high power microwave pulses through the air is also studied experimentally. The mechanism responsible for two different degrees of tail erosion were identified. The optimum amplitude of a 1.1 microsec pulse for maximum energy transfer through the air was determined. Author

N91-18529# Stanford Univ., CA. Space, Telecommunications, and Radioscience Lab.
OVERVIEW OF IONOSPHERIC MODIFICATION FROM SPACE PLATFORMS Abstract Only
PETER M. BANKS *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 2 p (SEE N91-18506 10-46) Oct. 1990
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Spaceborne, nonelectromagnetic methods of modifying the E- and F-regions of the terrestrial ionosphere are discussed. Of these methods, the most well-understood is the direct injection of chemical vapors into the ambient medium. The first injection of barium clouds into the upper atmosphere over two decades ago has led to evolution of understanding of complex electrodynamic processes acting in the ionosphere and spawned extensive studies of small-scale plasma instabilities. Modification to the ionosphere can last for hours from such injections. Other vapors have also been released, including water vapor, SF6, and other more noxious gases, in successful efforts to alter the chemistry of the ionosphere. In another direction, injections of high amu gases from orbiting spacecraft have been made in attempts to understand the non-classical ionization processes involved in the critical ionization velocity (CIV) concept. The results seem to indicate that for CIV to act in space, large quantities of injected gas are required to achieve a minimum interaction volume density. However, in these and other experiments, it was found that the potential CIV effects are supplemented by a variety of associated classical processes also acting for these same gases. Direct modification of the ionosphere via energetic electron beams has also been undertaken from rocket and satellite platforms. Results indicate that the process of electron energy deposition is much more complex than previously thought as a consequence of the need to take into account charging of the launching platform, the retarding effects of substantial electric

fields near the beam, and atmospheric scattering in the ionosphere. Other forms of ionospheric modification via ion beams, energetic neutral particle beams, x-ray sources, and MeV particle beams have also been proposed, but several of these remain to be consummated with experiments. Only the abstract and a discussion are presented. **Author**

N91-18530# Air Force Geophysics Lab., Hanscom AFB, MA. Space Physics Div.
PLASMA DENSITY MODIFICATIONS BY MEANS OF PULSED BEAM CIV IN THE IONOSPHERE
SHU T. LAI, WILLIAM J. MCNEIL (RADEX, Inc., Bedford, MA.), and EDMOND MURAD *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 6 p (SEE N91-18506 10-46) Oct. 1990
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Alven's critical ionization velocity (CIV) discharge gives rise to rapid increase in electron density. The existence of CIV has been proven in the laboratory. If CIV occurs in space, there would be important consequences. Not only would electromagnetic wave propagation be affected by the enhanced plasma density, but there would also be important implications in spacecraft contamination. In attempts to prove CIV in space, many researchers used the barium shaped charge explosion method. The results have been mostly negative with two exceptions. A modified CIV space experiment by means of a multiple pulse beam (MPB) of neutral atoms is proposed. The 'particle-in-cell' method is used to simulate CIV in a MPB under ionospheric conditions. A single or MPB neutral with seed ionization develops the modified two-stream instability which energizes the electrons. When the electrons become hot enough, they ionize the neutrals in the beam. Numerical simulation results of single and multiple pulse cases are compared, revealing the enhanced ionization for the MPB case. **Author**

N91-18531*# Stanford Univ., CA. Space, Telecommunications, and Radioscience Lab.
PLASMA DENSITY ENHANCEMENTS CREATED BY THE IONIZATION OF THE EARTH'S UPPER ATMOSPHERE BY ARTIFICIAL ELECTRON BEAMS
TORSTEN NEUBERT and PETER M. BANKS *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 6 p (SEE N91-18506 10-46) Oct. 1990
(Contract NAS8-35350; NAGW-1566; NAG5-607; F19628-89-K-0040)
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Analytical calculations and experimental observations relating to the interaction with the Earth's upper atmosphere of electron beams emitted from low altitude spacecraft are presented. The problem is described by two coupled nonlinear differential equations in the up-going (along a magnetic field line) and down-going differential energy flux. The equations are solved numerically, using the MSIS atmospheric model and the IRI ionospheric model. The results form the model compare well with recent observations from the CHARGE 2 sounding rocket experiment. Two aspects of the beam-neutral atmosphere interaction are discussed. First, the limits on the electron beam current that can be emitted from a spacecraft without substantial spacecraft charging are investigated. This is important because the charging of the spacecraft to positive potentials limits the current and the escape energy of the beam electrons and thereby limits the ionization of the neutral atmosphere. As an example, we find from CHARGE 2 observations and from the model calculations that below about 180 km, secondary electrons generated through the ionization of the neutral atmosphere by 1 to 10 keV electron beams from sounding rockets, completely balance the beam current, thereby allowing the emission of very high beam currents. Second, the amount of plasma production in the beam-streak is discussed. Results are shown for selected values of the beam energy, spacecraft velocity, and spacecraft altitude. **Author**

N91-18532*# Stanford Univ., CA. Space, Telecommunications, and Radioscience Lab.
IONOSPHERIC MODIFICATION USING RELATIVISTIC ELECTRON BEAMS
PETER M. BANKS, ANTHONY C. FRASER-SMITH, and B. E. GILCHRIST *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 18 p (SEE N91-18506 10-46) Oct. 1990
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The recent development of comparatively small electron linear accelerators (linacs) now makes possible a new class of ionospheric modification experiments using beams of relativistic electrons. These experiments can potentially provide much new information about the interactions of natural relativistic electrons with other particles in the upper atmosphere, and it may also make possible new forms of ionization structures extending down from the lower ionosphere into the largely un-ionized upper atmosphere. The consequences of firing a pulsed 1 A, 5 Mev electron beam downwards into the upper atmosphere are investigated. If a small pitch angle with respect to the ambient geomagnetic field is selected, the beam produces a narrow column of substantial ionization extending down from the source altitude to altitudes of approximately 40 to 45 km. This column is immediately polarized by the natural middle atmosphere fair weather electric field and an increasingly large potential difference is established between the column and the surrounding atmosphere. In the regions between 40 to 60 km, this potential can amount to many tens of kilovolts and the associated electric field can be greater than the field required for breakdown and discharge. Under these conditions, it may be possible to initiate lightning discharges along the initial ionization channel. Filamentation may also occur at the lower end to drive further currents in the partially ionized gases of the stratosphere. Such discharges would derive their energy from the earth-ionosphere electrical system and would be sustained until plasma depletion and/or electric field reduction brought the discharge under control. It is likely that this artificially-triggered lightning would produce measurable low-frequency radiation. **Author**

N91-18533# Centre National de la Recherche Scientifique, Orleans (France). Lab. de Physique et Chimie de l'Environnement.
ELECTRON GYRO-HARMONICS GENERATED BY SPACEBORNE ARTIFICIAL ELECTRON BEAM
D. MOURENAS and C. BEGHIN *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 15 p (SEE N91-18506 10-46) Oct. 1990
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Results on high-frequency waves generated by the phenomena induced by charged particle beam (PICPAB) experiment flown on the Spacelab-1 shuttle mission are presented. An interpretation for the wave generation mechanism associated with such an experiment is proposed. This experiment comprised both electron and ion accelerators of a few keV installed on board the space shuttle and associated with nearby diagnostic instruments such as plasma and wave analyzers. First, the observations are compared to previous results obtained in similar conditions and they are discussed in the frame of various beam-plasma interaction models. The main features are electron cyclotron harmonics which appear modulated in amplitude with maxima occurring near the harmonics of the upper hybrid resonance. An interaction between the return flux electrons and the ambient plasma is thought to have generated the first cyclotron harmonics close to f (sub uh) and, after nonlinear saturation and trapping processes, the entire spectrum. By means of a nonlinear single-wave model, developed analytically and solved numerically, most of the experimental features are finally recovered. **Author**

N91-18534# Norwegian Defence Research Establishment, Kjeller.
VEHICLE CHARGING IN LOW DENSITY PLASMAS
B. N. MAEHLUM and J. TROIM   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 11 p (SEE N91-18506 10-46) Oct. 1990
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Studies of electrical charging of space vehicles have been reported in a number of papers in the last ten years. These studies are based on charging due to onboard electron and ion accelerators as well as charging due to thermal and energetic electrically charge particles impinging on the surface of the vehicle. In spite of this significant effort made in the field, both theoretically and experimentally, the vehicle charging problem is far from being completely understood. Part of the problem relates to the effects of the plasma disturbances created by the beam. Several attempts have been made with a varying degree of success to simulate space plasma processes in large plasma chambers. The celebrated studies in the large chamber at Johnson Space Center show that the plasma may be very disturbed in the presence of a beam of fast electrons by a beam plasma discharge (BDP) process. This process was expected also to explain phenomena observed in the upper atmosphere and possible various aspects of the vehicle charging. However, there are still some doubts as to whether the BDP really occurs in space, and the significance of the laboratory simulation experiments conducted in the past remains obscure. A number of high vehicle chargings generated by electron beams is presented, and how this charging depends on the characteristics of the plasma environment is discussed. Also, some results from a simulation study of these problems conducted in the NDRE plasma chamber are reviewed.   Author

N91-18535*# Massachusetts Inst. of Tech., Cambridge. Plasma Fusion Center.
PLANNING FOR COORDINATED SPACE AND GROUND-BASED IONOSPHERIC MODIFICATION EXPERIMENTS
M. C. LEE, WILLIAM J. BURKE, HERBERT C. CARLSON, JOHN L. HECKSCHER, PAUL A. KOSSEY, E. J. WEBER, and S. P. KUO (Polytechnic Univ., Farmingdale, NY.)   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 8 p (SEE N91-18506 10-46) Oct. 1990
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The planning and conduction of coordinated space and ground-based ionospheric modification experiments are discussed. The purpose of these experiments is to discuss: (1) the nonlinear VLF wave interaction with the ionospheric plasmas; and (2) the nonlinear propagation of VLF waves in the HF-modified ionosphere. It is expected that the HF-induced ionospheric density striations can render the nonlinear mode conversion of VLF waved into lower hybrid waves. Lower hybrid waves can also be excited parametrically by the VLF waves in the absence of the density striations if the VLF waves are intense enough. Laboratory experiments are planned for crosschecking the results obtained from the field experiments.   Author

N91-18536# Centre National de la Recherche Scientifique, Orleans (France).   Lab de Physique et Chimie de l'Environnement.
WAVE-PARTICLE INTERACTIONS ASSOCIATED WITH VLF TRANSMITTERS
FRANCOIS LEFEUVRE   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 11 p (SEE N91-18506 10-46) Oct. 1990
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Wave-particle and wave-wave interactions associated with VLF ground-based transmitters are reviewed. The topics covered include: particle precipitation, amplification and triggering of new emissions, and excitation of resonant frequencies.   Author

N91-18537# Cranfield Inst. of Tech., Bedford (England). Coll. of Aeronautics.
CAUSES AND EFFECTS OF INTERACTIONS BETWEEN ENERGETIC ELECTRONS AND WHISTLER-MODE WAVES IN THE COUPLED MAGNETOSPHERE-IONOSPHERE-ATMOSPHERE SYSTEM
M. J. RYCROFT   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 9 p (SEE N91-18506 10-46) Oct. 1990
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The physical mechanism of a cyclotron resonance interaction between trapped energetic electrons and whistler-mode waves in the magnetosphere is discussed. Not only do the electrons have their pitch angles reduced in this interaction, so that they may be precipitated into the upper atmosphere, but also the waves can be amplified. Such a flux of precipitating electrons can, either by direct ionization or via bremsstrahlung radiation, cause a pimple to be produced on the bottom of the ionosphere. That can significantly modify the amplitude and/or phase of very low frequency radio signals propagating in the Earth-ionosphere waveguide. Various experimental observations that demonstrate the reality of such effects are presented.   Author

N91-18538# Air Force Geophysics Lab., Hanscom AFB, MA.
IONOSPHERIC HEATING FOR RADIATION BELT CONTROL
WILLIAM J. BURKE and ELENA VILLALON (Northeastern Univ., Boston, MA.)   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 7 p (SEE N91-18506 10-46) Oct. 1990
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Pitch-angle scattering interactions of electromagnetic waves in the ELF/VLF bands with trapped electrons describe the dynamics of the freshly filled radiation belts flux tubes. The natural existence of a 'slot' region with electron fluxes below the Kennel-Petschek limit requires non-local wave sources. A set of planned, active experiments is described in which VLF radiation is injected from ground and space band transmitters in conjunction with the Combined Release and Radiation Effects Satellite in the radiation belts. These experiments can measure the intensity if waves driving pitch-angle diffusion and the electron energies in gyroresonance with the waves.   Author

N91-18539# Stanford Univ., CA. STAR Lab.
MODIFICATION OF THE LOWER IONOSPHERE IN LIGHTNING-INDUCED ELECTRON PRECIPITATION EVENTS AND THROUGH VLF HEATING
UMRAN S. INAN   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 12 p (SEE N91-18506 10-46) Oct. 1990
(Contract N00014-82-K-0489; NSF DPP-86-11623; NSF ATM-88-04273)
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Different mechanisms by which VLF waves from ground based sources modify the nighttime lower ionosphere (D-region) are discussed. One process by which the ionosphere is regularly disturbed involves the precipitation of short bursts of energetic electrons out of the radiation belts in gyroresonant interactions with whistler waves launched by lightning discharges. A second process involves direct upward coupling of lightning electric fields to the lower ionosphere leading to intense electric fields and ionization enhancements. A third process is the heating of the lower ionosphere by upgoing VLF waves from ground based transmitters and lightning, leading to up to 100 percent increase in electron temperature at 80 to 90 km altitudes.   Author

N91-18540*# Naval Research Lab., Washington, DC. Space Plasma Branch.
IONOSPHERIC CHEMICAL RELEASES
PAUL A. BERNHARDT and W. A. SCALES *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 10 p (SEE N91-18506 10-46) Oct. 1990 Sponsored by NASA, Washington
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Ionospheric plasma density irregularities can be produced by chemical releases into the upper atmosphere. F-region plasma modification occurs by: (1) chemically enhancing the electron number density; (2) chemically reducing the electron population; or (3) physically convecting the plasma from one region to another. The three processes (production, loss, and transport) determine the effectiveness of ionospheric chemical releases in subtle and surprising ways. Initially, a chemical release produces a localized change in plasma density. Subsequent processes, however, can lead to enhanced transport in chemically modified regions. Ionospheric modifications by chemical releases excites artificial enhancements in airglow intensities by exothermic chemical reactions between the newly created plasma species. Numerical models were developed to describe the creation and evolution of large scale density irregularities and airglow clouds generated by artificial means. Experimental data compares favorably with theses models. It was found that chemical releases produce transient, large amplitude perturbations in electron density which can evolve into fine scale irregularities via nonlinear transport properties.
Author

N91-18541# Commissariat a l'Energie Atomique, Bruyeres-le-Chatel (France). Lab. de Detection et de Geophysique.
OBSERVATIONS OF PERTURBATIONS PRODUCED BY POWERFUL CHEMICAL EXPLOSIONS IN THE IONOSPHERE [OBSERVATIONS DE PERTURBATIONS PRODUITES PAR DES EXPLOSIONS CHIMIQUES PUISSANTES DANS L'IONOSPHERE]
ELISABETH BLANC and ABRAM R. JACOBSON (Los Alamos National Lab., NM.) *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 12 p (SEE N91-18506 10-46) Oct. 1990 In FRENCH; ENGLISH summary
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Observations by HF ionospheric sounding of disturbances produced by powerful chemical explosions (several KT) are described. These experiments were performed at distances of about 30 to 40 km from the explosion point. Because of the amplification due to the atmospheric density decrease with increasing altitude, the acoustic waves from such explosions are characterized by shock waves features when they reach the ionosphere. The development of the disturbance was studied from the lower E region up to the F2 region by using 8 sounding frequencies. It is shown that a blanketing sporadic E layer undergoes small scale fluctuations and becomes semi-transparent after the passage of the disturbance. Several wave fronts with different properties are followed to the F1 region. In the lower E region, the wave induced stratifications on which the radio waves are partially reflected. The echoes totally reflected in the E region undergo an amplitude modulation with a period of about 2 seconds, persisting about 30 minutes. The variations of the total reflection height and of the Doppler frequency shift are most noticeable in the F1 region. The wave loses its shock wave feature in the F2 region and the disturbance signature is then that of a pseudo-sinusoidal wave with a wave length of several tens of kilometers.
Author

N91-18542# Naval Research Lab., Washington, DC. Space Plasma Branch.
LABORATORY SIMULATION OF HIGH-ALTITUDE DISRUPTIVE EFFECTS
BARRETT H. RIPIN, J. GRUN, C. K. MANKA, J. A. STAMPER, E. A. MCLEAN, J. RESNICK, R. BURRIS, J. CRAWFORD, J. D. HUBA, and G. GANGULI *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 12 p (SEE N91-18506 10-46) Oct. 1990 Sponsored in part by ONR and DNA
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Disturbed ionospheric and space conditions are simulated and studied with laser-produced plasmas. Intense laser pulses produce plasma energy densities, comparable to those occurring in nuclear detonations. The expansion of these plasmas through a background ambient magnetized plasma simulate high-altitude nuclear explosion effects, as well as supernova shock and other energetic space plasma conditions. Some effects, such as blast-waves and plasma instabilities leading to non-uniform and disturbed space environments that can affect space-based communications and sensor systems, are discussed. The laser experiment is useful for investigation of mechanisms accompanying less energetic active space experiments also, such as chemical releases and particle beam injections.
Author

N91-18543# Hamburg Univ. (Germany, F.R.). Meteorological Inst.
MODIFICATION OF TROPOSPHERIC PROPAGATION CONDITIONS
H. JESKE *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 11 p (SEE N91-18506 10-46) Oct. 1990
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The propagation mechanisms of ultra-short radio waves and microwaves are governed by the composition of the troposphere and their space-time structure of the refractive index field. Useful effects are obtained by chaff clouds concerning communication channels, masking of targets or meteorological research. A wide field of posibilities seems to be within the scope of weather modification experiments. But due to the huge variability of cloud and rain parameters only minor propagation changes are to be expected. A successful application of remotely determining atmospheric temperature profiles is the modulation of the atmospheric refractive index field by sound waves and tracking the acoustic wave fronts by a Doppler radar (Radio Acoustic Sounding System). Oil and alga slicks on water surfaces may change the reflection/scattering and emission properties for radar waves. They also suppress evaporation which may influence the development of tropical storms but just so evaporation duct propagation of microwaves.
Author

N91-18544# Forschungsinstitut fuer Hochfrequenzphysik, Werthhoven (Germany, F.R.).
IONOSPHERIC MODIFICATION AND IMAGINABLE SYSTEM APPLICATIONS
H. J. ALBRECHT *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 18 p (SEE N91-18506 10-46) Oct. 1990
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The nowadays predominant areas of imaginable system applications of anthropogenic modifications applied to the ionosphere are reviewed. Relevant conditions are indicated, such as the natural systems environment, areas of possible modifications, and aspects of compatibility and interference. Resultant criteria of applications to systems and required support measures are also discussed.
Author

N91-18545# ARCO Power Technologies, Inc., Washington, DC.
ARTIFICIAL IONOSPHERIC MIRRORS FOR RADAR APPLICATIONS
ROBERT D. SHORT, TOM WALLACE, CLAYTON V. STEWART, PIERRE LALLEMENT, and PETER KOERT   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 12 p (SEE N91-18506 10-46) Oct. 1990
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Recognition of performance limitations associated with traditional skywave over-the-horizon (OTH) HF radars has led a number of investigators to propose the creation of an Artificial Ionospheric Mirror (AIM) in the upper atmosphere, in order to reflect ground-based radar signals for OTH surveillance. The AIM is produced by beaming sufficient electromagnetic power to the lower ionosphere (around 70 km) to enhance the in situ ionization level to 10(exp 7) to 10(exp 8) electrons/cu cm, thereby providing an ionized layer capable of reflecting radar frequencies of 5 to 90 MHz. A baseline AIM system concept and an associated performance evaluation are presented, based upon the relevant ionization and propagation physics and in the context of air surveillance for the cruise missile threat. Results of the subject indicate that a system using this concept would both complement and enhance the performance of the existing skywave OTH radars.   Author

N91-18546# ARCO Power Technologies, Inc., Washington, DC.
ELECTROJET MODULATION ELF COMMUNICATIONS
K. PAPADOPOULOS (Maryland Univ., College Park.), RAMY A. SHANNY, L. SUSMAN, M. MACHINA, and P. STAMBOULIS   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 9 p (SEE N91-18506 10-46) Oct. 1990 Sponsored in part by DARPA and ONR
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The causes fir the inefficient conversion of HF to ELF waves by ionospheric heating observed in recent experiments are examined. It is found that for the low frequency HF range 2.5 to 4 MHz used in the present experiments the modified conductance saturates during a fraction of the HF irradiation cycle. As a result most of the HF energy is transferred to processes that do not affect the conductance significantly. This was confirmed experimentally. Techniques relying on fast HF antenna sweeping by which the efficiency can increase by more than two orders of magnitude are presented.   Author

N91-18547# Pennsylvania State Univ., University Park. Communications and Space Sciences Lab.
INVESTIGATION OF THE POLAR ELECTROJET CURRENT SYSTEM USING RADIO WAVE HEATING FROM A GROUND-BASED FACILITY
D. H. WERNER, A. J. FERRARO, and RICHARD G. BRANDT (O''ice of Naval Research, Arlington, VA.)   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 13 p (SEE N91-18506 10-46) Oct. 1990
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The High Power Auroral Stimulation (HIPAS) heating facility was used to modulate D region ionospheric currents at high latitudes, producing very low frequency (VLF) radio wave emission. The behavior of these ionospheric currents can be deduced from a comprehensive study of the VLF signals received at a local field site. The relationship is examined between the VLF magnetic field strength measured on the ground and the intensity of an overhead electrojet current for the purpose of enhancing communications. The mapping of the polar electrojet current is investigated. A finite difference solution to the electrojet mapping problem is presented. The obtained results are also presented and discussed. A promising new diagnostic technique for studying ionospheric D region currents was implemented. This technique involves high frequency beam steering for localized VLF generation in the mapped region below electrojets. Beam steering was used to estimate the strength and current distribution of the polar

electrojet, and for charting the movements of overhead currents.
                                                                     Author

N91-18548# Rice Univ., Houston, TX. Dept. of Space Physics and Astronomy.
THE GENERATION OF ULF WAVES IN THE IONOSPHERE
S. T. NOBLE and WILLIAM E. GORDON   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 4 p (SEE N91-18506 10-46) Oct. 1990
(AGARD-CP-485) Copyright Avail: NTIS HC/MF A21; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

One explanation for the generation of HF sidebands during two-frequency heating experiments is based on the interaction between the beat frequency wave and the HF waves. To test this, simultaneous HF sideband and ULF measurements were made. The ULF measurement technique and recent findings are discussed. At the core of the ULF receiving system are three mutually perpendicular magnetometer sensors. For most studies, only the band 0.5 to 20 Hz is utilized. Although based upon a limited data set, underdense heating has yielded no signs of ULF production in the ionosphere. Although HF swelling near the reflection height can amplify the fields significantly during overdense heating, no signs of ULF were observed at these times either.
                                                                     Author

N91-18549# Los Alamos National Lab., NM. Atmospheric Sciences Div.
HF PROPAGATION THROUGH ACTIVELY MODIFIED IONOSPHERES: MODELLING AND EXPERIMENTAL RESULTS
PAUL E. ARGO, T. JOSEPH FITZGERALD, JOHN H. WOLCOTT, and DAVID J. SIMONS   *In* AGARD, Ionospheric Modification and its Potential to Enhance or Degrade the Performance of Military Systems 10 p (SEE N91-18506 10-46) Oct. 1990 Sponsored in part by DOE
(AGARD-CP-485) Copyright Avail: NTIS HC/MF A21; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A computer modelling capability was developed for predicting the effects of localized electron density perturbations created by ionospheric chemical releases upon oblique, one-hop HF propagation paths. A three-dimensional description of the depleted or enhanced ionization, including formation, evolution, and drift are presented. The code uses a homing ray tracing technique to calculate the energy propagation paths through the modified ionosphere and hence can predict multipath effects.   Author

N91-26151*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MEASUREMENT OF ATMOSPHERIC TURBULENCE
HAROLD N. MURROW   *In* AGARD, Manual on the Flight of Flexible Aircraft in Turbulence p 1-30 (SEE N91-26150 18-08) May 1991
(AGARD-AG-317) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive   CSCL 04/1

The material contained is primarily a compilation of information that has already been published. The attached reference list should be adequate for clarifying points to any detail desired. The purpose is to provide a description of the methodology required for measuring atmospheric turbulence in the form of true gust velocity. The content will include instrumentation requirements and selections used, flight assessments of the measurement system, some data reduction considerations, and finally some typical data obtained.   Author

N91-30364# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
OPTIMUM SPACE, TIME, AND FREQUENCY SAMPLING OF THE IONOSPHERE WITH ADVANCED DIGITAL IONOSONDES
ADOLF K. PAUL and DAVID B. SAILORS *In* AGARD, Use or Reduction of Propagation and Noise Effects in Distributed Military Systems 8 p (SEE N91-30362 22-32) 1990
(AGARD-CP-486) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Ionosondes were always an important tool for the observation of the ionosphere. The traditional analog instruments were only capable of measuring the travel time or virtual height as a function of frequency with limited accuracy. Advanced digital radiosondes are now capable of recording additional information, such as the radio phase and the amplitude of each echo. If the echoes are recorded at several receiving antennas, the change of phase with antenna location permits a highly accurate estimate of the angle of arrival or the apparent location of the reflection point. Repeating the transmission of a given frequency a short time later yields the Doppler frequency as a function of the radio frequency. Author

N91-31172# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany, F.R.). Inst. for Atmospheric Physics.
A DOCUMENTATION OF VERTICAL AND HORIZONTAL AIRCRAFT SOUNDINGS OF ICING RELEVANT CLOUDPHYSICAL PARAMETERS
H.-E. HOFFMANN *In* AGARD, Low Temperature Environment Operations of Turboengines (Design and User's Problems) 14 p (SEE N91-31144 23-07) 1990
(AGARD-CP-480) Copyright Avail: NTIS HC/MF A16; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

In a homogeneous st-cloud (in a high pressure area) the total water content (TWC) is nearly linearly increasing with increasing distance from the cloud base and obtains its largest value near the top (0.39 respectively 0.49 g/cu m). The median volume diameter (MVD) is nearly remaining constant and has predominantly small values (between 15 and 23 microns). The phase of particles in all st-clouds, evaluated up to now, was fluid. Such a regularity was not found in any of the other types of inhomogeneous clouds of a warm front. Apart from temperature (T), which is decreasing nearly linearly in these clouds too, the course of TWC and MVD is very irregular. Both the parameters can have several maxima at different distances from the base. The maxima values of TWC can be up to 0.45 g/cu m and those of the MVD up to 460 microns. The phase of the particles could vary between fluid and solid. Not only the vertical structures, but also the horizontal structures show great differences in the particle distributions. In the clouds of a high pressure area more than 90 percent of the particles had diameters between 2 and 32 microns. Author

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METEOROLOGY AND CLIMATOLOGY

Includes weather forecasting and modification.

N90-15044# Technische Univ., Brunswick (Germany, F.R.). Inst. of Guidance and Control.
WIND SHEAR MODELS FOR AIRCRAFT HAZARD INVESTIGATION
MANFRED SWOLINSKY *In* AGARD, Flight in Adverse Environmental Conditions 17 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Wind shear hazard investigations, flight simulation for pilot training as well as design, development, and testing of flight control systems require suitable wind models. Based on flight test data, airline flight data and meteorological tower measurements, engineering models for dangerous wind shear situations were developed in the frame of different wind shear research projects.

Derived from simplified fluid dynamic concepts the engineering models for downburst, frontal wind shear, and low level jet meet the requirements for real-time flight simulation. The comparison of the wind models with measured wind data show good accordance. For the analyses of simulated landing approaches in wind shear conditions a hazard definition is given by means of aircraft energy height deficit, respectively the required energy supply for landing approach on nominal glide slope and constant air speed. Author

N90-15045*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ANALYSIS OF SEVERE ATMOSPHERIC DISTURBANCES FROM AIRLINE FLIGHT RECORDS
R. C. WINGROVE, R. E. BACH, JR., and T. A. SCHULTZ *In* AGARD, Flight in Adverse Environmental Conditions 7 p (SEE N90-15041 07-01) Sep. 1989 Previously announced as N89-25977
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 04/2

Advanced methods were developed to determine time varying winds and turbulence from digital flight data recorders carried aboard modern airliners. Analysis of several cases involving severe clear air turbulence encounters at cruise altitudes has shown that the aircraft encountered vortex arrays generated by destabilized wind shear layers above mountains or thunderstorms. A model was developed to identify the strength, size, and spacing of vortex arrays. This model is used to study the effects of severe wind hazards on operational safety for different types of aircraft. It is demonstrated that small remotely piloted vehicles and executive aircraft exhibit more violent behavior than do large airliners during encounters with high-altitude vortices. Analysis of digital flight data from the accident at Dallas/Ft. Worth in 1985 indicates that the aircraft encountered a microburst with rapidly changing winds embedded in a strong outflow near the ground. A multiple-vortex-ring model was developed to represent the microburst wind pattern. This model can be used in flight simulators to better understand the control problems in severe microburst encounters. Author

N90-15046# Aerodata Flugmesstechnik G.m.b.H., Brunswick (Germany, F.R.).
SYSTEMS FOR AIRBORNE WIND AND TURBULENCE MEASUREMENT
PETER VOERSMANN *In* AGARD, Flight in Adverse Environmental Conditions 12 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

For many years aircraft were equipped for research in wind and turbulence measurements. Very often the system installation consisted of sensors and recording hardware which was spread all over the aircraft. A modern system solution, where all components are integrated in an external pod for aircraft and helicopter applications is described. After a brief description of the principles for airborne wind measurements, advantages and disadvantages for different system solutions will be discussed. The presented pod solution includes a software and hardware concept, which allows to determine all three components of the wind vector in real time on-board the aircraft. Flight test results are presented, which demonstrate the achievable accuracies for the horizontal and especially the vertical wind component. This includes the effects of dynamic aircraft maneuvers. Finally an outlook is given, what kind of precision can be achieved in the future, when satellite navigation systems will be available on a 24 hour basis. Author

N90-15049# Royal Aircraft Establishment, Bedford (England).
CLASSIFICATION OF WINDSHEAR SEVERITY
A. A. WOODFIELD *In* AGARD, Flight in Adverse Environmental Conditions 13 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A simplified model of aircraft and pilot response to wind shear is used to identify the potential height loss during wind shear encounters. This potential height loss is directly related to the possibility of unscheduled ground contact and is proposed as a primary indicator of wind shear severity. Key factors of wind shear

strength and aircraft performance which influence the potential height loss are identified using this simple model. This helps to provide a better understanding of the complex interactions between the pilot/aircraft and the wind shear. Various practical severity factors are examined in relation to both the potential height loss and the probability of encountering various shears. It is shown that severity factors based on pseudo-energy-rate have fundamental problems in resolving the conflict between false alarms and providing timely information to a pilot when used with current sensors on aircraft or sensors that scan and probe (such as Doppler radar or laser). An improved severity factor based on the potential height loss analysis is shown to have a low risk of false or missed alarms, and appropriate threshold values are easily identified for all aircraft types. This improved severity factor requires probe and scan sensors.   Author

N90-15052#   National Aeronautical Establishment, Ottawa (Ontario). Flight Research Lab.
ADVERSE WEATHER OPERATIONS DURING THE CANADIAN ATLANTIC STORMS PROGRAM
J. I. MACPHERSON and G. A. ISAAC (Atmospheric Environment Service, Downsview, Ontario)   *In* AGARD, Flight in Adverse Environmental Conditions 13 p (SEE N90-15041 07-01)   Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    For cooperative research programs with the Atmospheric Environment Service of Canada, the NRC Twin Otter Atmospheric Research Aircraft was instrumented to measure the motion and thermal structure of the atmosphere and the microphysics of cloud and precipitation. In 1986 the aircraft was flown in the Canadian Atlantic Storms Program to investigate large east-coast storms that typically account for the bulk of the winter-time precipitation in the Maritime provinces, and cause havoc for airborne and surface transportation. A variety of adverse flight conditions were experienced including heavy snow contributing to limited IFR alternates, airframe icing, wind shear and crosswinds on landing. Examples are presented of these incidents analyzed from both a flight research and meteorological perspective using aircraft recorded data. For this project, additional specially-designed deicing boots were installed on the Twin Otter's vertical tail and the wing and landing gear struts. The performance of the enhanced aircraft deicing system will be discussed using data from three deicing encounters.   Author

N90-15059#   Technische Univ., Hanover (Germany, F.R.). Inst. fuer Meteorologie und Klimatologie.
MEASUREMENTS OF HORIZONTAL VISIBILITY IN THE LOWEST 300 M OVER NORTHERN GERMANY
R. ROTH and A. R. SIEMER   *In* AGARD, Flight in Adverse Environmental Conditions 10 p (SEE N90-15041 07-01)   Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    In order to establish a climatology of the vertical structure of horizontal visibility in the lowlands of Northern Germany continuous measurements were carried out on radio tower at six different levels up to 300 m above the ground for two and a half year between 1982 and 1985. Ten minute mean values of horizontal visibility, temperature, and dewpoint at each level were recorded automatically as well as the cloud ceiling up to 1500 m above ground. For selected weather situations an additional high resolution vertical sounding system supplied more detailed data on the vertical structure. A statistical analysis of the data was performed showing that there is a relationship between typical patterns of the diurnal variation of the vertical visibility profile and the large scale weather situations in Middle Europe classified according to schemes well established in meteorology. Special cases were examined to study the variation of the vertical visibility profile during fog formation, during the passage of atmospheric fronts and in cases of rapid visibility increases and decreases.
                                          Author

N90-21920#   Defence Research Establishment Valcartier (Quebec).
INTERPRETING METEOROLOGICAL DATA REPORTS FOR LOWTRAN NAVY AEROSOL MODEL EXTINCTION CALCULATIONS
A. J. BEAULIEU   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 9 p (SEE N90-21907 15-32)   Mar. 1990
(AGARD-CP-454) Copyright Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    To evaluate the aerosol extinction, one of the most advanced models is the LOWTRAN 6 Navy Aerosol model. However, evaluating the extinction corresponding to weather conditions derived from meteorological reports is often difficult because these reports lack one critical parameter required by the model: the Air Mass parameter value. Using default values for this parameter can lead to substantial errors in the extinction at the longer wavelengths. Furthermore, the LOWTRAN model does not accept values of relative humidities greater than 98 percent. These deficiencies become serious when it is desired to derive statistics of the IR extinction from meteorological records. A meteorological data interpreter model has been developed to overcome these problems. This model uses the visibility to determine the effective Air Mass parameter as well as adjusting the RH, the wind velocities and the precipitation rates through a series of logical selections to arrive at a physically consistent solution with respect to the available data. This model was tested on a large number of weather scenarios which shows its validity and its effects on IR system performance assessment.   Author

N90-21923#   Forschungsinstitut fuer Optik, Tuebingen (Germany, F.R.).
MODELLING OF OPTICALLY AND IR EFFECTIVE ATMOSPHERIC TURBULENCE
V. THIERMANN and A. KOHNLE   *In* AGARD, Atmospheric Propagation in the UV, Visible, IR, and MM-Wave Region and Related Systems Aspects 12 p (SEE N90-21907 15-32)   Mar. 1990
(AGARD-CP-454) Copyright Avail: NTIS HC A16/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The problem area of modeling atmospheric turbulence, which is limiting electro-optical, especially laser systems performance is examined. The practical use of Monin-Oboukhov (MO) similarity for predicting the structure constant c_n^2 and the inner length scale l_n of refractive index fluctuations are discussed. Even though MO similarity originally was stated for an ideal surface layer which is nearly nowhere found, it can be expected to be helpful also in natural terrain under real meteorological conditions. A set of parameterizations of the surface fluxes, which are required in the MO similarity expressions, is proposed. These parameterizations need only very basic environmental input data. Results of an experiment are presented showing reasonable agreement between model predictions and direct measurements at different heights. Model input parameters were measured explicitly here. In many cases, input parameters have to be estimated or there are only simple, not fully representative measurements available. A sensitivity analysis with respect to all input parameters is performed. The overall model error in high refractivity turbulence level situations is found to be about half an order of magnitude for c_n^2 if summed up over all contributions. For the inner scale l_n this is less than 40 percent.   Author

N90-27441#   Aerospace Corp., Los Angeles, CA.
DMSP'S INTERACTIVE TACTICAL TERMINAL
NEAL K. BAKER   *In* AGARD, Tactical Applications of Space Systems 4 p (SEE N90-27438 21-66)   May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The Defense Meteorological Satellite Program (DMSP) is in the process of developing an interactive weather terminal as a functional replacement for their older tactical terminals. These new terminals will have fifty times the computer capability of the older Mark 4. This increase in computer capability allowed flexibility in developing system concepts. Four basic concepts were developed.

The first was a build and apply concept for the operation of the system. In this concept, local data bases would be developed using the primary DMSP and NOAA sensors along with the microwave sensors. In addition, depending on the site location, various geosynchronous satellites would also be observed with that information added to the data base. The forecaster then would utilize this initial data base and build products. Another basic system concept was the quality control of the weather products. Quality control of the local data base environment was especially necessary because of immature sensor algorithms. Many functions were added for the purpose of quality control. In addition, since the forecaster is very busy with other tasks, the third system concept was to have a system which would collect data automatically and yet rapidly respond to the user when needed. The final system concept was graceful degradation, i.e. the ability to work with data dropouts, lack of individual sensor data, and other normal failures and yet still produce products. The hardware design incorporates redundancy to meet a high availability requirement and yet keep the corrective maintenance actions to a minimum. Corrective maintenance actions are to be done under a variety of conditions. In addition, a large number of built in test functions allows rapid analysis of failure modes. The combination of graceful degradation and the high availability requirements will produce a system that will work under tactical conditions. Author

N91-11006# European Organization for the Safety of Air Navigation, Brussells (Belgium). Engineering Directorate.
DEVELOPMENTS TO ENHANCE METEOROLOGICAL FORECASTING FOR AIR TRAFFIC SERVICES
M. E. COX and D. A. FORRESTER (Meteorological Office, Bracknell, England) In AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 12 p (SEE N91-10981 02-05) May 1990
(AGARD-AG-301-VOL-2-PT-4-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
In the future, the quality of the meteorological data available for use both in ground-based systems and on aircraft will become even more important as ATC strives to handle increasing volumes of traffic in the most efficient manner. An indication of the effect of errors in meteorological data on the precision of predictions of aircraft trajectories is discussed and the variability of wind and temperature is examined, showing the influence of location, altitude and season, in the European area. An outline of present-day forecasting methods follows (the data used and accuracies achieved are included). Potential sources of improvements are then discussed with the emphasis being placed on the use of aircraft-derived data (details are given of the accuracy of such data, possible methods of recovery, and their application within the Meteorological Services). The impact is described of turbulence on both the safety of air traffic and the accuracy of flight profile predictions (possible methods of providing aircraft with the means for the automatic reporting of turbulence are included). Some experimental work either performed or being planned in the European area is also described, aimed at improving the quality of the meteorological data made available for ATS purposes as a result of using data recovered from aircraft through both satellite and ground-based (Mode S SSR) systems. Author

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OCEANOGRAPHY

Includes biological, dynamic, and physical oceanography; and marine resources.

N90-27442# Naval Observatory, Washington, DC. Office of the Oceanographer of the Navy.
TACTICAL OCEANOGRAPHY FROM SPACE: THE NEXT DECADE
JONATHAN T. MALAY In AGARD, Tactical Applications of Space Systems 5 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Naval Oceanography from space is a tactical force multiplier. Space systems are play. an ever increasing role in command, control and communications; surveillance and targeting; navigation; and environmental remote sensing. Oceanographic and meteorological satellites are supporting the fleet today and will be even more important in the next decade. Tactical oceanography from space is briefly described and current plans to participate in space technology development is briefly discussed. Author

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LIFE SCIENCES (GENERAL)

N92-13547# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
NEUROLOGICAL, PSYCHIATRIC AND PSYCHOLOGICAL ASPECTS OF AEROSPACE MEDICINE
Sep. 1991 80 p Course held in Pensacola, FL, 18-20 Oct. 1989, in Brussels, Belgium, 25-27 Oct. 1989, and in Ankara, Turkey, 30 Oct. - 1 Nov. 1989
(AGARD-AG-324; ISBN-92-835-0631-6; AD-A244245) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An overview of the neurological, psychiatric, and psychological aspects of aerospace medicine is presented. The purpose is to further the knowledge of the flight surgeon and aeromedical examiner in the issues of neuropsychiatry. Aeromedical information is provided for the neuropsychiatric specialist. The unique application of psychiatry, psychology, and neurology to the aviation environment is described. Topics such as motivation to fly, human performance, stress in aviation, and the failing aviator are discussed. Further psychiatric and neurologic disorders found among aviators are presented. The unique aspects of assessment and decision making about flying status among neuropsychiatric cases are presented. The concepts and information currently available in aeromedical neuropsychiatry are summarized. For individual titles, see N92-13548 through N92-13566.

N92-18974# Toronto Univ. (Ontario). Dept. of Mechanical Engineering.
BUBBLE NUCLEATION THRESHOLD IN DECOMPLEMENTED PLASMA
C. A. WARD, D. YEE, D. MCCULLOUGH, and W. D. FRASER (Defence and Civil Inst. of Environmental Medicine, North York, Ontario) In AGARD, High Altitude and High Acceleration Protection for Military Aircrew 4 p (SEE N92-18972 09-52) Oct. 1991 Sponsored in part by Defence and Civil Inst. of Environmental Medicine, North York, Ontario
(AGARD-CP-516) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Previous work has indicated that rabbits that are more susceptible to decompression sickness (DCS) are also more sensitive to complement activation by air bubbles, and that rabbits

can be protected from DCS if they are pharmacologically decomplemented before they are subjected to the pressure profile. We have investigated a possible means by which decomplementing a rabbit could protect it from DCS. Since DCS is thought to be produced by bubbles that are formed in the tissues of an animal because of its tissues becoming oversaturated with dissolved gas as the animal undergoes a pressure profile, we have investigated the possibility that decomplementing an animal protects it from DCS by making it more difficult to form bubbles in one of the tissues of primary concern, blood plasma. This investigation was performed with three test liquids: (1) water; (2) native rabbit plasma; and (3) decomplemented plasma. We find that the threshold for bubble nucleation in water is greater than that in either plasma or decomplemented plasma, but we do not find any difference between the nucleation threshold of the two types of plasma. Thus, the indications are that the protection from DCS that results from decomplementing a rabbit does not appear to develop because of a change in the nucleation threshold of the decomplemented plasma. **Author**

N92-18982# Air Force Systems Command, Brooks AFB, TX. Crew Technology Div.
HEMODYNAMIC RESPONSES TO PRESSURE BREATHING DURING +GZ (PBG) IN SWINE
J. W. BURNS, J. W. FANTON, and J. L. DESMOND *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 5 p (SEE N92-18972 09-52) Oct. 1991
(AGARD-CP-516) Copyright Avail: NTIS HC/MF A12;
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Twelve chronically instrumented, unanesthetized, miniature swine were used to investigate the hemodynamic interrelationships of positive pressure breathing at G (PBG), the anti-G straining maneuver (AGSM), and the G-suit, during gradual onset rate (GOR) and simulated aerial combat maneuver (SACM) +Gz profiles. Maximum left ventricular pressure (LVP) and aortic pressure (AP) of over 300 mmHg, and left ventricular end-diastolic pressure (LVEDP) and right ventricular end-diastolic pressure (RVEDP) of over 160 mmHg and 100 mmHg, respectively, were common during the GOR and SACM exposures at 9 +Gz using an extended coverage G-suit (ECGS). A concurrent, substantial increase in intrathoracic pressure attenuated transmural vascular pressures within the thorax. The performance of the ECGS was significantly better than the abdominal bladder G-suit (ABGS), with or without PBG. A PBG effect could not be demonstrated while using the ECGS, during either the GOR or SACM profiles. **Author**

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AEROSPACE MEDICINE

Includes physiological factors; biological effects of radiation; and effects of weightlessness on man and animals.

N89-27330# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
SHORT COURSE ON CARDIOPULMONARY ASPECTS OF AEROSPACE MEDICINE
G. W. GRAY, ed. (Defence and Civil Inst. of Environmental Medicine, Toronto, Ontario) May 1989 81 p
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AGARD Report 758, Short Course on Cardiopulmonary Aspects of Aerospace Medicine, presented the lecture material and case history information from a Short Course by the Aerospace Medical Panel during Spring 1987. This Addendum presents the discussions which took place throughout the duration of the Short Course. **Author**

N90-17612# Rouen Univ. (France). Lab. de Toxicologie.
METHOD FOR THE EVALUATION OF TOXICITY OF COMBUSTION PRODUCTS FROM AIRCRAFT CABIN MATERIALS: ANALYSIS AND RESULTS [METHODE D'EVALUATION DE LA TOXICITE DES PRODUITS DE THERMOLYSE DES MATERIAUX DE CABINE AVION ANALYSE DES RESULTATS]
J. M. JOUANY and M. FAVAND (Centre d'Essais Aeronautique Toulouse, France) *In* AGARD, Aircraft Fire Safety 8 p (SEE N90-17581 10-03) Oct. 1989 In FRENCH
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In order to aid in the selection of aircraft cabin materials, an experimental method was developed for the evaluation of toxic decomposition products from burning materials. The complete methodology combines a fire model and an experimental procedure that permits, on the one hand, an assessment of the material combustion reaction in terms of physico-chemical factors (weight loss, flammability, heat emission, and emission of fumes) and, on the other hand, an analysis of combustion product toxicity in terms of biological factors measured in mice (incapacitation and mortality). Methods for the statistical multivariate analysis of the collected data (principal components analysis) are discussed and a technique for the classification of materials is proposed. **Transl. by M.G.**

N90-17617# Royal Air Force Inst. of Pathology and Tropical Medicine, Aylesbury (England).
THE INVESTIGATION OF PARTICULATE MATTER IN THE LUNGS OF SMOKE INHALATION DEATH VICTIMS
I. R. HILL and B. P. MICHELSON *In* AGARD, Aircraft Fire Safety 9 p (SEE N90-17581 10-03) Oct. 1989
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Although the mechanisms involved in the causation of injury and death, due to the inhalation of the products of combustion are incompletely understood, the potential hazard is well recognized and was, at least in part, for many year. The response to smoke and toxic fume inhalation are many and varied, and include airway obstruction, bronchitis, atalectasis, pneumonitis, and respiratory failture. Damage to the cilia in the upper respiratory tract and to respiratory macrophages, may cause changes in the pulmonary defence mechanisms, which may in turn predispose to lung infection. The Manchester Airport Boeing 737 accident in 1985, and subsequently a series of domestic fires, have refocused lay interest in the various hazards. Insofar as house fires are concerned, 30 people died when soft furnishings were the first item ignited in 1962; 20 years later 152 people died. Research workers in various countries have long expressed an interest in this problem and there was considerable expenditure of effort and resources, in attempts to fully understand the mechanisms involved. Unfortunately contrary views still persist and this has its effects upon attempts to understand mechanisms and to propose logical solutions, which will improve the safety of the environment in fires. The literature and the results of some microscopical studies of the victims of fires investigated in an attempt to explain some of the observed phenomena. **Author**

N90-17618# Royal Albert Edward Infirmary, Wigan (England).
THE IMPORTANCE OF PATHOPHYSIOLOGICAL PARAMETERS IN FIRE MODELLING OF AIRCRAFT ACCIDENTS
JOHN S. S. STEWART *In* AGARD, Aircraft Fire Safety 12 p (SEE N90-17581 10-03) Oct. 1989
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The importance of pathophysiological parameters in fire modeling of aircraft accidents was under estimated. Pathological and toxicological studies and survivors' evidence all indicate rapid incapacitation by kerosene smoke. A combination of anoxic and stagnant anoxia can explain the evidence. Incapacitation by smoke is the important event which leads to death from cyanide and carbon monoxide poisoning. Fire blocking and fire hardening, although useful in some limited situations, are largely irrelevant to real accidents involving fatalities. Fire models which purport to establish a safety benefit, on the sole basis of escape time to

flashover, are far too simplistic. Much more weight should be given to protective breathing equipmemt and to water spray systems.   Author

N90-17619#   Huntingdon Research Centre Ltd. (England).
MODELLING TIME TO INCAPACITATION AND DEATH FROM TOXIC AND PHYSICAL HAZARDS IN AIRCRAFT FIRES
DAVID A. PURSER   *In* AGARD, Aircraft Fire Safety 13 p (SEE N90-17581 10-03)   Oct. 1989
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     Studies of incapacitation and lethality in laboratory animals and human fire victims, resulting from exposure to thermal decomposition products from many materials, indicate two main mechanisms of toxicity, narcosis (asphyxia) and irritancy. Narcotic effects are caused by the common asphyxiant gases, CO, HCN, low O_2, and CO_2 and can be predicted to a reasonable degree with existing knowledge. Irritant effects are caused by a variety of combustion products some of which are unknown, but can be quantified from small scale rodent combustion toxicity tests in terms of the mass loss concentration of combustion products using an index of respiratory tract irritation, and an index of lethality, in mg/min/liter. A mathematical model is presented for estimating toxic and physical hazard in fire in terms of time to incapacitation or death. The model takes the concentration/time profiles of the above products, smoke optical density, temperature and radiant heat flux (derived from other mathematical models of aircraft fires or large scale fire tests) and calculates time to incapacitation using a Fractional Effective Dose method based upon the known toxic effects to the combustion products, and of the physical hazards, in man, primates and rodents.   Author

N90-25459#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Aerospace Medical Panel.
NECK INJURY IN ADVANCED MILITARY AIRCRAFT ENVIRONMENTS
Feb. 1990   201 p   In ENGLISH and FRENCH   Symposium held in Munich, Fed. Republic of Germany, 24-28 Apr. 1989
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     Anecdotal evidence suggests that soft tissue neck injury may be an occupational hazard for fighter pilots, particulary those in the later generation trainer and combat aircraft. Recent advances in helmet-mounted devices increase the potential for injury. There is an acute need for guidance on the maximum mass and mass distribution characteristics of head-mounted devices. The extent of risk and its control through the design of helmet-mounted devices, protective systems and aircrew training and conditioning are discussed. For individual titles, see N90-25460 through N90-25479.

N90-25460#   Air Force Medical Group (347th), Moody AFB, GA.
PREVALENCE OF G-INDUCED CERVICAL INJURY IN US AIR FORCE PILOTS
RODGER D. VENDERBEEK   *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 7 p (SEE N90-25459 19-52)   Feb. 1990   Submitted for publication
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     Pilots of high performance aircraft are frequentiy exposed to significant accelerative forces; the effect of this exposure on the cervical vertebral column is an unquantified clinical and epidemiological problem. The findings are presented from a period of prevalence study of acute neck injury secondary to high G forces in U.S. Air Force pilots. A sample of 437 pilots of three different fighter aircraft was surveyed, and the data is stratified and analyzed to test the strength of association of injury prevalence with pilot age, type of aircraft, and type of flying environment. Results indicate that minor injury is common in these pilots, and that higher aircraft performance is associated with increased injury prevalence. Increased age is associated with increased prevalence of major cervical injuries. Preventive strategies may be helpful in reducing injury frequency and in avoiding serious injuries.   Author

N90-25461#   Nebraska Univ., Omaha. Dept. of Otolaryngology.
NON-EJECTION NECK INJURIES IN HIGH PERFORMANCE AIRCRAFT
DAVID G. SCHALL   *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 10 p (SEE N90-25459 19-52)   Feb. 1990
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     The potential for significant neck injuries exists in today's high performance fighter aircraft. The G-loads required to produce injury need not be excessive, nor is experience level necossarily protective. Eight cervical spine injury cases, due to or aggravated by +G(sub z) in F-15 and F-16 aircrew members are reviewed. These include two compression fractures (C5/C7), three left HNP's (C5-6/C6-7), one fracture of the spinous process (C7), one interspinous ligament tear (C6-7), and one myofascial syndrome (C6). Mechanisms of injury and evaluation are discussed. Exercise conditioning may play an important role in prevention and protection. The role of screening x rays and improving equipment remain as areas where further work needs to be done.   Author

N90-25462#   Belgian Air Force, Beauvechain.
A SURVEY OF CERVICAL PAIN IN PILOTS OF A BELGIAN F-16 AIR DEFENCE WING
I. BIESEMANS, M. INGELS, and P. VANDENBOSCH (Belgian Air Force, Brussels.)   *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 5 p (SEE N90-25459 19-52)   Feb. 1990
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     Since the F-16 replaced the F-104 Starfighter in 1977, the pilots of the 1 deg Fighter Wing (1 deg FW) complained frequently from neck injuries sustained during and after their High + Gz interceptions. Until recently, Aerospace Medical community paid scant attention to this new clinical problem, although it was well known among pilots flying high performance aircraft (HPA) and flight surgeons. The results of an anonymous questionnaire, concerning neck problems in pilots flying the F-16 in an almost exclusive air to air role is communicated. A sample of 30 pilots answered these questionnaires in 1984 and in 1988. Analysis of these questionnaires showed 50 percent of the pilots reported having neck problems flying the F-16. No positive correlation between the age of the pilots and the prevalence of cervical pain could be demonstrated in this small group of fighter pilots. Subsequent factors in the neck injuries are the weight of the flying helmet as well as the combination of an inappropriate and insufficient physical training program. Neck injuries in pilots of HPA are a real occupational hazard and further long term follow up studies are needed to assess an eventually cumulative effect of repetitive high G loading on the cervical spine.   Author

N90-25463#   Royal Norwegian Air Force, Oslo. Inst. of Aviation Medicine.
RADIOLOGICAL INVESTIGATION OF THE VERTEBRAL COLUMN OF CANDIDATES FOR MILITARY FLYING TRAINING THE THE ROYAL NORWEGIAN AIR FORCE
HARALD T. ANDERSEN   *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 6 p (SEE N90-25459 19-52)   Feb. 1990
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     Neck injury with associated pain in the cervical spine and its supporting structures of ligaments and muscles are frequent complaints among aviators flying high performance fighter (HPF) aircraft. Two recent surveys conducted among air crew of the United States Air Force (USAF) and the United States Navy (USN), respectively, report incidences of neck pain incurred during flight of approximately 50 and 75 percent in these two HPF pilot populations (Knudsen et al., 1988, Vanderbeek 1988). Muscular pain, ruptured ligaments, sliding vertebrae and compression fractures were described resulting from violent manuevering during HPF air combat exercises (Andersen 1988). The cervical spinal column carries a heavy load during high-G accelerations supporting the head and various pieces of personal flying equipment. This top - heaviness is expected to increase further with night vision goggles and integrated weapon systems control devices added in an attempt to extend operable conditions. Moreover, since the

aeromedical emphasis was on developments supporting cardio-vascular and respiratory functions, the neck and the delicate structures of vessels and nerves running with it are becoming increasingly vulnerable to damage. Literarily speaking, the neck has become pinched between the desire to add weight to the head for purposes other than protection, and, the support to cardio-vascular and respiratory organ systems which allows additional intensity and time spent during excursions into the high-G environment. For these reasons, and because the vertical column is relatively inaccessible to clinical examination, the medical selection procedures for military flying training with the Royal Norwegian Air Force (RNoAF) were extended some years ago to include a series of roentgen films of the vertebral column with emphasis on the cervical spine. Main findings and their consequences for admission to military flying training are presented.   Author

N90-25464# Royal Norwegian Air Force, Oslo.
DATA ANALYSIS IN CERVICAL TRAUMA
LEIF A. LEVIN, HARALD T. ANDERSEN, LEON E. KAZARIAN, PATRICK HAYES, and HARALD U. SVERDRUP (Oslo Emergency Medical Center, Norway) *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 5 p (SEE N90-25459 19-52) Feb. 1990
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    The curvature of the cervical spine in lateral view is discussed and a method based on statistical analysis is used to reproduce quantitative data of the curvature. Part 1 is a study based on the lateral view in the neutral position in 142 aviators. The radiograms are divided in 3 main groups: normal cervical lordosis; marked straightening of the cervical spine; segmental straightening with reversal of the curve. Part 2 discusses the use of the digital analysis to determine the displacement in subjects that have sustained ligamentous injuries of the cervical spine following whiplash injury.   Author

N90-25465# National Defence Medical Centre, Ottawa (Ontario). Rehabilitation Centre.
PROGRESSIVE CERVICAL OSTEOARTHRITIS IN HIGH PERFORMANCE AIRCRAFT PILOTS
MARTIN H. GILLEN and DENIS RAYMOND *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 6 p (SEE N90-25459 19-52) Feb. 1990
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    Thirty-one pilots who were subjected to a repetitive $+G(sub\ z)$ environment were evaluated clinically and roentgenographically against age and sex-matched controls. Analyses demonstrated significant deterioration in the young pilot groups compared to controls in terms of neck range of motion, osteophytic spurring at C5/C6 and disc space narrowing at C4/5 and C5/6. While the pilots remain relatively asymptomatic during their flying career, they may be at greater risk for symptomatic cervical disease later in life. The $+G(sub\ z)$ environment appears to play a role in an accelerated rate of cervical osteoarthritis in high performance pilots. This must be taken into consideration when systems that will increase the longitudinal impact load on the neck are being contemplated.   Author

N90-25466# Amsterdam Univ. (Netherlands). Academisch Medisch Centrum.
ELECTRONYSTAGMOGRAPHIC FINDINGS FOLLOWING CERVICAL INJURIES
W. J. OOSTERVELD, H. W. KORTSCHOT, G. G. KINGMA, H. A. A. DEJONG, and M. R. SAATCI *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 4 p (SEE N90-25459 19-52) Feb. 1990
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    The biomechanical model of the head-neck system pursuits a whole spectrum of movements in all planes of motion and for a variety of speeds. The muscle actions are constrained by the physical properties of the vertical column, whose articulations differ in their ranges and directions of mobility. This model has three

types of elements: the flexible beams; the rigid mass of the head; and the neck muscle complex. Origins and insertions, axial rotation and muscle tensions can be approximated easily, so that the resulting peak static torques are compatible with the known torques generated voluntarily in various directions. All types of rotational movements can be performed with this construction, while the axis of rotation changes automatically with changing conditions. The neck muscle system has eight neural controller locations and eight locations for sensory feed-back. It is clear that the complicated network of muscles and neural mechanisms makes the cervical area vulnerable to traumata. Among the blunt traumas to the cervical region are the acceleration-deceleration accidents, better known as cervical whiplash injuries. One hundred and seventy-three patients, suffering from the consequences of an acceleration accident of the neck were investigated during the last two years. All patients acquired the trauma at an automobile accident. The patients visited the department because of consistent complaints as headache, dizziness, tinnitus and visual disturbances. In all patients an ENT investigation, audiometry, vestibulometry and visual tracking tests were performed. Although all patients had the type of injury in common, combinations of complaints differed considerably. The results of the examinations are discussed.
                                                                    Author

N90-25467# Naval Air Systems Command, Washington, DC. Escape Systems.
AIRCREW NECK INJURIES: A NEW, OR AN EXISTING, MISUNDERSTOOD PHENOMENON
FREDERICK C. GUILL and G. RONALD HERD *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 12 p (SEE N90-25459 19-52) Feb. 1990
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    The first U.S. Navy ejection occurred on 9 August 1949. Since then, the Navy has experienced 4,335 ejections through March 1988. The first serious neck injury, a paracervical strain, associated with an ejection occurred on 20 February 1953. That injury, also, was the Navy's first vertebral/ paravertebral injury associated with ejection. Initially, assessment of such neck injuries was accomplished as simply another vertebral injury; however, in more recent years it has become more apparent that the cervical/paracervical injuries reported in connection with ejections do not exhibit the same pattern characteristics as other vertebral/paravertebral injuries. The injuries occur at different rates than would be expected based upon the rates of injury for other vertebral regions. Further, although a clear relationship between through-the-canopy ejection and higher incidence rates of vertebral injuries was established, (and a causal mechanism identified), that appeared not to be the case cervical/paracervical injuries. In addition, while vertebral/paravertebral injury incidence rates have fallen with the changes in catapult boost acceleration, cervical/paracervical injury incidence rates have steadily increased. Why cervical/paracervical injuries associated with ejection are increasing; why have they not declined as the injury incidence rates have for other spinal regions are examined. Anecdotal and statistical mishap data examined and compared in this and prior studies suggest that the answer might lie in the aircraft maneuvering capabilities and in the increased frequency of ejection during, or following, gyrations resulting from loss of control of aircraft. The answers obtained suggest that considerable caution needs to be exercised in the current trend to integrate manifold systems elements into aircrew helmets, especially in light of the man-limited capabilities of today's modern tactical aircraft.   Author

N90-25468# Duke Univ., Durham, NC. Dept. of Biomedical Engineering.
FLEXION, EXTENSION AND LATERAL BENDING RESPONSES OF THE CERVICAL SPINE
JAMES H. MCELHANEY, BRIAN J. DOHERTY, JACQUELINE G. PAVER, BARRY S. MYERS, and LINDA GREY *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 10 p (SEE N90-25459 19-52) Feb. 1990
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The lateral, anterior, and posterior passive bending responses of the human cervical spine were investigated using unembalmed cervical spinal elements obtained from cadavers. Bending stiffness was measured in six modes ranging from tension- extension through compression-flexion. A five-axis load cell was used to establish the end conditions. Results include moment-angle curves, relaxation moduli and the effect of cyclic conditioning on bending stiffness. The Hybrid 3 ATD neck was also tested and its responses are compared with the human. It was observed that the Hybrid 3 neck was more rate sensitive than the human, that mechanical conditioning significantly changed the stiffness of the human specimens, and that changing the end-condition from pinned-pinned to fixed-pinned increased the stiffness by a large factor. The bending stiffness was significantly influenced by the direction of the bending moment, the type of end restraint, the magnitude of the deformation and the previous deformation history. The shear force produced by the end conditions was an important factor in the applied moment. This shear force not only changes the moment acting on the specimen but also influences the failure mode. These experiments indicate that when the loading is eccentric (as it almost always is), the primary deformation mode is bending, and the moment applied to the specimen is strongly influenced by shear forces and the magnitude of the eccentricity. The axial load is therefore a poor indicator of the type and magnitude of failure stresses. MR and CT was used to visualize the damage after loading. When compared to the dissection results MR was clearly superior to CT in detecting soft tissue and ligamentous injuries.
Author

N90-25469# Naval Biodynamics Lab., New Orleans, LA.
A KINEMATIC/DYNAMIC MODEL FOR PREDICTION OF NECK INJURY DURING IMPACT ACCELERATION
MARC S. WEISS, S. J. GUCCIONE, JR., and TERRY A. WATKINS (New Orleans Univ., LA.) *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 6 p (SEE N90-25459 19-52) Feb. 1990
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A statistical study was made of six head kinematic response curves for a set of 57 human and 29 animal (rhesus) -X impact acceleration tests conducted at the Naval Biodynamics Laboratory. The acceleration levels ranged from six to fifteen g's for humans and 42 to 106 g's for animals. The six analyzed responses included the X and Z components of the linear acceleration and displacement and the Y axis angular acceleration and displacement. Each head kinematic response variable was nonlinearly regressed on sled acceleration profile and head orientation parameters. Regression equations for rhesus and human kinematics had the same exponential functional form with correlations ranging from 0.50 to 0.95. Statistical measures of goodness-of-fit were highly significant. The results confirm that the rhesus head/neck is a good biomechanical model for the human. Extension of this approach can lead to the scaling of kinematics between humans and animals which can be used to develop an injury prediction model for humans. Future applications include re-analysis of previous results on the effects of mass distribution parameters on head/neck dynamic response.
Author

N90-25470# Erasmus Univ., Rotterdam (Netherlands). Dept. of Biomedical Physics.
ANALYSIS OF THE BIOMECHANIC AND ERGONOMIC ASPECTS OF THE CERVICAL SPINE UNDER LOAD
C. J. SNIJDERS and E. R. ROOSCH (Royal Netherlands Air Force, Soesterberg.) *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 8 p (SEE N90-25459 19-52) Feb. 1990
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In high performance aircraft complicated loading situations arise, e.g., when the head of the flier is turned backwards and rapid accelerations appear. To obtain more insight in the forces on the cervical spine a spatial biomechanical computer model was introduced. The research started with the development of a kinematic model which imposes the axes of rotation and mutual position of head and vertebrae in relation to flexion, extension, lateroflexion, and torsion. Subsequently lines of action of muscle forces were introduced as well as external loads acting on the center of mass of head and helmet born by gravity and by accelerations in different directions. Measurements were carried out of accelerations and head positions during several flights, a.o. representing air combat. Next, with the help of the biomechanical model, forces in vertebrae and muscles could be estimated. Although in the present stage of the research results of calculations must be interpreted carefully, conclusions can be drawn with respect to sitting posture, head position and helmet devices. Maximal forces calculated appear to be rather high. However, too few data on failure behavior exist to draw conclusions as to (long term) detrimental effects.
Author

N90-25471# Calspan Corp., Buffalo, NY.
EFFECTS OF HEAD MOUNTED DEVICES ON HEAD-NECK DYNAMIC RESPONSE TO +G(SUB Z) ACCELERATIONS
EBERHARDT PRIVITZER and INTS KALEPS (Aerospace Medical Research Labs., Wright-Patterson AFB, OH.) *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 14 p (SEE N90-25459 19-52) Feb. 1990
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An investigation is described which addresses the inertial loading effects of Head Mounted Device (HMD) on aviator head-neck-spine dynamic response during high +G(sub z) acceleration exposure. The primary objectives were to develop a methodology which could be used to establish limits on HMD inertial properties and to apply this methodology to the evaluation of the severity of the internal loads (occurring in the neck and upper spine) associated with certain specific HMD ensembles. The Head-Spine Model (HSM), a highly discretized, 3-D mathematical representation of the human head-spine-torso structure, was used to: establish a set of baseline response criteria (BRC); establish a preliminary methodology for setting limits on HMD inertial properties; and evaluate the severity of the loading associated with possible chemical defense (CD) ensembles.
Author

N90-25472# Paris V Univ. (France). Lab. d'Anthropologie Appliquee.
DYNAMICAL MODIFICATIONS TO THE HEAD, LOAD FACTORS FROM ADDITIONAL WEIGHT [MODIFICATION DE LA DUNAMIQUE DE LA TETE, CHARGEE PAR DES MASSES ADDITIONNELLES]
P. Y. HENNION, A. COBLENTZ, and R. MOLLARD *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 8 p (SEE N90-25459 19-52) Feb. 1990 In FRENCH
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Numerous devices impose upon the user added weight on the head. Their use is almost a technical requirement. It is rare that the restrictions caused by their use is considered at their conception. This idea was studied for a commonly used system. For the first time, the location of the center and moment of inertia was studied by a experimental method. The change in the inertia parameters of a head with a device which adds weight was precisely followed in an analysis of the movement of the center of inertia and the various moments of weight on a bare head, and in relation to the center of rotation which remains unchanged. The influence

of added weight was observed on four subjects with motion measured and identified as defined by target sighting which caused the head to rotate in many directions without added weight. From a dynamical aspect, some variations in the level and duration of the rotation acceleration were raised in relation to the increase of inertia. The offset of the center of inertia was also induced by the vertical acceleration perturbation. This was confirmed by an increase of activity in cervical neck muscles, and from movement of the head by use of muscles in the nape of the neck. Another observation of lesser import was obvious, the interference caused by the introduction of devices for the maintenance of posture. Some strong variations were seen in stabilograms while target sighting when in an upright position. This change in head dynamics leads to a perceptable loss of performance, as seen by errors and an increased response time in the sighting of aerial targets. Equipment designers do not think of operator efficiency when adding weight to the head with helmet mounted devices. It is established in this study that the functional senses of the operator must be considered as well as the increased inertia and performance criteria.   Transl. by E.R.

N90-25473#   Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France). Centre d'Essais en Vol.
MOBILITY OF THE HEAD AND LOAD EFFECTS: EXPERIMENTAL APPROACH IN A CENTRIFUGE [MOBILITE DE LA TETE ET FACTEUR DE CHARGE: APPROCHE EXPERIMENTALE EN CENTRIFUGEUSE]
A. LEGER, P. SANDOR, J. M. CLERE, and G. OSSARD   *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 8 p (SEE N90-25459 19-52)   Feb. 1990   In FRENCH
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The environment of modern combat pilots is very hazardous for the head-neck systems. The introduction of helmet mounted optronic systems caused even more problems with high G acceleration. Studies in centrifuges were used in order to show the influence of some environmental parameters (tilt of seat, high G and variations of acceleration forces) on head mobility. Two hundred and eighty centrifugal turns were made without causing traumatic injuries. The results show that up to 5 G, the head movements are changed very little. However, variations in the level of acceleration bring about perturbations of stability. The subsystems reflexes involved in head stabilization are influenced by voluntary control, these optional controls during aviation combat will be able to establish points of interest in the study of physiopathology of the pilot head-neck system.   Transl. by E.R.

N90-25474#   German Air Force, Fuerstenfeldbruck (Germany, F.R.). Inst. of Aerospace Medicine.
NECK INJURY PREVENTION POSSIBILITIES IN A HIGH-G-ENVIROMENT EXPERIENCE WITH HIGH SUSTAINED +G(SUB Z) TRAINING OF PILOTS IN THE GAF IAM HUMAN CENTRIFUGE
W. H. WURSTER, J. LANGHOFF, and E. C. BURCHARD   *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 6 p (SEE N90-25459 19-52)   Feb. 1990
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New generations of high performance military aircraft are able to produce higher G-rates of onset, attain higher G-levels for prolonged periods and in the future will confront man and machine more often with changing acceleration peaks than previous fighter generations have. These enhanced performance capabilities will require additional anti-G protection equipment as well as special education and training of pilots to tolerate high-G environment levels so they can fulfill complex tasks during special inflight conditions without suffering from G-induced cardiovascular, pulmonary, cerebral or musculoskeletal problems. Therefore an extensive study in 238 young G-stress unexperienced pilot candidates (aged between 18 to 24 years) of the GAF - Officers' - Academy was performed within a period of 23 months (1 Oct. 1985 to 1 Sep. 1987) who participated in a high-G training program as volunteers with more than 1250 centrifuge rides partially up to +8 G(sub z) for 30 sec on the GAF IAM Human Centrifuge. By means of an anonymous questionnaire answered by the pilot candidates immediately after G(sub z) exposure and post-acceleration check-up, different data were obtained. The intention of this investigation was in maintaining vision and consciousness as well as neck injury prevention at high sustained +G(sub z) levels in G-unexperienced pilot candidates. The findings in the search for methods to protect a subject under +G(sub z) stress in the human centrifuge from G-induced symptoms, especially of potential cervical spine problems, are described.
                                                              Author

N90-25475#   Association Peugeot-Renault, Nanterre (France). Lab. de Physiologie et de Biomecanique.
RISK OF CERVICAL INJURY IN REAL AND SIMULATED ACCIDENTS [RISQUE DE LESIONS CERVICALES EN ACCIDENTS REELS ET SIMULES]
C. TARRIERE, J. Y. FORET-BRUNO, J. Y. LECOZ, C. GOT, and F. GUILLON (Hopital Raymond Poincare, Garches, France)   *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 17 p (SEE N90-25459 19-52)   Feb. 1990   In FRENCH
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The Lab of Physiology and Biomechanics in association with PSA and Renault made use of two sources of data which adds to the understanding of risk and mechanics associated with vertebral injury. The data is from real multidisciplinary tests of 6589 vehicle occupants involved in accidents with body injuries and 9789 injuries involving the front seat of a vehicle and from 375 experimental tests with cadavers (simulated frontal and lateral, free fall, collision tests, etc.). The first part is essentially about the risk of vertebral injury with or without direct impact on the head with only seat belt simulated in different types of real accidents. The second part concerns the tests with cadavers which gives a better understanding of the mechanics of vertebral injury, thanks to the measurement of different physical parameters (maximum angle of head-chest, speed and angular acceleration, etc.).
                                                              Transl. by E.R.

N90-25476#   Waterloo Univ. (Ontario). Dept. of Kinesiology.
A COMPUTER SIMULATION MODEL FOR STUDYING CERVICAL SPINE INJURY PREVENTION
P. J. BISHOP and R. P. WELLS   *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 5 p (SEE N90-25459 19-52)   Feb. 1990
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Cervical spine fractures, particularly of the burst type due to axial compressive loading of the spine, are a problem in sports and transportation. Such injuries are usually associated with a head first collision, in which the head strikes a rigid surface (e.g., windscreen, dashboard, etc.), with the neck partially to fully flexed. A computer simulation model was developed as one means by which protective devices can be evaluated. The model consists of two rigid masses (head and torso), three spring elements (dashpots and non-linear springs) representing the neck and the compliance of the cranium and scalp, and three optional spring elements taken to represent the characteristics of the protective devices. Simulations using the model, at impact velocities of 1.8 and 3.0 m/sec, suggest that to maintain cervical spine loads at a non-injurious level (e.g., below 20000N) requires a padding material thickness incompatible with wearing a helmet.   Author

N90-25477#   Institut de Recherche de Transports, Bron (France). Lab. de Chocs et de Biomecanique.
BIOFIDELITY OF A DUMMY'S NECK DURING AUTOMOBILE COLLISION TESTING [BIOFIDELITE DES COUS DE MANNEQUINS AU COURS DES ESSAIS DE CHOCS AUTOMOBILES]
R. WILLINGER and D. CESARI   *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 11 p (SEE N90-25459 19-52)   Feb. 1990   In FRENCH
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Dummies are widely used in research on the protection of automobile passengers. The dummies were designed for use in acquiring knowledge of the biomechanics of the human body subjected to collisions. The necks of some of the dummies were

designed in such a way as to behave similar to those of humans. Herein, an analysis is proposed based also on a bibliographic survey, of the 3-D kinematics of the heads of dummies (SID, Hybrid 3, and EUROSID) with the object of studying their biofidelity. Generally, the biofidelity is better in frontal as opposed to lateral collisions. This is essentially explained by the fact that the head rotation around its vertical axis is not taken into account in the design of dummies. The biofidelity and performance of dummies rest on the biomechanic conclusions sometimes drawn from cadavers. The validity of these tests is studied along with suggestions for future testing.   Transl. by E.R.

N90-25478# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Delft (Netherlands). Road-Vehicles Research Inst.
OMNI-DIRECTIONAL HUMAN HEAD-NECK RESPONSE
Abstract Only
J. WISMANS *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 1 p (SEE N90-25459 19-52) Feb. 1990 Presented at the 1986 STAPP Car Crash Conference
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The Naval Biodynamics Laboratory (NBDL) in New Orleans has conducted an extensive research program over the past years to determine the head-neck response of volunteers to impact acceleration. These subjects were exposed to impacts in frontal, lateral, and oblique directions. An analysis of a limited number of frontal and lateral tests from a first series conducted in the late seventies with two subjects showed that the observed head-neck dynamics can be described by means of a relatively simple 2-pivot analog system. This analysis is extended to a more recent NBDL test program with 16 human subjects. The database consists of 119 frontal, 72 lateral, and 62 oblique tests. The research methodology used for this analysis includes a detailed description of three-dimensional kinematics as well as load calculations near T1 and the occipital condyles. A description of this research methodology and a summary of the major test results is presented. Special attention is given to the influence of impact severity and impact direction on the head-neck dynamics. It is shown that a similiar analog system as proposed earlier for frontal and lateral impacts is suitable for all impact directions. Geometrical properties of this analog were determined by means of newly developed numerical techniques rather than through the graphical techniques that were used earlier. Findings of this analysis are discussed in view of future omni-directional mechanical neck developments.
                                                                      Author

N90-25479# Naval Air Development Center, Warminster, PA.
MEASUREMENT TECHNIQUES, EVALUATION CRITERIA AND INJURY PROBABILITY ASSESSMENT METHODOLOGIES DEVELOPED FOR NAVY EJECTION AND CRASHWORTHY SEAT EVALUATIONS
GEORGE D. FRISCH, LAWRENCE E. KINKER, and PAUL H. FRISCH (Applied Physics, Inc., Nanuet, NY.) *In* AGARD, Neck Injury in Advanced Military Aircraft Environments 8 p (SEE N90-25459 19-52) Feb. 1990
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Head and neck injuries are of particular concern to Navy researchers and extensive programs were initiated to address head and neck response of both live human subjects and human analogs to crash impact forces. This concern was somewhat heightened by the apparently conflicting operational requirements of having canopy penetration as the principal means of ejection in several aircraft prototypes, coupled to the requirement of introducing night vision capability in attack aircraft. The latter will most probably lead to increased helmet volume, and possibly weight, which increases the probability of helmet canopy acrylic interaction during canopy penetration. Increased helmet weight and center of gravity shifts, together with altered helmet to head coupling, will certainly change head and neck response to even presumably safe exposure levels. In order to adequately parameterize head and neck response and relate the gathered data to known living human subject and cadaver data, both inertial response and load data must be obtained at well defined, anatomically correctable points. A modified Hybrid 3 type head and neck complex was developed, ballasted to be in compliance with Navy generated head and neck mass distribution

parameters, and fully instrumented at the head center of gravity (CG), occipital condyles, and the base of the neck. The fully instrumented head and neck system was utilized to evaluated various helmet configurations and the effect on head and neck response with changes in helmet weight and geometry. Additionally, neck extension, compression, shear forces, and torques were obtained during dynamic ejection tests ranging from 0/0 to 720 KEAS. At the higher speeds, the effects of aerodynamic lift can be identified on the monitored neck compression tension values. With such data, injury modalities and probabilities can be addressed in considerably greater detail than the present norm and the effectiveness of protective equipment established.
                                                                      Author

N90-28987# Hamburg Univ. (Germany, F.R.) Dept. of Eyes.
EXPERIMENTAL TESTS ON THE MINIMAL VISUAL ACUITY REQUIRED FOR SAFE AIR CREW AND AIR CONTROL PERSONNEL PERFORMANCE
J. DRAEGER and R. SCHWARTZ *In* AGARD, Situational Awareness in Aerospace Operations 3 p (SEE N90-28972 23-53) Apr. 1990
(AGARD-CP-478) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

National and international directives specify minimal requirements for corrected and uncorrected visual acuity in military as well as civil aviation. There is a striking difference between the corrected visual acuity and the minimal visual acuity specified as a lower limit. The present experimental study concerning military pilots deals intensively with the minimal requirements on visual acuity which guarantee the safe operation of an aircraft. The investigation revealed that the specified visual acuity without correction as stated in all directives is not acceptable as a lower border limit for safe operation of an aircraft. It would therefore be possible to dispense completely with specified minimal uncorrected visual acuity values. However, a safe wearing of visual aids at all times, considering cockpit environment specific conditions must then be guaranteed. For air control personnel the uncorrected visual acuity should not have further significances. In additional studies we examined the minimal requirements for the radar controller. While reducing the visual acuity in defined steps the radar controller had to recognize critical situations during a simulated approach. For the special situation of the tower controller a visual acuity of 1.0 is required. The tests with radar controllers reveal that a reduced visual acuity between 0.5 and 1.0 had no significant influence on the failure rates. The visual acuity in that range is not as important as for pilots and tower personnel.
                                                                      Author

N90-28991# Institute of Aviation Medicine, Madrid (Spain).
EVALUATION OF THE PERFORMANCE CAPABILITY OF THE AVIATOR UNDER HYPOXIC CONDITIONS OPERATIONAL EXPERIENCE
FRANCISCO RIOS TEJADA, LUIS MARQUEZ DELAPLATA, CESAR ALONSO RODRIGUEZ, and JUAN J. CANTON ROMERO *In* AGARD, Situational Awareness in Aerospace Operations 6 p (SEE N90-28972 23-53) Apr. 1990
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Performance capacity under hypoxia conditions was determined in 48 subjects exposed to a simulated altitude of 25,000 feet (7,620 mts.). The method was a modified Toulouse-Pieron Test (TTM) and a Digit Span Test (DST), completed at 3 altitudinal conditions: Ground Level (GL), FL 250 and Placebo (PL). Maximum hypoxia time was 4 minutes and it was measured every 30 sec. The Direct Partial Score (DPS) 8 times through the 4 min., and the Direct Total Score (DTS) was obtained by the Tolouse application formula. Significant decrements in test performance were found by comparing GL to FL 250 and FL 250 to PL in pairs at .001 confidence level after point 90 sec. time for DPS. Similar results were obtained for DST. For DTS, the comparative analysis of the average values were also significant. The application of the TTM is considered as useful, simple and profitable in the evaluation of Attention Capacity of the aviator under hypoxia conditions. The Incapacitation Curve is a term which expresses, in a quantitative and chronological way, the psychomotor performance. Both, the TTM and DTS, are between each other

complementary tools in the evaluation of the psychomotor pilot efficiency. Author

N90-28992# McGill Univ., Montreal (Quebec).
EFFECTS OF SHORT-TERM WEIGHTLESSNESS ON ROLL CIRCULARVECTION
D. G. D. WATT and J. P. LANDOLT   *In* AGARD, Situational Awareness in Aerospace Operations 6 p (SEE N90-28972 23-53) Apr. 1990   Sponsored in part by Medical Research Council of Canada and National Research Council of Canada Prepared in cooperation with Defence and Civil Inst. of Environmental Medicine, Toronto, Ontario
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Roll circularvection is an illusion of self-rotation about the fore-aft axis experienced when a stationary subject is exposed to a visual field rotating in the frontal plane. In these experiments, subjects were asked to estimate the strength of this phenomenon while undergoing visual stimulation in the upright and supine positions, and during parabolic aircraft flight. The results indicate that the steady roll component of vection is not affected by the magnitude or direction of the gravity vector. The unpredictable and sudden loss of this compelling illusion could contribute to serious episodes of pilot disorientation. Author

N90-28993# Naval Aerospace Medical Research Lab., Pensacola, FL.
MAINTAINING SPATIAL ORIENTATION AWARENESS
A. RUPERT, A. MATECZUN, and F. E. GUEDRY, JR.   *In* AGARD, Situational Awareness in Aerospace Operations 5 p (SEE N90-28972 23-53) Apr. 1990
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It is believed that training paradigms which vividly demonstrate to pilots the need and way to maintain spatial orientation awareness during formation flight will reduce the incidence of these very costly mishaps. Several training paradigms are under development using the Dynasim, a cockpit mounted on a short-arm centrifuge. The pilot controls both pitch and roll axes of the Dynasim cockpit to maintain the position on a wing aircraft projected onto a visual surround. Pilot's attention is intermittently distracted from the lead aircraft and from attitude display(s) by simultaneous performance of other cockpit tasks. The orientation experienced by pilots is controlled by varying information in the visual surround and in the onboard instruments (including a Malcolm Horizon) and by controlling the direction of the gravitoinertial field of the short-arm centrifuge. A second stage of the research will investigate new concepts in displays to improve pilot orientation awareness. The inevitable distraction of visual attention, which accompanies emergency situations, engenders consideration of peripheral vision and nonvisual channels to convey aircraft attitude and target information and maintain spatial orientation awareness. Author

N91-11370# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE APPLICATION OF USAF FEMALE ANTHROPOMETRIC DATA TO IDENTIFY PROBLEMS WITH THE INTRODUCTION OF FEMALE AIRCREW INTO THE ROYAL AIR FORCE
G. M. TURNER   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 3 p (SEE N91-11358 02-53) Aug. 1990
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The Royal Air Force (RAF) decided in 1989 to recruit female pilots and navigators. Since there is little statistical data on the distribution of the critical body dimensions for the UK female population the USAF female anthropometric data was employed to predict the effects of imposing the present RAF minimum selection limits on the female population. These predictions are discussed and the effects for individual aircraft types considered. Certain questions are raised concerning limb strength related to aircraft controls and to the possible requirement for a minimum weight for ejection seat occupants. The USAF female data so far employed was only from the published percentile tables Further studies will be conducted using the raw data transferred from the

US AMRL Data Bank Library to the Institute of Aviation Medicine computer. Author

N91-11376# Institute of Aviation Medicine, Oslo (Norway).
PREGNANCY: A CAUSE FOR GROUNDING OF FEMALE AIR CREW
HARALD T. ANDERSEN and OTTAR LUNDE   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 3 p (SEE N91-11358 02-53) Aug. 1990   Prepared in cooperation with University Hospital, Oslo, Norway
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Military aviation is a rather demanding profession. The medical priorities pertinent to pregnant aviators are considered. Complications to pregnancy which are capable of causing events which interfere with flying duties are examined. The three trimesters of pregnancy are explained along with the problems each presents. The medical consequences of the operational requirements are considered as well as the complications outlined, since adequate treatment depends upon skilled intervention in well equipped institutions. Author

N91-11377# School of Aerospace Medicine, Brooks AFB, TX. Clinical Sciences Div.
EKG FINDINGS IN FEMALE AVIATORS IN THE US AIR FORCE
ROBERT A. MUNSON   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 5 p (SEE N91-11358 02-53) Aug. 1990
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The initial EKGs from 309 female aviators and 309 age-matched male aviators were read to compare the prevalence of findings. Abnormal readings were unusual, as would be expected in this selected group. About 1.3 percent of the males and none of the females had abnormal readings, a difference which is not significant ($p = .0455$). The abnormal readings were two cases of left anterior hemiblock and two of Wolff-Parkinson-White. Possibly abnormal findings, which required a second order workup to rule out the presence of cardiac disease, occurred at a similar rate between the groups (22.7 percent of females vs 16.2 percent of males, $p = .0634$). The preponderance of possibly abnormal findings in women were due to nonspecific ST and T-wave abnormalities. Normal variant tracings were more common in men (60.2 percent female vs 74.1 percent male, $p = .0004$) while women were more likely to have an EKG without significant finding (17.1 percent females vs 8.4 percent male, $p = .0018$). These findings support the concept that EKG criteria that were developed for men can be used aeromedically for women. Author

N91-11378# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Systems Div.
IMPACT ON WOMEN: A RETROSPECTIVE LOOK AT IMPACT ACCELERATION TESTING AT THE HARRY G. ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY
CYNTHIA N. RANDALL and JAMES W. BRINKLEY   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 6 p (SEE N91-11358 02-53) Aug. 1990
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In today's society, women are occupying an increasing number of previously male dominated jobs. This is especially true in the United States Armed Forces. Women have served as pilots in the military since the early 1970's (1973 for Army and Navy; 1976 for Air Force) but cannot be assigned to high performance, ejection seat aircraft unless they are an instructor or test pilot. Consequently, research was directed at the 5th to 95th percentile male crewmember, and little information is available with respect to performance, limitations, and potential dangers that might be encountered with female aircrew. In the Biomechanical Protection Branch of the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL), women are routinely used as subjects in impact experiments since 1976. Seven women of 132 total subjects (5.3 percent) have taken part in 110 of 2108 (5.2 percent) of the impact testing. Although the numbers are small, a retrospective

review of the data obtained from these female subjects at AAMR is provided and compared to the male subject data to determine if there are any trends. Author

N91-11379# School of Aerospace Medicine, Brooks AFB, TX.
RELATIONSHIP OF MENSTRUAL HISTORY TO ALTITUDE CHAMBER DECOMPRESSION SICKNESS
FREDERICK W. RUDGE *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 4 p (SEE N91-11358 02-53) Aug. 1990 Submitted for publication
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Records at the United States Air Force School of Aerospace Medicine, Division of Hyperbaric Medicine, were reviewed to determine the relationship between the incidence of altitude chamber decompression sickness (DCS) in females and menstrual history. The study period spans 11 years, from January 1978 to December 1988. Eighty-one records were suitable for study. A significant inverse linear relationship was noted between the number of days since the start of last menstrual period and the incidence of DCS. This relationship was noted with both Type 1 and Type 2 DCS. Lack of information on the population at risk precluded an analysis of the effects of birth control pills on this phenomenon. The underlying mechanism for the correlation between menstrual cycle and susceptibility to development of DCS is unknown. The conclusion is that women are at higher risk of developing altitude-related decompression sickness during menses, with the risk decreasing linearly as the time since last menstrual period increases. Author

N91-13863# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
ECHOCARDIOGRAPHY IN NATO AIRCREW
Oct. 1990 104 p
(AGARD-AR-297; AGARD-WG-13; ISBN-92-835-0593-X;
AD-A230481) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The protocol is considered for a planned cross-sectional and a longitudinal study on echocardiography in NATO aircrew. It gives an overview of the procedures manual, technical manual, the echo data sheet, the software program, and the quality control manual. Included is the multinational protocol for the performance and reporting of echocardiograms. Author

N91-16554# Institute of Aviation Medicine, Farnborough (England).
CEREBRAL OXYGEN STATUS AND G-INDUCED LOSS OF CONSCIOUSNESS
DAVID H. GLAISTER *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 4 p (SEE N91-16553 08-54) Sep. 1990
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G-induced loss of consciousness (G-LOC) is a common event and has led to the loss of many aircraft and aircrew. While most body systems are ultimately affected, the final common path for its initiation is an inadequate supply of oxygen to the brain. Thus, a measure of cerebral oxygen sufficiency could provide a specific monitor for incipient G-LOC and serve either as a warning to the pilot or as a trigger for an autorecovery system. Multiwavelength near IR spectrophotometry permits the noninvasive in vivo measurement of the oxygen content of blood within the cerebral microcirculation, and also of the oxygen status of cytochrome-c oxidase within the brain cells. This technique was validated in human subjects during exposure to hypoxia; in presyncope induced by lower body negative pressure; and during +G sub z induced loss of consciousness. As well as providing an important new tool for acceleration research, the technique has the potential to be developed into an inflight monitor for aircrew. Author

N91-16555# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
DETECTION OF LOSS OF CONSCIOUSNESS IN FLIGHT BY DOPPLER METHOD [DETECTION DES PERTES DE CONNAISSANCE EN VOL PAR METHODE DOPPLER]
J. M. CLERE, G. OSSARD, D. LEJEUNE, A. LEGER, and A. RONCIN (Tours Univ., France) *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 6 p (SEE N91-16553 08-54) Sep. 1990 In FRENCH
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The use of transcranial Doppler monitoring is recommended for detecting acceleration induced loss of consciousness (LOC). One transcranial Doppler pulse device was developed specifically to function in a centrifuge and another for use in a Mirage 2000, causing limitations to respect the secure environment required by use in flight. During a study conducted for the evaluation of acceleration tolerance of 9 subjects at +8 Gz, the transcranial Doppler device showed the existence in 23 instances of a relationship between velocimetric signal reduction of an average cerebral arterial circulation and the decrease of the field of view; in 9 instances, this relationship was not observed, and in 1 case a weak decrease of the Doppler signal was followed by LOC. The detection and analysis of LOC in flight of many physiological and flight factors will cause the release of automatic safety procedures by the onboard computer. This necessitates the development of new and complex procedures. In this case, the best treatment for LOC consist of being put in a preventive position thanks to new anti-G protection (inclined seat, positive pressure respiration, anti-G pants for the lower body). Transl. by E.R.

N91-25603# Hamburg Univ. (Germany, F.R.). Dept. of Eyes.
LASER EFFECTS UPON THE STRUCTURE AND FUNCTION OF THE EYE AS A FUNCTION OF DIFFERENT WAVELENGTHS
J. DRAEGER, R. SCHWARTZ, and C. STERN *In* AGARD, Ocular Hazards in Flight and Remedial Measures 4 p (SEE N91-25602 17-54) May 1991
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A laser produces a narrow beam of monochromatic, coherent light in the visible, infrared, or ultraviolet parts of the spectrum. The power in a continuous beam can range from a fraction of a milliwatt to more than a megawatt. The applications and range of laser devices is broad. Helium-neon, argon, carbon dioxide, excimer, neodymium, and YAG lasers are described. The attendant hazards of laser operations vary greatly depending upon the exact type of laser and its application. The effects of optical radiation on the eye vary significantly with wavelength. Injuries to the anterior and posterior part of the eye are described. Prevention of laser-induced injuries are briefly discussed. Author

N91-25604# Army Aeromedical Research Lab., Fort Rucker, AL. Visual Sciences Branch.
ULTRAVIOLET RADIATION EFFECTS ON THE CORNEAL EPITHELIUM
MORRIS R. LATTIMORE, JR. *In* AGARD, Ocular Hazards in Flight and Remedial Measures 5 p (SEE N91-25602 17-54) May 1991
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Since military troops are involved in extensive outdoor activities with chronic exposure to solar radiation, and since ultraviolet radiation (UVR) lasers may play a role in the future military environment, a thorough understanding of UVR damage mechanisms is crucial to the development of intervention and treatment modalities. The present research was directed at quantifying possible alterations in corneal epithelial metabolic activity secondary to in-vivo exposure to UVR in the rabbit. Author

N91-25605# Institute of Aviation Medicine, Fuerstenfeldbruck (Germany, F.R.).
EYE DAMAGE INDUCED BY SOLAR RADIATION
H. BRANDL and F.-J. DAUMANN *In* AGARD, Ocular Hazards in Flight and Remedial Measures 5 p (SEE N91-25602 17-54) May 1991
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With the current methods including color vision tests with the Hue-test 100 no eye damages in the blue-light spectrum of solar radiation could so far be verified in flight filtering effect and a complete blocking in the UV-spectrum most likely provide adequate protection. The previous experience, however, should not keep one from striving for refinement of examination methods especially in the blue-light spectrum in order not to overlook insidious damage. The point is to avoid phototoxic damage. It is the task to provide safety for the pilot; this can be achieved by an advancement of knowledge, measuring methods, and consequent actions. Author

N91-25608# Institute for Perception RVO-TNO, Soesterberg (Netherlands).
A TWO CLASS MODEL FOR PHOTOCHEMICAL DAMAGE OF THE RETINA
D. VANNORREN *In* AGARD, Ocular Hazards in Flight and Remedial Measures 4 p (SEE N91-25602 17-54) May 1991
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A basic understanding of the mechanisms involved in photochemical damage to the eye is needed. The focus is on retinal light hazards mediated by photochemical processes, and related to exposures lasting from a few seconds to one or two days. It is proposed that from a simple model with two retinal photosensitizers, the shape of the threshold curve for light damage can be predicted. Because the action spectrum for light damage is also known from this model, the damage threshold can be calculated for an arbitrary light source. Author

N91-25610# Office of the Air Force Surgeon General, Washington, DC.
USE OF CONTACT LENSES (CL) BY AIRCREW IN THE USAF
Progress Report
THOMAS M. MCNISH *In* AGARD, Ocular Hazards in Flight and Remedial Measures 4 p (SEE N91-25602 17-54) May 1991
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In Jun. 1989, the Chief of Staff, USAF approved a plan authorizing, for the first time, the use of corrective CL (contact lenses) in flight by aircrews of the USAF. Eligible aircrew under this plan include all those requiring distant vision correction and having less than 2 diopters astigmatism. There is a recognized operational advantage to the use of CL vice spectacles in several air force missions. These include, most notably, the operation of high performance aircraft, and/or the use of night vision goggles to accomplish the mission. Therefore, the use of CL in flight is now optional for all physically qualified aircrew in the USAF. Prior to initiation of this program, a thorough literature search was accomplished. Based on data from studies on the complications associated with CL, the loss of 70 flying days per 1000 CL wearing aviators and four permanent groundings per 10000 CL-wearing aviators per year were predicted from CL-related problems. Safety of flight in high performance aircraft with CL was determined by a 1-year study of 89 aviators in Tactical Air Command, completed in 1989. Complication rates were very close to those predicted. In order to further validate predictions, or rapidly detect any any negative trends, the implementation plan includes a requirement for close professional followup of all CL-wearing aviators. Detailed quarterly reports on total number of CL-wearing aircrew, CL-related medical groundings, safety incidents, etc., are required by the Surgeon General, USAF. So far, there have been no permanent groundings nor CL-related safety incidents. After 856 aircrew-years of CL use, the rate of temporary grounding remains close to early predictions. Author

N91-25611# Army Aeromedical Research Lab., Fort Rucker, AL. Visual Sciences Branch.
CONTACT LENSES IN THE US ARMY ATTACK HELICOPTER ENVIRONMENT
MORRIS R. LATTIMORE, JR. *In* AGARD, Ocular Hazards in Flight and Remedial Measures 3 p (SEE N91-25602 17-54) May 1991
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Recent technological advances have had a major impact on military aviation. While modern methods of providing visual information via electro-optics/visionics systems have extended the aviator's operational envelope, these devices are becoming increasingly incompatible with spectacle wear. Since approximately 20 percent of Army aviators are ametropic (spectacle wearing), alternative means of providing a refractive error correction need to be investigated. One alternative being considered is the use of a contact lense correction. For the past year, the U.S. Army Aeromedical Research Laboratory (USAAEL) has been conducting a worldwide, AH-64 Apache contact lense research project in order to develop a comprehensive database on contact lens wear in a variety of environments. A three-tier contact lens fitting system is being used: two different types of soft lenses and one rigid gas permeable (RGP) lens type. The wearing schedule is set at a maximum of 7 days/6 nights of extended lens wear. Fundamental operational data is being chronicled by unit flight surgeons. Standard clinical data is being used in on-going command deliberations on future medical policy decisions concerning contact lens wear by Army aviators. Basic research information is being gathered in an effort to determine the fundamental physiological response to the cornea to the presence of a contact lens. Up-to-date results are presented as an introduction to interactive discussions. The subjective assessment of contact lens applications within the aviation community is universal acceptance. While current clinical data indicate some ocular health risk, flight safety risks are minimal. Establishment of long-term contact lens efficiency likely will depend on the ensuing analysis of physiological data. Author

N91-25612# Royal Air Force, London (England).
TEN YEARS FLYING WITH SOFT CONTACT LENSES
J. K. CLOHERTY *In* AGARD, Ocular Hazards in Flight and Remedial Measures 12 p (SEE N91-25602 17-54) May 1991
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In 1980 the RAF started an Aircrew Soft Contact Lenses (ASCL) Trial, Phase 1, to assess the value and safety of soft contact lenses for those aircrew who wear corrected flying spectacles (CFS). For this trial two soft contact lenses were selected. The high water content Scanlens 75 and the Medium water content Snoflex 50. The volunteers were selected from aircrew and medical officers. The subjects were measure (pre-fitting and post-fitting) and exposed to adverse environmental conditions likely to be encountered in flight. In all instances, the visual performance wearing soft contact lenses did not differ significantly from their performance when wearing CFS. In 1981 the Snoflex 50 lenses were abandoned because they were unsuitable for extended wear. In 1985 the care regime of the Scanlens 75 was changed to the SEPTICON care system. It was concluded that soft contact lenses are a viable and worthwhile alternative to CFS for aircrew. B.G.

N91-25613# Rigshospitalet, Copenhagen (Denmark). Dept. of Aviation Medicine.
SOFT CONTACT LENS WEAR AND AVIATION
STEEN TINNING and JANNIK BOBERG-ANS *In* AGARD, Ocular Hazards in Flight and Remedial Measures 3 p (SEE N91-25602 17-54) May 1991
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Soft contact lenses were proposed as an alternative to spectacles, when refractive errors are corrected in high performance fighter pilots. In the present study the effect on visual acuity was examined, when soft contact lenses were used during altitude simulated flying within a low pressure chamber. It can be concluded, that neither visual acuity nor visual comfort are effected

by the use of soft contact lenses. Based on the experience from one pilot, soft contact lenses seems to be superior to spectacles when refractive errors has to be corrected in high performance fighter pilots. Author

N91-25614# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Crew Systems Effectiveness Branch.
EFFECT OF AIRCRAFT CABIN ALTITUDE AND HUMIDITY ON OXYGEN TENSION UNDER SOFT AND HARD GAS-PERMEABLE CONTACT LENSES
MELVIN R. ONEAL *In* AGARD, Ocular Hazards in Flight and Remedial Measures 9 p (SEE N91-25602 17-54) May 1991
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The primary source of oxygen to the cornea is from the ambient air. Contact lenses decrease the oxygen getting to the corneal surface; and below a critical oxygen level corneal hypoxia occurs and the cornea swells. Repeated corneal edema may be implicated in the adverse effects of extended contact lens wear. The military flying environment includes aircraft cabin pressure that is decreased from normal sea level and cabin humidity that is usually much lower than normal. A calculational approach was used to access the effect of various cabin environments on oxygen levels under both soft and hard gas-permeable (HGP) contact lenses. The oxygen tension under 55 percent and 71 percent H_2O soft lenses during normal wear and at 18 percent relative humidity and under HGP lenses of various oxygen transmissibility was calculated for 8000 and 16000 ft cabin altitudes. Both altitude and dehydration affect the oxygen under soft lenses, while hard lenses do not dehydrate and have the benefit of added oxygen with tear exchange during blinking. The calculated oxygen tension under the hard lens is 2 to 3 times that under soft lenses at all cabin altitudes. In normal soft lens extended wear the cornea deswells the following day; however, during flight, the lower oxygen under soft lenses could affect corneal recovery in aircrew. The cabin environment is shown to result in calculated oxygen levels under contact lenses that are substantially reduced from normal, and needs consideration. Author

N91-25615# Institute of Aviation Medicine, Fuerstenfeldbruck (Germany, F.R.).
INTRA-OCULAR LENSES AND MILITARY FLYING QUALIFICATIONS
F.-J. DAUMANN and H. BRANDL *In* AGARD, Ocular Hazards in Flight and Remedial Measures 4 p (SEE N91-25602 17-54) May 1991
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The development of intra-ocular lenses (IOLs) to the present day routine implantation was accompanied by mixed emotions. In order to understand this reception, a brief history of cataract surgery is discussed. In 1975 IOL's were implanted at a more favorable site. Lens design and materials were considerably improved, the surfaces polished, sterilization and instruments improved. Now an assessment of the qualifications for military flying duty was made by examining aircrew and their performance (with IOLs). It was decided that in assessing whether flight crews should be granted wavers after cataract surgery with IOLs, that the surgery as such cannot meet the requirement. Each case must be evaluated separately. The following criteria must be met: visual acuity must be 1.0; no measurable disturbance through glare; intra-ocular eye pressure must be normal; and no inflamatory process. B.G.

N91-25616# School of Aerospace Medicine, Brooks AFB, TX. Ophthalmology Branch.
CATARACT SURGERY AND INTRAOCULAR LENSES IN USAF AVIATORS
DEBRA L. MOORMAN and ROBERT P. GREEN *In* AGARD, Ocular Hazards in Flight and Remedial Measures 6 p (SEE N91-25602 17-54) May 1991
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More than one million cataract surgeries, most with implantation of intraocular lenses, are performed in the United States each year. The early data on the United States Air Force's prospective study on the use of these surgical techniques in its military flyers are presented. From 1979 to 1990, 23 military aviators were evaluated by the United States Air Force School of Aerospace Medicine (USAFSAM) after cataract extraction with intraocular lens implantation. Their USAFSAM evaluation records were reviewed. Long-term follow-up (greater than 3 years) was available on only 3 subjects. All 23 subject were male Caucasians, with a mean age of 43 years. Ninety-one percent of the subjects were pilots, and, of these, 8 were qualified in high-performance aircraft. There were a total of 28 eyes, 86 percent (24) of which had received extracapsular cataract extractions (ECCE) with posterior chamber lenses. Best-corrected, postoperative vision was 20/20 or better in 100 percent of the eyes. Posterior capsule opacification occurred in 60 percent of the ECCE eyes, with one-third of those requiring Nd:YAG laser capsulotomies. Only one aviator was disqualified from flying duties for ocular reasons, a visually-qualified-to-fly rate of 96 percent. Eight aviators have actually flown since surgery. Although follow-up was short, the initial results are very encouraging. Author

N91-25617# Rigshospitalet, Copenhagen (Denmark). Dept. of Aviation Medicine.
CONTRAST SENSITIVITY AND GLARE FOLLOWING KERATOTOMY
STEEN TINNING *In* AGARD, Ocular Hazards in Flight and Remedial Measures 3 p (SEE N91-25602 17-54) May 1991
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During the later years radial keratotomy has been proposed as a possibility for young myops to obtain adequate visual acuity to fulfill the visual requirements for military pilots. Post keratotomy applicants are never the less not usually accepted as pilots, due to reports describing reduced visual functions, increased sensitivity to glare, and unstable refraction following keratotomy. With the purpose to evaluate the visual problems following keratotomy, a number of postkeratotomy applicants has been referred to the eye-clinic at the Department of Aviation Medicine for extended eye-examination. Refraction was stable in all eyes but one. The visual functions at low illumination was reduced in one third of the eyes, and more than half of the eyes had reduced contrast sensibility during radial glare. It is generally advised not to accept postkeratotomy patients as pilots. Demonstrated stability of refraction and acceptable visual function during glare and reduced illumination should be regarded as minimum requirement, if a postkeratotomy patient is to be accepted as an aviator. Author

N91-25618# Institute of Ophthalmology, London (England). Dept. of Clinical Ophthalmology.
A SURVEY OF COLOUR DISCRIMINATION IN GERMAN OPHTHALMOLOGISTS: CHANGES ASSOCIATED WITH THE USE OF LASERS AND OPERATING MICROSCOPES
G. B. ARDEN, T. BERNINGER, C. R. HOGG, and E. LUND (Munich Eye Hospital, Germany, F.R.) *In* AGARD, Ocular Hazards in Flight and Remedial Measures 6 p (SEE N91-25602 17-54) May 1991 Sponsored in part by Wellcome Trust and Wolfson Foundation
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Color vision tests were performed on 211 German ophthalmologists during their annual meeting at Essen. The subjects also filled in detailed questionnaires about their use of lasers and operating microscopes, and their ocular and general health. It was found that compared to those doctors who do not use lasers or operating microscopes, 33 percent of those who do have decreased color discrimination, for colors in a tritan color-confusion axis (greater than 2SD above normal). There is a relationship between number of patients treated and the degree of threshold elevation. Thirty hours of use of the operating microscope produces an increase in tritan threshold equivalent to 1 panretinal photocoagulation. After treating between 1000 to 10000 patients with Argon lasers, the average color threshold will be greater than 2SD above the normal mean. There is an important additional source of variation of color vision in surgeons who use lasers, due to to a factor which apparently offers protection against light hazard. Author

N91-25619# School of Aerospace Medicine, Brooks AFB, TX. Human Systems Div.

MEDICAL MANAGEMENT OF COMBAT LASER EYE INJURIES

ROBERT P. GREEN, JR., ROBERT M. CARTLEDGE, FRANK E. CHENEY, and ARTHUR R. MENENDEZ *In* AGARD, Ocular Hazards in Flight and Remedial Measures 7 p (SEE N91-25602 17-54) May 1991

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The rapid growth of laser science and engineering has resulted in an increased use of lasers by the military. It is likely that in future engagements lasers will be used directly against the forces, and their effects on the health and mission performance of the aircrews are of particular concern. Since the optics of the eye can increase the retinal irradiance by a factor of 100,000 times over that which is incident at the cornea, the retina is especially vulnerable. Laser range finders and target designators are used in military operations, and energy inputs from these and other potential laser sources are sufficient to produce significant eye injury at distances of 1 km or more. Glare and flashblindness, which are temporary visual effects caused by visible lasers, are present for laser energies considerably below the damage threshold and can, therefore, interfere with mission performance at considerable longer range. Aircrews partially protected by windscreens and canopies are still at risk from near infrared and visible lasers, while other personnel, such as air base ground defense forces, are additionally at risk from ultraviolet and far infrared lasers. Patients' symptoms from laser exposure will vary depending upon the power and wavelength of the laser, the structure of the eye affected, how close the exposure was to the visual axis, and the extent of the temporary or permanent effects on visual structures. Since most medical personnel in the field have never previously dealt with a patient who has had a laser exposure, a report which provides background information on lasers and guidance on handling these patients was written. Author

N91-32759# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

MOTION SICKNESS: SIGNIFICANCE IN AEROSPACE OPERATIONS AND PROPHYLAXIS

Sep. 1991 201 p In ENGLISH and FRENCH Lecture series held in Toronto, Ontario, 7-8 Oct. 1991, in Athens, Greece, 24-25 Oct. 1991, and in De Bilt, Netherlands, 28-29 Oct. 1991

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In aerospace activities, motion sickness, specifically air sickness, continues to be a problem during flying training and in regular operations for aircrew and passengers. Simulator sickness can degrade the effectiveness of simulator training and space sickness reduces the efficiency of astronauts. Sea sickness is also of aeromedical concern in so far as it affects aircrew operating from ships and the survivability of ditched sailors. The presentation is proposed as an aid to flight surgeons in the performance of their primary care duties. For individual titles, see N91-32760 through N91-32769.

N91-32760# Defence and Civil Inst. of Environmental Medicine, North York (Ontario).

SIGNS AND SYMPTOMS OF MOTION SICKNESS AND ITS BASIC NATURE

K. E. MONEY (Canadian Space Agency, Ottawa, Ontario) *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 4 p (SEE N91-32759 24-52) Sep. 1991

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The cardinal signs and symptoms of motion sickness are malaise, pallor, (and/or flushing), cold sweating, abdominal discomfort, changes in gastric motility, and changes in levels of circulating hormones. Cardiovascular, respiratory, and other signs have also been reported, as have a variety of other sensations, feelings, and performance changes. It is reasonable to think that motion sickness is basically the activation, by motion, of a poison response mechanism. Author

N91-32761# Naval Aerospace Medical Inst., Pensacola, FL.

MOTION SICKNESS AND ITS RELATION TO SOME FORMS OF SPATIAL ORIENTATION: MECHANISMS AND THEORY

FRED E. GUEDRY (University of West Florida, Pensacola.) *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 30 p (SEE N91-32759 24-52) Sep. 1991

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The mechanisms of motion sickness fall under three component topics, which separately involve distinctive subject matters and together challenge the entire scope of neuroscience disciplines. The components are as follows: (1) the process involved in the sensorimotor and perceptual motor adjustments to the sustained experience of unusual motion; (2) the neurochemical link whereby the neurochemical processes and byproducts of sensorimotor adjustment accumulate to a threshold level that when exceeded elicits the sickness syndrome; and (3) the sickness syndrome, which includes emesis and all of the autonomic and physiological accompaniments that degrade performance. These mechanisms are studied in detail. Author

N91-32762# Southampton Univ. (England). Human Factors Research Unit.

PHYSICAL CHARACTERISTICS OF STIMULI PROVOKING MOTION SICKNESS

MICHAEL J. GRIFFIN *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 32 p (SEE N91-32759 24-52) Sep. 1991

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The physical characteristics of motion stimuli responsible for motion sickness are reviewed in two parts. The provocative stimuli are categorized and their nauseogenic properties discussed qualitatively in terms of the sensory conflict theory of motion sickness. Quantitative data available from experimental studies with specific types of motion is then summarized. The motions of the body considered include translational oscillation, swing motions, rotation about a vertical axis, rotation about an off-vertical axis, rotational oscillation, and cross coupled (i.e., Coriolis) stimulation. Conditions producing visually induced motion sickness are also summarized. Author

N91-32763# Naval Aerospace Medical Inst., Pensacola, FL.

FACTORS INFLUENCING SUSCEPTIBILITY: INDIVIDUAL DIFFERENCES AND HUMAN FACTORS

FRED E. GUEDRY (University of West Florida, Pensacola.) *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 18 p (SEE N91-32759 24-52) Sep. 1991

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From a conceptual viewpoint, individual differences in susceptibility to motion sickness are determined by differences in the following: initial reactivity (receptivity), ability to adapt to the motion, ability to retain the adaptation during abstinence periods, and ability to reinstate adaptive responses upon reexposure to motion. From a theoretical viewpoint, the adaptive adjustment involves alteration of the timing, magnitude, and direction of sensorimotor reactions so as to increase the efficiency of postural control in the motion environment. However, the threshold linking the sensorimotor adaptive process to the processes that set-off the signs and symptoms of motion sickness may also be an individual characteristic. A conceptual model is presented to organize the discussion of individual differences in motion sickness susceptibility. Factors that have been reported to influence incidence of motion sickness such as age, mental activity, anxiety and fear, perceptual style, physical fitness, active control of the inducing motion, concomitant visual stimulation, quality of the initial exposure to the motion environment, and conditioned motion sickness are discussed. Author

N91-32764# Defence and Civil Inst. of Environmental Medicine, North York (Ontario)

SPACE SICKNESS

K. E. MONEY (Canadian Space Agency, Ottawa, Ontario) *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 5 p (SEE N91-32759 24-52) Sep. 1991 (AGARD-LS-175) Copyright Avail: NTIS HC/MF A10;
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Motion sickness in spaceflight occurred only rarely in the earliest space flights in small capsules, but in the larger Space Shuttle the incidence is fully 70 pct. Apparently, in larger spacecraft the requirement to make head movements and body movements in weightlessness, increases the likelihood of space sickness. Typically, after its appearance in the first day of a spaceflight, space sickness is made worse by head movements and by disorientation, and it is ameliorated by remaining motionless. Antimotion sickness drugs have been useful in dealing with space sickness and biofeedback techniques might be useful, but attempts to predict susceptibility (except by assessing susceptibility on previous spaceflights) have not been successful. Author

N91-32765# Defence and Civil Inst. of Environmental Medicine, North York (Ontario).

SIMULATOR SICKNESS

K. E. MONEY (Canadian Space Agency, Ottawa, Ontario) *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 4 p (SEE N91-32759 24-52) Sep. 1991 (AGARD-LS-175) Copyright Avail: NTIS HC/MF A10;
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Sickness in a flight simulator can compromise training, and it can also give rise to effects that persist afterwards and create hazards for the trainee. Generally, simulator sickness involves more visual disturbances, more dizziness, and more aftereffects than in other kinds of motion sickness, and less gastrointestinal disturbance (although a few instances of frank vomiting have been reported, both in the simulator and after leaving it). Simulator sickness can interfere with, and discourage participation in, simulator training. Its aftereffects could cause accidents, and to avoid these accidents, the trainees are often grounded for a while after flying the simulators. Different incidences of simulator sickness, most between 10 and 60 pct., were found in different simulators and depend partly on the criteria for the sickness and on how the simulator is used. Procedures for minimizing the problem were developed. Author

N91-32766# Southampton Univ. (England). Human Factors Research Unit.

SEA SICKNESS

MICHAEL J. GRIFFIN *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 20 p (SEE N91-32759 24-52) Sep. 1991 (AGARD-LS-175) Copyright Avail: NTIS HC/MF A10;
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A historical illustration of the prevalence of motion sickness at sea is followed by a review of experimental studies in which both ship motion and sickness were quantified. The motions responsible for sea sickness are identified and alternative methods of predicting sea sickness from measures of ship motion are defined. The influence of causal factors other than motion are also considered. Author

N91-32767# Institute of Aviation Medicine, Farnborough (England).

PREVENTION AND TREATMENT OF MOTION SICKNESS: NON-PHARMACOLOGICAL THERAPY

J. R. R. STOTT *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 9 p (SEE N91-32759 24-52) Sep. 1991 (AGARD-LS-175) Copyright Avail: NTIS HC/MF A10;
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The concept that conflicting sensory patterns of motion constitute the stimulus that in susceptible subjects gives rise to motion sickness, allows rational measures to be taken aimed at minimizing sensory conflict and thereby reducing the incidence of symptoms. Such measures add to the effectiveness of prophylactic drugs and may alone be sufficient to prevent motion sickness. It is well known among sailors and astronauts that continued or repeated exposure to an initially nauseogenic motion stimulus leads to a state of increased resistance to its effect. This provides a spontaneous cure for some individuals and forms the basis of therapeutic programs to assist others. The strategies that individuals can adopt to minimize their exposure to nauseogenic stimuli are presented, as well as with adaptation and its application to the treatment of chronic airsickness in aircrew. Also considered are some of the nonpharmalogical measures that have been used in the treatment of motion sickness. Author

N91-32768# Amsterdam Univ. (Netherlands). University Hospital.

ASSESSMENT OF DRUG EFFECTIVENESS

W. J. OOSTERVELD *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 8 p (SEE N91-32759 24-52) Sep. 1991 (AGARD-LS-175) Copyright Avail: NTIS HC/MF A10;
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The inhibitory effect was studied of Touristil, a combination of Cinnarizine 40 mg and Domperidone 30 mg, on the labyrinth. Each of these two compounds exerts a vestibular inhibition separately, albeit through different mechanisms. The activity of Cinnarizine (C) is rather slow at the onset, and reaches a maximum after 2 to 3 hours, while the peak effect of Domperidone (D) comes about more rapidly. It emerged from this study that the two separate compounds C and D, once in combination in Touristil (C+D), has a synergistic effect on the vestibular system in the form of an inhibition. The maximum reduction of about 60 pct. obtained is altogether exceptional and clearly underlines the potency of the new combination. Also, it is shown that Touristil is most effective in those subjects who are not affected by C, the most potent of the two, when given exclusively. As there is an obvious relationship between the inhibitory action of a drug on the labyrinth and its value as a medication against motion sickness, it may be concluded that Touristil is a very potent preparation against motion sickness. Author

N91-32769# Institute of Aviation Medicine, Farnborough (England).

MANAGEMENT OF ACUTE AND CHRONIC MOTION SICKNESS

J. R. R. STOTT *In* AGARD, Motion Sickness: Significance in Aerospace Operations and Prophylaxis 7 p (SEE N91-32759 24-52) Sep. 1991 (AGARD-LS-175) Copyright Avail: NTIS HC/MF A10;
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To the general physician, the problem of motion sickness typically is presented as a request for advice on how to avoid motion sickness when travelling, or during leisure activities such as gliding or sailing. More urgently, a doctor aboard ship in rough weather may be confronted with the need to treat individuals prostrated by repeated vomiting as a result of sea sickness. The military doctor may have to deal with the operational problem of air sickness in trainee aircrew, sea sickness in sailors, or motion sickness among troops transferred by air, in enclosed army personnel carriers, landing craft or tanks. Finally, because motion sickness may have financial implications by contributing to the failure rate in a costly training program, medical advice may be sought in order to minimize the economic problem of wastage in training. These and other factors are considered in the diagnosis and prophylactic treatment of motion sickness. Author

N92-13549# School of Aerospace Medicine, Brooks AFB, TX.

INTRODUCTION TO AEROSPACE NEUROLOGY

MARC S. KATCHEN *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 3 p (SEE N92-13547 04-51) Sep. 1991 (AGARD-AG-324) Copyright Avail: NTIS HC/MF A05;
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The bottom line in aerospace neurology is the evaluation for the: (1) potential of sudden incapacitation, e.g., post traumatic seizures; (2) possibility of a sudden neurological deficit which would

prevent the aircrew member from performing their job and thereby affect mission completion, flight or personal safety, e.g., neurologic deficits with headaches; and (3) risk of any neurologic or neuropsychologic deficit which would persist after the initial injury, e.g., post traumatic syndrome. Reasonable criteria for making an aeromedical decision in specific neurological syndromes are presented, and some work up guidelines are established. Areas of controversy are identified, and the aeromedical issues involved are raised.   Author

N92-13553# School of Aerospace Medicine, Brooks AFB, TX.
UNEXPLAINED LOSS OF CONSCIOUSNESS
MARC S. KATCHEN   *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 3 p (SEE N92-13547 04-51) Sep. 1991
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The unexplained loss of consciousness in aircraft crews is discussed, with emphasis on diagnosis. The several reasons for loss of consciousness are surveyed. The evaluation of unexplained loss of consciousness requires a detailed history from the subject and eye witnesses, and evaluation of vital signs and a physical and neurological examination, along with both detailed cardiovascular and neurological workups.   Author

N92-13550# School of Aerospace Medicine, Brooks AFB, TX.
SEQUELAE OF HEAD INJURY
MARC S. KATCHEN   *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 3 p (SEE N92-13547 04-51) Sep. 1991
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Closed head injury is discussed. The Aeromedical questions, after closed head injury, can be divided into three categories: (1) the risk of permanent neurological deficit; (2) the risk of sudden incapacitation; and (3) transient neurologic and neuro-psychological deficits.   Author

N92-13562# School of Aerospace Medicine, Brooks AFB, TX.
SELECTED CONCERNS/EXCESSIVE DAYTIME SLEEPINESS
MARC S. KATCHEN   *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 2 p (SEE N92-13547 04-51) Sep. 1991
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A retrospective study was performed involving all patients referred for the diagnosis of excessive daytime sleepiness between 1958 and 1987. A review of the literature was also performed, and the findings were compared with those reported from United States Sleep Laboratories. The evaluation of sleep disorders and the growth of sleep medicine are discussed.   Author

N92-13563# School of Aerospace Medicine, Brooks AFB, TX.
MULTIPLE SCLEROSIS AND OPTIC NEURITIS
MARC S. KATCHEN   *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 10 p (SEE N92-13547 04-51) Sep. 1991
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The literature review of the relationship of optic neuritis (ON) in multiple sclerosis (MS) is presented. It is our goal to review the world's literature to: (1) see what subpopulation of ON was identified to be at high risk for MS; (2) present a standard for working up and diagnosing MS; and (3) suggest a policy or establish research guidelines for handling ON in the aircrew population. In addition, we reviewed the cases of ON and MS evaluated at USAFSAM over the past 15 years to look for the patterns and effects on retention and flight safety.   Author

N92-13564# School of Aerospace Medicine, Brooks AFB, TX.
HEADACHE
MARC S. KATCHEN   *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 3 p (SEE N92-13547 04-51) Sep. 1991
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Headaches of some type were reported to occur in up to 70 percent of the population of the United States at some point in their lifetime. Vascular headaches are reported in up to 20 percent of this population. Our task is to properly classify the headache, discover any triggers or unique circumstances of the headache and decide if it is aeromedically significant.   Author

N92-13565# School of Aerospace Medicine, Brooks AFB, TX.
Aerospace Clinical Psychology Function.
MISHAP AFTERCARE
JOHN C. PATTERSON   *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 2 p (SEE N92-13547 04-51) Sep. 1991
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Of primary concern after a mishap are physical and somatic matters. Secondly, however, evidence is mounting that emotional and psychological adjustments to a mishap can be very important to various categories of victims who may be involved in a mishap. Relatively simple and straightforward psychological mishap aftercare principles are available and were tested in a variety of disaster scenarios. Victim identification and intervention are key concepts in mishap psychological aftercare.   Author

N92-18972# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
HIGH ALTITUDE AND HIGH ACCELERATION PROTECTION FOR MILITARY AIRCREW
Oct. 1991   264 p   In ENGLISH and FRENCH   Symposium held in Pensacola, FL, 27-30 Apr. 1991
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These proceedings include the technical evaluation report, the keynote address, and the 28 papers of the symposium. The papers addressed a variety of topics including (1) decompression sickness and ebullism at high altitude; (2) effects of high acceleration in terms of G-induced loss of consciousness (GLOC), positive pressure breathing (PBG), the anti-G straining maneuver (AGSM), and neck injury protection; (3) modeling effects of high acceleration on the cardiovascular system; (4) very high altitude protection; and (5) integrative protection equipment to high altitude, high acceleration, and other harmful stressors. For individual titles, see N92-18973 through N92-19000.

N92-18973# Air Force Systems Command, Brooks AFB, TX. Armstrong Lab.
DECOMPRESSION SICKNESS AND EBULLISM AT HIGH ALTITUDES
ANDREW A. PILMANIS and BARBARA J. STEGMANN (Krug Life Sciences, Inc., San Antonio, TX.)   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 11 p (SEE N92-18972 09-52) Oct. 1991
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The use of high altitude air space for military activities exposes flight crews to the hazards of near vacuum ambient pressures. Both the U.S. Advanced Tactical Fighter and the National Aerospace Plane will travel at heights where unprotected exposure to the environment leads to severe physiological consequences, including decompression sickness (DCS) and ebullism. Information about DCS occurring at or above altitudes of 40,000 feet is minimal. Theoretically, bubble growth will be rapid and latency of symptoms short. The ultimate DCS consequences of such high exposures, even very short ones, may be influenced by the pre- and post-events of a rapid decompression (RD), including prebreathing, and post-exposure medical intervention. Ebullism, or the

vaporization of body fluids, poses additional physiological risks to flight above 63,000 feet. Medical treatment protocols for ebullism in the event of accidental manned exposures to extreme altitudes do not exist. As research, training, and operational flights of new measures and treatment protocols becomes essential.   Author

N92-18975#   Air Force Systems Command, Brooks AFB, TX.
High Altitude Protection Function.
THE 1990 HYPOBARIC DECOMPRESSION SICKNESS WORKSHOP: SUMMARY AND CONCLUSIONS
ANDREW A. PILMANIS, ed.   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 4 p (SEE N92-18972 09-52)   Oct. 1991   Workshop held at Brooks AFB, TX, Oct. 1990
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    Decompression sickness resulting from exposure to the hypobaric environment was reviewed and discussed at a three-day workshop hosted by the U.S. Air Force in Oct. 1990. This milestone meeting updated the current understanding of this condition. Gaps in this understanding were identified based on input from both research and operational participants. The results of this workshop are summarized.   Author

N92-18976#   Krug Life Sciences, Inc., San Antonio, TX.
PREBREATHING AS A MEANS TO DECREASE THE INCIDENCE OF DECOMPRESSION SICKNESS AT ALTITUDE
BARBARA J. STEGMANN and ANDREW A. PILMANIS (Air Force Systems Command, Brooks AFB, TX.)   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 8 p (SEE N92-18972 09-52)   Oct. 1991
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    Prebreathing with 100 percent oxygen for protection against serious decompression sickness (DCS) is standard practice in the U.S. Air Force (USAF). Before prebreathing became routine, there were 18 reported deaths directly related to altitude DCS. Since prebreathing has become instituted, only one death has been reported. However, DCS cases still occur and are primarily associated with training in altitude chambers. At the Armstrong Laboratory (AL), Brooks Air Force Base, Texas, research on the use of prebreathing to enhance denitrogenation is directed at optimizing schedules for current operational requirements in both aviation and space. Concurrently, development of a decompression/denitrogenation computer is also underway. This analytical model is based on both laboratory and operational data bases, and will have both real-time and predictive capability. However, the accuracy of these data bases is in question. DCE reporting problems, inconsistencies in medical diagnosis, arbitrary classification of symptoms, historical variation in symptom definition, and the subjectiveness of intravascular bubble detection techniques must be taken into account before reasonable reliability can be applied to this model.   Author

N92-18977#   Air Force Systems Command, Brooks AFB, TX.
Armstrong Lab.
G-INDUCED LOSS OF CONSCIOUSNESS ACCIDENTS: USAF EXPERIENCE 1982-1990
TERENCE J. LYONS, RICHARD HARDING, JAMES FREEMAN, and CAROLYN OAKLEY   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 9 p (SEE N92-18972 09-52)   Oct. 1991   Previously announced in IAA as A92-20719   Prepared in cooperation with Air Force Inspection and Safety Center, Norton AFB, CA
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    A review of the 18 accidents attributable to loss of consciousness induced by high-G flight (G-LOC) is conducted to discuss potential acceleration-protection measures. The data show that all accidents are found to have significantly higher systolic blood pressure and fewer aircraft-specific flying hours than other pilots. The pilots seem to represent a typical cross section of the pilot pool in terms of personal variables. It is suggested that the most important variables contributing to the accidents are G

duration, G magnitude, the use of G trousers, and experience with the aircraft in question.   Author

N92-18978#   Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
PULMONARY EFFECTS OF HIGH-G AND POSITIVE PRESSURE BREATHING
DAVID H. GLAISTER   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 4 p (SEE N92-18972 09-52)   Oct. 1991
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    Since positive pressure breathing (PPB) can provoke syncope even at low gravity, its use to support the circulation and prevent G-induced loss of consciousness (G-LOC) appears somewhat of a paradox. Furthermore, when right heart pressures are normally only a few mm Hg, an alveolar pressure of 65 mmHg produced by PPB appears alarming, and concern has been expressed as to the advisability of enhancing G protection. The effects of acceleration and pressure breathing on the circulation, particularly within the lungs, are examined, and it is concluded that when one considers pressure differentials across the walls of the major vessels and heart chambers, these concerns are largely unjustified.   Author

N92-18979#   Defence and Civil Inst. of Environmental Medicine, North York (Ontario).
MAXIMUM INTRA-THORACIC PRESSURE WITH PBG AND AGSM
F. BUICK, J. HARTLEY, and M. PECARIC   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 9 p (SEE N92-18972 09-52)   Oct. 1991
(AGARD-CP-516; DCIEM-91-43)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from
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    Positive pressure breathing during $+Gz$ (PBG) and anti-G straining maneuvers (AGSM) each improve $+Gz$ tolerance by increasing blood pressure through increases in intra-thoracic pressure, but the maximal intra-thoracic pressure from their combined effect is not known. Six subjects performed: (1) maximal AGSM at $+1Gz$; (2) assisted PBG (constant 60 mm Hg) at $+Gz$; (3) submaximal AGSM at $+Gz$ (enough to maintain peripheral vision); (4) maximal AGSM at $+Gz$; and (5) combined PBG and maximal AGSM at $+Gz$. They wore: Tactical Life Support System (TLSS) mask/helmet ensemble, CSU-15/P G-suit, and TLSS-style jerkin. Intra-thoracic pressure (Pes) was measured with a catheter tip pressure transducer in the esophagus. Gastric pressure (Pga) was also measured. For both Pes and Pga, there were no significant differences among experimental conditions (1), (4) and (5). Group mean Pes and Pga in these 3 conditions were 139 and 197 mm Hg, respectively. The similar results between maximal AGSM, and maximal AGSM and PBG are explained by: (1) limited support from the thoracic counter-pressure garment, and (2) the characteristics of the respiratory system.   Author

N92-18980#   Air Force Systems Command, Brooks AFB, TX. Crew Systems Directorate.
THE INFLUENCE OF HIGH, SUSTAINED ACCELERATION STRESS ON ELECTROMYOGRAPHIC ACTIVITY OF THE TRUNK AND LEG MUSCLES
LARRY P. KROCK and MARK W. CORNWALL   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 4 p (SEE N92-18972 09-52)   Oct. 1991   Prepared in cooperation with Arizona State Univ., Flagstaff
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    This study investigated the level and pattern of trunk and lower extremity muscle activity in aircrew performing the anti-G straining maneuver (AGSM) at high, sustained $+Gz$. Ten male, trained centrifuge riders experienced rapid onset profiles (4G/s) to $+6$ Gz , and sustained this level on the Armstrong Laboratory's Human Centrifuge until greyout. Surface electromyography (EMG) was recorded from the erector spinae, lateral abdominal, biceps femoris, vastus lateralis, and lateral gastrocnemius muscles of the subject's dominant side. The normalized root mean square (RMS) and mean power frequency (MPF) were calculated for each muscle

at 1-second intervals throughout the exposure. The RMS amplitude for the muscles of the lower extremity showed a marked decrease (-61.45 percent) while muscles of the trunk exhibited a slight increase (+3.45 percent). The MPF of the EMG signal did not demonstrate a significant change during the exposure. Motor unit recruitment decreased in the lower extremity muscles during exposure. None of the studied muscles demonstrated a shift in the MPF suggesting evidence of fatigue. The results of the present study suggest the importance of maintaining a high level of muscle activity in the legs throughout exposure to sustained high levels of acceleration stress that require use of the AGSM. Author

N92-18981# Royal Netherlands Air Force, Soesterberg. Dept. of Aviation Medicine.
THE VALSALVA MANEUVER AND ITS LIMITED VALUE IN PREDICTING +GZ-TOLERANCE
E. J. VANLIESHOUT, J. J. VANLIESHOUT, J. KROL, M. SIMONS, and J. M. KAREMAKER (Amsterdam Univ., Netherlands) *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 4 p (SEE N92-18972 09-52) Oct. 1991
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The aim of the present study was to investigate, in healthy subjects, if responses to a cardiovascular reflex test, the Valsalva maneuver (VM), might be predictive for +Gz-tolerance. The main finding is a significant correlation between blood pressure recovery during VM and peripheral light loss (relaxed, before executing the M1/L1-manuever) (r = 0.63, p less than 0.05). All other parameters, including baroreflex sensitivity, did not significantly correlate with +Gz-tolerance. Furthermore intact baroreflex pathways were determined in all subjects. These results indicate that the parameters derived from the cardiovascular responses to VM may only confirm baroreflex integrity. Therefore VM might be used in the diagnostic process for fighter pilots with repeated +Gz-loss of consciousness inflight who are suspected of an orthostatic disorder. However in a healthy subject VM has limited value in predicting +Gz-tolerance. Author

N92-18983# Air Force Systems Command, Brooks AFB, TX. Human Systems Div.
SUBJECTIVE REPORTS CONCERNING ASSISTED POSITIVE PRESSURE BREATHING UNDER HIGH SUSTAINED ACCELERATION
KATHY MCCLOSKEY, LLOYD D. TRIPP, DANIEL W. REPPERGER, and STEPHEN E. POPPER *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 6 p (SEE N92-18972 09-52) Oct. 1991
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Assisted positive pressure breathing, as found in the Combined Advanced Technology Enhanced Design G Ensemble (COMBAT EDGE) system, was shown to have distinct advantages and disadvantages concerning the subjective opinion of the system under sustained acceleration. Advantages include subjects' perceptions of the system as an advancement in G-protection technology, personal projections of increased tolerance to G-forces, decreases in fatigue due to a lessening of straining maneuver effort, and an increase in breathing ease during acceleration, at least for subjects with COMBAT EDGE experience. Disadvantages include an increased incidence of arm pain, breathing difficulties for subjects new to the system, and a tendency to rely too much on the system in lieu of traditional straining maneuvers. It is recommended that a training regimen be established to address these issues before the COMBAT EDGE system is deployed operationally. Author

N92-18984# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Bretigny sur Orge (France). Div. de Biomecanique.
G-LOC. GZ AND BRAIN HYPOXIA. GZ/S AND INTRACRANIAL HYPERTENSION
P. QUANDIEU, D. GAFFIE, PH. LIEBAERT, M. BRIANE, J. C. SARRON (Direction des Recherches, Etudes et Techniques, Paris, France), A. GUILLAUME, D. TRAN, and J. PH. HAYMANN *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 15 p (SEE N92-18972 09-52) Oct. 1991 Sponsored in part by DRET G9
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The tilt of aircraft during a slow steep turn subjects the pilot to an acceleration which is colinear to the longitudinal axis of the body and can reach several times the acceleration of earth gravity. The purpose of this study is to propose a strictly biomechanic explanation of sudden inflight Loss Of Consciousness (LOC), i.e., brain nerve structures subject to Rapid Onset Rate (ROR) +Gz become functionally inefficient, not because of a shortage of oxygen, but because a sudden rise in brain mechanical stresses causes sudden intercranial hypertension. A simple model is proposed to analyze the following parameters: pressure distribution in the Cerebro-Spinal Fluid (CSF); distribution of stresses and deformations throughout the brain; and changes in blood flow pulsed into the skull. Calculations show the influence of a sudden change in flow rate causing collapses and supercritical flows sometimes followed by intravascular shocks. The first results of this modeling study indicate that ROR +Gz acceleration could augment mechanical stresses inside nerve tissues, and therefore result in sudden intracranial hypertension. Author

N92-18985# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France). Centre d'Essais en Vol.
ASSISTED POSITIVE PRESSURE BREATHING: EFFECTS ON +GZ HUMAN TOLERANCE IN CENTRIFUGE
J. M. CLERE and J. W. BURNS (Air Force Systems Command, Brooks AFB, TX.) *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 8 p (SEE N92-18972 09-52) Oct. 1991 In FRENCH and ENGLISH
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The goal of this paper is to present an experiment on the effect of Assisted Positive Pressure Breathing (APPB) as a method of increasing G-time tolerance and improving very rapid onset rate (VROR) tolerance using APPB equipment. Six male volunteers were tested on a USAF centrifuge. The equipment used was a helmet with an occipital bladder for automatic mask tightening, mask, jerkin and G-suit, breathing regulator, and high flow G-valve. A standard ejection seat was used, positioned at 30 deg. Acceleration profiles were 9 | Gz for 10 sec at 1 G s(exp -1) or 4 G s(exp -1) and a 5-9 +Gz Simulated Aerial Combat Manoeuvre (SACM) profile at 4 G s(exp -1), with and without APPB. The anti-G straining maneuver (AGSM) was used as necessary to maintain adequate vision. APPB was a maximum of 9 kPa (68 mmHg) at 9 +Gz. Heart rate was calculated and heart rhythm anomalies were detected by an EKG. APPB had no significant effect on VROR tolerance or heart rate. APPB statistically increased G-time tolerance (167.9 +/- 38.4 s with APPB and 88.4 +/- 23.1 s without APPB (p less than 0.001)). Author

N92-18986# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE OPTIMISATION OF A POSITIVE PRESSURE BREATHING SYSTEM FOR ENHANCED G PROTECTION
A. R. J. PRIOR *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 11 p (SEE N92-18972 09-52) Oct. 1991
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An electronic, computer controlled system was developed that allows full control of mask pressure and anti-G trouser inflation pressure in a pressure breathing anti-G system (PBG) installed on a human centrifuge. The apparatus was used to study the effect of different mask and trouser inflation pressures upon G protection in four subjects exposed to +Gz acceleration in the range 3 to 7

G while wearing full coverage anti-G trousers and a chest counter pressure waistcoat. Eye level arterial blood pressure was used as an objective measurement of G protection while subjective assessment of peripheral vision, anti-G trouser inflation pressure, mask pressure, and arm discomfort was measured using a ten centimeter line technique. The results show that eye level arterial blood pressure is better maintained as both mask and trouser inflation pressure are increased, however, peripheral vision was degraded to only 34 pct. of normal under any of the experimental circumstances. Subjectively, the preferred schedule of inflation for the anti-G trousers was 1.3 psi/G with a cut-in of about 2 Gz; for the PBG mask pressure it was 14 mmHg/G with a 3 Gz cut-in point. Arm pain occurred in all subjects and may be related to venous pressure.   Author

N92-18987#   Air Force Systems Command, Brooks AFB, TX. Crew Technology Div.
EFFECTS ON GZ ENDURANCE/TOLERANCE OF REDUCED PRESSURE SCHEDULES USING THE ADVANCED TECHNOLOGY ANTI-G SUITE (ATAGS)
L. J. MEEKER   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 4 p (SEE N92-18972 09-52)   Oct. 1991
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An advanced lower body full coverage anti-G suit was developed and is called the Advanced Technology Anti-G Suit (ATAGS). Previous centrifuge studies using standard pressurization schedules, flight tests, and theoretical considerations suggest that the ATAGS might provide equivalent G protection using reduced pressures. This study was conducted to determine the G protection afforded by ATAGS using a lower pressure schedule. Six test subjects were exposed to three separate G profiles during three test sessions. The profiles were: a gradual onset with the subject relaxed; a rapid onset to 9 G for 10 seconds with the subject performing an anti-G straining maneuver (AGSM); and a rapid onset 5 to 9 G Simulated Aerial Combat Maneuver (SACM) with 10 sec at each level, repeated to exhaustion. A different anti-G suit pressurization schedule was used at each test session. Data were analyzed by making statistical comparisons of performance between different pressure profiles, both for tolerance and endurance. Results suggest that the present standard of 10 to 8 psig at 9 G without reducing G protection, but that a pressure schedule resulting in 6 psig at 9 G is insufficient.   Author

N92-18989#   Drexel Univ., Philadelphia, PA.
A CARDIOVASCULAR MODEL OF G-STRESS EFFECTS: PRELIMINARY STUDIES WITH POSITIVE PRESSURE BREATHING
DOV JARON, THOMAS W. MOORE, and PIERRE VIEYRES   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 7 p (SEE N92-18972 09-52)   Oct. 1991
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To study possible means of ameliorating the effects of gravitational acceleration on the cardiovascular system, a nonlinear digital computer model was developed. It combines a variable compliance model of the left ventricle, multielement models of the aorta and the systemic and venous systems, and lumped models of peripherial vascular beds. The vascular elements are obtained from the solution of the Navier-Stokes equations, combined with a set of simplifying assumptions. This closed loop system includes heart rate control and venous tone control, and the effects of acceleration forces. The model also can simulate the effect of several modes of G protection, including the anti-G suit, straining maneuvers, positive pressure breathing (PPB), and seat back angle. In this study, this model was used to gain an understanding of the effects of positive pressure breathing on G tolerance and to compare these effects to other protection methods.   Author

N92-18990#   Biodynamics International, Halifax (Nova Scotia).
ASSESSMENT OF PHYSIOLOGICAL REQUIREMENTS FOR PROTECTION OF THE HUMAN CARDIOVASCULAR SYSTEM AGAINST HIGH SUSTAINED GRAVITATIONAL STRESSES
RICHARD COLLINS and EMILIA MATEEVA   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 12 p (SEE N92-18972 09-52)   Oct. 1991
(AGARD-CP-516)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Satisfactory performance of combat pilots exposed to rapid onset of high sustained gravitational stress (+G) is compromized by caudalward fluid shifts which provoke 'compensatory' responses from the central nervous system. Such neural, metabolic, and humoral responses can lead to dramatic alterations in the heart rate, stroke volume, cardiac output, myocardial contractility, and vascular tonus, with the clear danger of loss of vision, loss of consciousness, and myocardial fibrillation and ischemia. A simple but complete model of the coronary circulation is proposed as a framework for organizing a systematic research program for the passive and active control of this circulation under conditions of extreme g-stress. Within such a framework, preliminary conclusions can be drawn concerning the study of effective countermeasures designed to enhance pilot tolerance in air-combat maneuvers.
                                      Author

N92-18991#   Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Direction de l'Energetique.
CIRCULATORY BIOMECHANICS EFFECTS OF ACCELERATIONS
D. GAFFIE, P. QUANDIEU, PH. LIEBAERT, D. COHEN-ZARDY, T. DAUMAS, and A. GUILLAUME (Centre d'Etudes et de Recherches de Medecine Aerospatiale, Bretigny sur Orge, France)
In AGARD, High Altitude and High Acceleration Protection for Military Aircrew 15 p (SEE N92-18972 09-52)   Oct. 1991   Original language document was announced in IAA as A91-45645   Sponsored in part by DRET
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A general physical model of blood flow behavior in vessels is proposed, to have a better understanding of mechanisms which cause inflight loss of consciousness (LOC) in fighter pilots. The problem in the situation when heart work and external disturbances induced by aircraft motions are concomitant. Disturbances are both volume and surface changes. Calculations show that under certain conditions blood flow is limited to a change in flow rate. It can then be hypothesized that under the effect of a sudden load, LOC could be caused by a factor other than brain hypoxia resulting from blood pooling in the pilot's lower limbs.   Author

N92-18992#   Victoria Univ. (British Columbia). Dept. of Mechanical Engineering.
FINITE ELEMENT MODELING OF SUSTAINED +GZ ACCELERATION INDUCED STRESSES IN THE HUMAN VENTRICLE MYOCARDIUM
J. MOORE, B. TABARROK, and W. FRASER (Defence and Civil Inst. of Environmental Medicine, Downsview, Ontario)   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 7 p (SEE N92-18972 09-52)   Oct. 1991
(AGARD-CP-516)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Due to reports of endocardial hemorrhaging and myofibrillar degradation in swines undergoing high sustained +Gz accelerations, questions arise as to the possibility of cardiac tissue damage in humans subjected to similar Gz forces. Noninvasive cardiological techniques used during experiments seem too insensitive to provide data to determine the presence of any localized cardiac damage. In addition, these tests involve some risk to the subject. Hence, there exists the need for a model to predict possible tissue damage under high sustained +Gz accelerations. The development is presented of such a model for the analysis of +Gz induced stresses in the human ventricle myocardium. The model is based on the finite element method where the effects of finite displacements, large strains and nonlinear nearly incompressible materials behavior are accounted for. When experiments cannot be justified, the computational model can

provide valuable quantitative (gross distortions and predicted stresses) data on the effects of +Gz induced stresses in humans. Ultimately, the goal is to provide some form of cardiac risk assessment for pilots of high performance aircraft.   Author

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BEHAVIORAL SCIENCES

Includes psychological factors; individual and group behavior; crew training and evaluation; and psychiatric research.

N90-17275#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Aerospace Medical Panel.
HUMAN BEHAVIOUR IN HIGH STRESS SITUATIONS IN AEROSPACE OPERATIONS
Jun. 1989   200 p   In ENGLISH and FRENCH   Symposium held in Hague, Netherlands, 24-28 Oct. 1988
(AGARD-CP-458; ISBN-92-835-0517-4; AD-A212884)   Copyright
Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   These Proceedings include the Technical Evaluation Report, the Keynote Address, 20 papers and ensuing discussions from the Symposium sponsored by the AGARD Aerospace Medical Panel held in The Hague, The Netherlands from 24 to 28 October 1989. As the human operator is more and more clearly shown to be the limiting factor in the operational performance of modern aerospace systems, more and more rigorous selection criteria must be applied for psychological as well as medical selection of aircrew. This Symposium examined this problem from the point of view of human behavior in high stress situations specifically looking at incident and accident experience, personality traits, responses to stress and prediction of behavioral responses. These proceedings will be of interest to those involved with the psychological selection and/or assessment of aircrew. For individual titles, see N90-17276 through N90-17295.

N90-17276#   Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
CAUSES OF AIRCREW ERROR IN THE ROYAL AIR FORCE
J. W. CHAPPELOW   In AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 9 p (SEE N90-17275 09-53) Jun. 1989
(AGARD-CP-458)   Copyright   Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   One hundred and forty nine military flying accidents were investigated by psychologists. Inspection of the data collected revealed that nearly half of the accidents involved inadequacies in equipment design, training or administration. Cognitive failure was a major cause of aircrew error and was more often associated with underarousal than with overarousal. Overarousal made a significant contribution to aircrew error, but largely as a secondary factor, i.e., it was generally a consequence of mechanical problems, disorientation, or prior mishandling of the aircraft. Personality factors also made a significant contribution, and the data suggest two distinct types of problem. Life stress and high workload appeared not to play a major part in stress-related accidents. Fatigue was not a major factor, but was closely associated with cognitive failure.   Author

N90-17277#   Belgian Air Force, Brussels.   Medical Aerospace Center.
REVIEW OF SERIOUS AIRCRAFT ACCIDENTS IN THE BELGIAN AIR FORCE: CAUSES AND COMPARISON WITH SELECTION DATA Report, Sep. 1973 - Jun. 1986 [REVUE DES ACCIDENTS AERIENS GRAVES A LA FORCE AERIENNE BELGE: CAUSES ET COMPARAISON AVEC QUELQUES DONNEES DE SELECTION]
J-C. GENON, P. TECK, and P. VANDENBOSCH   In AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 12 p (SEE N90-17275 09-53)   Jun. 1989   In FRENCH
(AGARD-CP-458)   Copyright   Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   Methods used by the Belgian Air Force for the analysis of aircraft accidents are outlined. Accident base data and the causal factors employed in the analyses are described. Causal factors are grouped into three categories including human factors, inexperience, and external (non-human) factors. Accident data are presented for each factor in isolation and factors conjugated with other factors. The relation between causal factors and pilot selection data (psychometric and personality) is also examined.
Transl. by M.G.

N90-17278#   Royal Norwegian Air Force, Blindern.   Inst. of Aviation Medicine.
ACCIDENTS IN FIGHTER AIRCRAFT CAUSED BY HUMAN FACTORS. WHY DO THEY OCCUR
GRETE MYHRE   In AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 6 p (SEE N90-17275 09-53) Jun. 1989
(AGARD-CP-458)   Copyright   Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   Pilots in fighter aircraft represent a rigorously selected group both physically and psychologically. Still, more than half of the incidents and accidents involving these aircraft can be attributed to human factor overloading, even during routine operations. In what way is this high number of human error accidents explained, considering the fact that the psychological selection tests have never been more sophisticated and thorough than they are today. Possible reasons for and answers to this question are examined.
Author

N90-17279#   Aeronautical Research Inst. of Sweden, Stockholm.
PSYCHOLOGICAL REACTIONS OF PILOTS INVOLVED IN ACCIDENTS IN THE SWEDISH AIR FORCE
KRISTINA POLLACK   In AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 4 p (SEE N90-17275 09-53) Jun. 1989
(AGARD-CP-458)   Copyright   Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   Every aircraft accident could be described as a unique life-event, complex in nature with varying causes and effects. Studies of the emotional consequences of accidents in military aircrew are sparse. Data obtained from pilots involved in accidents was examined to learn their psychological reactions to accidents. As a part of the air safety program in the Swedish Air Force retrospective information was obtained from 40 pilots who had survived military aircraft crashes during 1978 to 85. In order to collect objective and subjective data all pilots completed comprehensive questionnaires covering the following areas: (1) the air crash; (2) how events happened during the ejection and the following rescue; (3) the medical consequences and the emotional sequels, i.e., reactions, thoughts and mood after survival; and (4) attitudes towards resuming flying duty. Free comments were encouraged in the responses to questions concerning desired psychological support and rehabilitation. Results are examined.
Author

53 BEHAVIORAL SCIENCES

N90-17280# Israeli Air Force Aeromedical Center, Tel Hashomer. Psychology and Psychiatry.
THE DESCENT FROM THE OLIMPUS: THE EFFECT OF ACCIDENTS ON AIRCREW SURVIVORS
I. BARNEA *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 9 p (SEE N90-17275 09-53) Jun. 1989
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Limited research has been done studying the effects of flying accidents on surviving aircrews (pilots and navigators). In general, it consists of case studies conducted by squadron medical staff focusing on serious problems developed by the pilot and/or his family as a result of the accident. The most significant finding of this research has been that the return to flying following an accident in flight is not as simple as it may appear. To consider an accident as part of the training routine and to expect return to normal activities as if nothing out of the ordinary has occurred is to ignore the legitimate emotional reactions of the aircrew and the possible effects of those reactions on the development of physical and psychological symptoms including deterioration of flying performance, motivation and commitment. Return to flying with hidden, untreated symptoms is likely to aggravate them, prolong their resolution or even make them irreversible resulting in the loss of flight personnel. Two objectives were persued: (1) to improve the understanding of the relationship between a flying accident, the resulting emotional reactions and their effect on performance levels; and (2) to develop an effective intervention procedure to enable the accident survivors to return quickly to preaccident functioning, both emotionally and professionally. Several aircrew survivors of serious flying accidents in the past five years participated in a research conducted by a psychologist using a structured interview especially developed for the present study. Results of the interview showed that 44 percent of the survivors reported a decrease in their flight performance and feeling toward flying than prior to the accident. Author

N90-17281# Air Force Human Resources Lab., Brooks AFB, TX. Personnel Research Psychologist.
PERSONALITY CHARACTERISTICS OF USAF PILOT CANDIDATES
FREDERICK M. SIEM *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 7 p (SEE N90-17275 09-53) Jun. 1989
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To examine the utility of personality measures for enhancing current selection methods, a computerized personality inventory was administered to a sample of USAF pilot candidates prior to flying training. Analysis of the data suggested that two of five personality factors were associated with training outcomes, and that one of the measures added predictive utility to test scores currently used for pilot selection. Candidates who were self-confident and not dogmatic manifested higher graduation rates than pilot candidates who were either less self-confident or more dogmatic (less flexible in their values). For a subset of respondents, performance scores were available for two phases of training. Examination of the data indicated that personality characteristics (depression, activity level) that did not differentiate training graduates from non-graduates were associated with better performance in two phases of flight training. In contrast, characteristics on which graduates and non-graduates differed (self-confidence, values flexibility) did not appear to be associated with performance scores during training. The main conclusion from this research is personality measures can contribute predictive utility to a pilot selection system over and beyond that displayed by currently operational aptitude measures. A second conclusion is that careful consideration must be made in the selection of both predictor and criterion variables in quantifying the relationships best suited for determining operational utility of personality measures. Author

N90-17282*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
LEADER PERSONALITY AND CREW EFFECTIVENESS: FACTORS INFLUENCING PERFORMANCE IN FULL-MISSION AIR TRANSPORT SIMULATION
THOMAS R. CHIDESTER and H. CLAYTON FOUSHEE *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 9 p (SEE N90-17275 09-53) Jun. 1989
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A full mission simulation research study was completed to assess the potential for selection along dimensions of personality. Using a selection algorithm described by Chidester (1987), captains were classified as fitting one of three profiles using a battery of personality assessment scales, and the performances of 23 crews led by captains fitting each profile were contrasted over a one and one-half day simulated trip. Crews led by captains fitting a Positive Instrumental Expressive profile (high achievement motivation and interpersonal skill) were consistently effective and made fewer errors. Crews led by captains fitting a Negative Communion profile (below average achievement motivation, negative expressive style, such as complaining) were consistently less effective and made more errors. Crews led by captains fitting a Negative Instrumental profile (high levels of Competitiveness, Verbal Aggressiveness, and Impatience and Irritability) were less effective on the first day but equal to the best on the second day. These results underscore the importance of stable personality variables as predictors of team coordination and performance. Author

N90-17283# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
REACTIONS TO EMERGENCY SITUATIONS IN ACTUAL AND SIMULATED FLIGHT
GLENN F. WILSON, JUNE SKELLY, and BRADLEY PURVIS *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 15 p (SEE N90-17275 09-53) Jun. 1989
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Four emergency situations occurred during inflight and simulated air-to-ground training missions. Heart rate data were recorded from the pilots as part of a study designed to determine the effects of mission segment and flight position. A 50 percent increase in heart rate was found to occur only during actual flight but not during simulated flight emergencies. Heart rate variability decreased in all cases but to a greater extent during the inflight emergencies. Author

N90-17284# Illinois Univ., Urbana-Champaign. Inst. of Aviation.
EXPERTISE, STRESS, AND PILOT JUDGMENT
CHRISTOPHER D. WICKENS, BARBARA BARNETT, ALAN STOKES, TOM DAVIS, JR., and FRED HYMAN *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 9 p (SEE N90-17275 09-53) Jun. 1989
(Contract C87-101376-2)
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Two studies are described of pilot judgment, examining the effects of stress and of expertise. Both studies were carried out on a computer-based aviation decision making simulation called MIDIS. In the first study the cognitive abilities of 40 instrument rated pilots, 20 novices and 20 experts were assessed. These pilots then flew the MIDIS simulator on a simulated cross country flight during which their performance on a number of in-flight decisions was assessed. Experts were more confident than novices, but did not perform more optimally. The pattern of ability differences that predicted novice performance was different from that which predicted expert performance. In the second study, 10 instrument-rated pilots flew a different flight on MIDIS under conditions of stress (imposed by time pressure, noise, financial risk, and task loading), while 10 subjects flew in a nonstressed control condition. Stress had different effects on different kinds of decision problems. It degraded performance on those problems imposing high demand on working memory, but left unaffected those problems imposing high demand on the retrieval of facts

from long term memory. The results are discussed in terms of the commonalities between the effects of expertise and stress, on the mechanisms of working memory and long term memory in pilot judgment. Author

N90-17285# Norwegian Underwater Technology Center Ltd., Laksevaag.
STRESS AND PERFORMANCE DURING A SIMULATED FLIGHT IN A F-16 SIMULATOR
RAGNAR J. VAERNES, MARIT WARNCKE, GRETE MYHRE, and ASBJORN AAKVAAG *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 9 p (SEE N90-17275 09-53) Jun. 1989 Prepared in cooperation with Institute of Aviation Medicine, Oslo, Norway
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Sixteen Norwegian F-16 pilots (average age = 24.2 years, average experience = 2.2 years) were tested before, during and after a 90 min flight in a F-16 simulator. During the flight different emergency operations and landings in difficult weather conditions had to be performed. The pilot performance was logged continuously during the flight (Accepted/Not accepted). Heart rate (HR)/heart rate variability (HRV) was monitored continuously. Saliva for cortisol analysis and urine for catecholamine analysis were sampled before and after the flight. Tests of anxiety (state and trait) and defense mechanisms (Plutchik's Life Style Index, LSI) were administered. In addition to the pilots' test results on Krag's Defense Mechanism Test (DMT), results on psychomotor performance from the selection period were used. The endocrine and the HR-results indicated that the pilots were very activated during the flight. A HR of 120 beats/min was registrated. There were significant correlations between endocrine levels and not-accepted performance. Pilots with high defense mechanisms were significantly less activated on HRV, but had more pilot errors. Pilots with high defense considered simulator training as less important and they also trusted more the instruments in the aircraft. There was a significant correlation between high defense and number of near miss episodes during real flights. The results confirm previous studies which have shown that high defense correlates both to endocrine activation and impaired performance during stress in high risk occupations. Author

N90-17286# Civil Aeromedical Inst., Oklahoma City, OK.
PERFORMANCE RECOVERY FOLLOWING STARTLE: A LABORATORY APPROACH TO THE STUDY OF BEHAVIORAL RESPONSE TO SUDDEN AIRCRAFT EMERGENCIES
RICHARD I. THACKRAY *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 7 p (SEE N90-17275 09-53) Jun. 1989
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The use of response/recovery to auditory startle as a laboratory technique for simulating some of the principal aspects of the initial shock phase of sudden emergency situations is examined. It is submitted that auditory startle, with its unexpectedness, pronounced autonomic reaction, fear-like subjective experience, and frequent behavioral disruption, approximates the response pattern to be expected in the initial shock phase of sudden traumatic emergencies, and that by studying the time course of performance recovery following startle, as well as individual differences in response/recovery, a better understanding may be gained of some of the variables related to extreme reactions displayed by individuals in real life emergency situations. Research studies on performance impairment/recovery following startle are reviewed. These studies include those dealing with initial reaction time to the startle stimulus itself, disruption and recovery rate of perceptual-motor (tracking) performance following startle, and the time-course of performance recovery in information processing tasks after exposure to startle. Data are also presented showing a relationship of several individual difference variables to performance response/recovery following startle. These variables include autonomic response to the startle stimulus and level of task proficiency prior to startle. Author

N90-17287# Spanish Air Force (23rd Wing), Talavera AFB.
PERIPHERAL NERVOUS VELOCITY OF CONDUCTION IN FIGHTER PILOTS
J. L. GARCIA ALCON, J. M. MORENO VAZQUEZ, J. E. CAMPILLO ALVAREZ, and A. GONZALEZ RONCERO (National Health Inst., Badajoz, Spain) *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 7 p (SEE N90-17275 09-53) Jun. 1989
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Fighter pilot is under an important stress because of his special professional activity. It origins an automatic response through neurohormonal mechanisms. The most important among these mechanisms is the catecholamins secretion. These hormones will produce very important changes in the general homeostasy. The peripheral nervous system and mainly its mielyn sheath, is highly sensitive to variations in the internal environment. When that sheath is damaged the rapidity of nervous impulse transmission decrease. The system for to know that injury, is through measuring of the nervous velocity of conduction. This work shows the abnormal behavior of sensitive nervous velocity of conduction in fighter pilots in depending of flight hours. The great consumption of oxygen could be the reason for that alteration. Authors have found an important increase in Catalase and Glutathione-Peroxidase, that enzymes are protective systems in front to oxidations. Author

N90-17288# University of Southern California, Los Angeles. Dept. of Human Factors.
TRAINING AND SELECTING INDIVIDUALS FOR HIGH LEVELS OF INFORMATION PROCESSING LOAD
DIANE DAMOS *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 5 p (SEE N90-17275 09-53) Jun. 1989
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Techniques are examined for training and selecting pilots to deal with high information processing loads. Models of human information processing are briefly reviewed, then four methods of selecting pilots who can process large amounts of information quickly are discussed. Three of these four methods (selection based on the Type A behavioral pattern, measures of specific timesharing abilities, and the specific multiple-task response strategy) are recommended either for immediate use or for more extensive evaluation. Automation, the development of timesharing skills, and the development of flexible visual scan patterns are techniques that could be used to increase a pilot's information processing rate. None of these techniques has a basic research data base sufficient for the development of operational training techniques. All three are, however, promising and should be pursued in a systematic fashion. Author

N90-17289# Naval Aerospace Medical Research Lab., Pensacola, FL.
PERSONALITY ASSESSMENT IN AVIATION SELECTION
DANIEL L. DOLGIN *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 7 p (SEE N90-17275 09-53) Jun. 1989
(AGARD-CP-458) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A comprehensive review of the personality literature as it relates to aircrew selection was conducted. The purpose was to identify specific tests that warrant further research as potential prediction instruments. Aviation selection techniques in the U.S. Navy and U.S. Air Force were reviewed. Individual tests used in aviation selection are discussed in terms of their results. The advent of performance-based personality assessment in the 1970s is examined, and implications for future test development are explored. The majority of personality instruments reviewed were invalid for pilot selection. In some cases, methodological difficulties may have obviated more promising results. Recommendations are made for continued research with several tests that appear to be both effective in pilot selection and psychometrically sound. Those recommended selection tests include the Defense Mechanism Test because of its effectiveness in predicting pilot training success

and safety in the Swedish and Danish forces. The Personality Research Form is recommended due to both its psychometric construction and current research efforts that are ongoing in the Canadian Armed Forces and U.S. Air Force. The Locus of Control is also proposed for both closer and continued attention. Other recommended selection instruments include the Work and Family Orientation Questionnaire and Extended Personality Attributes Questionnaire. Safety in aviation is also addressed as a major, emerging area of interest in the 1980s. Author

N90-17290# Bergen Univ. (Norway). Dept. of Physiological Psychology.
ACTIVATION: POSITIVE AND NEGATIVE EFFECTS OF THE ALARM SYSTEM IN THE BRAIN
HOLGER URSIN In AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 11 p (SEE N90-17275 09-53) Jun. 1989
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There is hardly any human activity where the level of wakefulness may have so dramatic effects on performance with consequences for life and death, as aviation and other forms of rapid transportation. All aspects of the problem area seem to be present: boredom and lack of attention during long periods of routine operation, bursts of activity at top performance level, and the possibility that there are long term effects which may be harmful in the long run. Numerically land transport is by far the most dangerous and costly operation, counted in lives lost or invalids produced. However, the concern herein is aviation, but the factors involved are general psychological and physiological principles valid for many types of activity. The mechanisms are actually biologically general as well, and some of the relevant data derive from animal experimentation. The mechanisms are examined in detail. Author

N90-17291# Ministry of Defence, London (England).
THE TRIALS AND TRIBULATIONS OF RAF DEFENCE MECHANISM TESTING
G. J. WALKER-SMITH In AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 6 p (SEE N90-17275 09-53) Jun. 1989
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The Defense Mechanism Test (DMT) is a projective personality test that was devised in Sweden, in the 1950s. It was designed to identify how individuals cope with a threat and to assess what defence mechanisms are used to protect the individual in a stressful situation. Swedish validity studies have shown that the DMT can predict training wastage and pilot error flying accidents. Consequently the DMT has been used for pilot selection. The test has also been used for Air Force pilot selection in Norway, Denmark, Greece and the Netherlands and is undergoing trials in other countries. Since 1976 empirical investigations have been carried out to test the validity of using the DMT to select Royal Air Force (RAF) pilots. Owing to methodological inadequacies, early RAF trials proved inconclusive. However, in 1984 a DMT trial was set up where the Swedish method of testing was followed. DMT scores were collected from a sample of 253 pilot trainees and their flying training results and flying accident involvement are being monitored. So far this DMT trial has shown that the DMT scores fail to predict flying training performance. The discrepancy between the RSwAF results and the RAF findings is considered. Author

N90-17292# Institut d'Aeronomie Spatiale de Belgique, Brussels.
PRINCIPLE GUIDELINES FOR THE PSYCHOLOGICAL SCREENING OF CANDIDATE PILOTS FOR THE BELGIAN AIR FORCE [LIGNES DIRECTRICES PRINCIPALES FONDANT LA SELECTION PSYCHOLOGIQUE DES CANDIDATS PILOTES A LA FORCE AERIENNE BELGE]
J-C. GENON and P. VANDERBOSCH (Belgian Air Force, Brussels.) In AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 5 p (SEE N90-17275 09-53) Jun. 1989
In FRENCH
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Various psychological testing and screening methods employed by the Belgian Air Force for the selection of pilots are described. Emphasis is given to the description of guidelines for the candidate selection process. Selection criteria, interpretation of results, functional models, and the use of simulation are also addressed. Transl. by M.G.

N90-17293# Institute for Perception RVO-TNO, Soesterberg (Netherlands).
PREDICTION OF SUCCESS IN FLIGHT TRAINING BY SINGLE- AND DUAL-TASK PERFORMANCE
P. G. A. M. JORNA In AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 10 p (SEE N90-17275 09-53) Jun. 1989
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Advanced technology has changed the type and the amount of information a pilot has to process. The military pilot is particularly involved in performing multiple tasks under difficult working conditions. Some aspirant pilots are not able to finish advanced training, apparently for reasons of an insufficient multiple task performance. A reduction of such attrition is highly desirable to reduce the cost of training. A test based on dual-task performance was developed to investigate the trainability of aspirant pilots to perform under such demanding conditions. The dual-task was a combination of a pursuit tracking task with preview and a continuous memory task (CMT). Aspirant pilots practiced the tracking task and were tested under single- and dual-task conditions. Dual-task performance was expected to be related to pilot aptitude as assessed by other criteria. The results were validated against the level of pilot aptitude as assessed by traditional selection procedures, a flight simulator test and advanced flight training for the Lockheed Orion and the Westland Lynx helicopter. Successful aspirants, now operational pilots, were characterized by their excellent performance under dual-task conditions. Less successful aspirants performed less efficient under dual-task conditions as well as single-task conditions, depending on how soon they failed in the selection and training process. Prior flying experience did not influence tracking performance and was not found to be a critical factor in predicting success in advanced or operational flight training. Author

N90-17294# Naval Aerospace Medical Research Lab., Pensacola, FL.
PREDICTING AIR COMBAT MANEUVERING (ACM) PERFORMANCE
G. R. GRIFFIN In AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 13 p (SEE N90-17275 09-53) Jun. 1989
(AGARD-CP-458) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A difficult aspect of predicting fleet pilot performance is acquiring meaningful and reliable, inflight criteria. Air Combat Maneuvering (ACM) performance was provided using performance-based laboratory tests and the VF-43 adversary squadron's grading of inflight ACM performance was evaluated in the Fleet Fighter ACM Readiness Program. In an initial evaluation, F-4 pilots performed in Fleet Fighter ACM Readiness exercises and completed performance-based perceptual motor and multitask tests. Results indicated that dichotic listening test measures, obtained during multitask conditions, could be used to reliably predict ACM inflight criteria. Results assigned by VF-43 adversary personnel can be

predicted reliably by an objective kill difference composite score and three subjective measures: situational awareness, mutual support, and energy management. These measures accounted for 78 percent of the variance with the OAG. A correlational analysis suggests that the VF-43 grading process is reliable and consistent. Author

N90-17295# Institute for Perception RVO-TNO, Soesterberg (Netherlands).
STANDARDIZED TESTS FOR RESEARCH WITH ENVIRONMENTAL STRESSORS: THE AGARD STRES BATTERY
L. C. BOER, E. W. FARMER, and GLENN F. WILSON (Aerospace Medical Research Labs., Wright-Patterson AFB, OH.) *In* AGARD, Human Behaviour in High Stress Situations in Aerospace Operations 16 p (SEE N90-17275 09-53) Jun. 1989
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Assessment of human cognitive performance under stress is highly desirable, but is hampered by lack of standardization. Most tasks used in stress research are based on the paradigms of Human Performance Theory, that are frameworks for the manipulation of variables, not yardsticks for assessing stressor effects. In consequence, the results of two different studies cannot be compared directly. Even if the studies used the same paradigm, the particular task may have differed on such variables as condition of testing, number of trials, amount of training, or type of stimuli. Thus, for applied work there is a need for standardization. The AGARD STRES battery (Standardized Tests for Research with Environmental Stressors) is described as proposed by AGARD. The battery consists of seven tasks based on widely-used paradigms. The seven tasks and a data-exchange format are described. Author

N90-17613# Cranfield Inst. of Tech., Bedford (England). Applied Psychology Unit.
PASSENGER BEHAVIOUR IN AIRCRAFT EMERGENCIES INVOLVING SMOKE AND FIRE
CLAIRE HARRISON and HELEN MUIR *In* AGARD, Aircraft Fire Safety 14 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A review of the accident literature has indicated that in aircraft emergencies involving smoke and fire both environmental and behavioral factors will influence passenger survival rates. These factors include the number of operational exits, the presence of toxic fumes, the extent to which anxiety, disorientation, feelings of depersonalization, panic, and behavioral inaction occur among the passengers. Furthermore, in situations in which life is placed under severe threat, in addition to the experience of fear, people will compete with each other in order to survive. As a consequence the orderly process of evacuation for which passengers are briefed, frequently breaks down and the behavior of passengers appears to be confused and disorderly. In an experimental program, a series of evacuation exercises were performed, in which incentive payments were made in order to introduce the element of competition which is known to lead to a disorderly evacuation in some aircraft accidents. Using this technique six configurations at the vestibule prior the type 1 exits, and seven seating configurations adjacent to the overwing exit were investigated. Author

N90-17615# Lufthansa German Airlines, Frankfurt (Germany, F.R.). Emergency Training.
FLIGHT CREW TRAINING FOR FIRE FIGHTING
ERNST-ALBRECHT LIMLEY *In* AGARD, Aircraft Fire Safety 6 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A description is contained of Lufthansa emergency training aspects for flight-and cabin crews in respect to fire fighting. It addresses topics as preventive measures, on board fire fighting equipment, measures in case of an on board fire, training for actual fire fighting, and future developments. Author

N90-28972# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
SITUATIONAL AWARENESS IN AEROSPACE OPERATIONS
Apr. 1990 200 p In ENGLISH and FRENCH Symposium held in Copenhagen, Denmark, 2-6 Oct. 1989
(AGARD-CP-478; ISBN-92-835-0554-9; AD-A223939) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The Symposium examined aviator situational awareness with consideration of conditions where problems occur, methods to assess situational awareness and latest methods for information management and presentation in the cockpit. Indications for future research needs were discussed. These Proceedings will be of interest to those involved with human perception and cognition and those responsible for design of modern aircraft cockpits. For individual titles, see N90-28973 through N90-28993.

N90-28973# Netherlands Aerospace Medical Centre, Soesterberg.
SPATIAL DISORIENTATION INCIDENTS IN THE RNLAF F16 AND F5 AIRCRAFT AND SUGGESTIONS FOR PREVENTION
A. KUIPERS, A. KAPPERS, C. R. VANHOLTEN, J. H. W. VANBERGEN, and W. J. OOSTERVELD (Amsterdam Univ., Netherlands) *In* AGARD, Situational Awareness in Aerospace Operations 16 p (SEE N90-28972 23-53) Apr. 1990
(AGARD-CP-478) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Controlled flight into terrain caused several accidents within the Royal Netherlands Airforce. Two hundred and nine RNLAF fighter pilots were interviewed to obtain information about the occurrence of spatial disorientation in flight. The incident, which left the greatest impression on each pilot, was analyzed. Thirty-four percent of those incidents is considered by the aviators as a very serious risk for flight safety. The incidents are caused by a combination of factors, of which weather conditions, psychological factors and visual reference are the most important. Visual and vestibular illusions are common, as well as certain psychological conditions which lead to a wrong perception of position or motion. The aspects of the sensation of disorientation are described in detail. All pilots have experienced disorientation in some way and 26 percent report that it has caused one or more narrow escapes. Seventy-three percent of the pilots report a greater susceptibility for disorientation in a F16, compared with other types of aircraft. Suggestions for prevention of disorientation accidents are given. Author

N90-28974# Northrop Corp., Hawthorne, CA. Aircraft Div.
A METHODOLOGY FOR THE OBJECTIVE MEASUREMENT OF PILOT SITUATION AWARENESS
MICA R. ENDSLEY *In* AGARD, Situational Awareness in Aerospace Operations 9 p (SEE N90-28972 23-53) Apr. 1990
(AGARD-CP-478) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The ability of the pilot to maintain situation awareness is recognized in the pilot community as crucial to mission success and survivability. The design of the pilot vehicle interface must therefore be guided by the goal of maintaining and enhancing pilot situation awareness. A formal definition of situation awareness is presented in addition to a detailed description of the Situation Awareness Global Assessment Technique (SAGAT). SAGAT was developed as an objective measure of a pilot's situation awareness, including pilot knowledge of ownship status, the tactical environment, his overall comprehension of the situation, and his ability to project the tactical situation into the near future. SAGAT allows for a variety of system design concepts to be evaluated on the basis of situation awareness, as well as workload and performance, thus providing the design community with a much needed tool. Author

N90-28975# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
SITUATIONAL AWARENESS RATING TECHNIQUE (SART): THE DEVELOPMENT OF A TOOL FOR AIRCREW SYSTEMS DESIGN
R. M. TAYLOR *In* AGARD, Situational Awareness in Aerospace Operations 17 p (SEE N90-28972 23-53) Apr. 1990
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Human engineering activities in aircrew system design traditionally were concerned with the reduction and management of operator workload. Recent advances in automation technology have radically changed the role of the human operator and highlighted the essential human function for making adaptive decisions in situations involving uncertainty. Improving and enhancing operator situational awareness has become the major crew station design driver for achieving survivability and mission effectiveness criteria. How aircrew understand situational awareness (SA) is investigated and tools were developed for its subjective estimation. Author

N90-28976# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
PERFORMANCE-BASED MEASURES OF MERIT FOR TACTICAL SITUATION AWARENESS
MICHAEL VENTURINO, WILLIAM L. HAMILTON, and STEPHEN R. DVORCHAK (Hamilton and Associates, Las Vegas, NV.) *In* AGARD, Situational Awareness in Aerospace Operations 5 p (SEE N90-28972 23-53) Apr. 1990
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Pilot situation awareness is not a well-understood concept. Most attempts at understanding situation awareness have relied almost exclusively on subjective reports, and have not led to a clear understanding of the concept. A performance based approach to assessing situation awareness, where the relationship between pilot-reported situation awareness and tactical task performance is investigated is represented. Aspects of a high realism air combat simulation were analyzed in terms of a priori hypotheses regarding performance of a tactical task (fire point selection), its relation to pilot-reported situation awareness, and its relation with mission outcome. Results showed that pilot-reported situation awareness by itself was not a reliable indicator of pilot performance (based on mission outcome). Further, pilot performance by itself was not systematically related to fire point selection. Only when the simultaneous operation of pilot performance, fire point selection, and pilot-reported situation awareness are considered does a systematic relationship emerge. The highest mission performance scores were associated with both a FPS within a preferred zone (80 to 100 percent RMAX2) and high pilot-reported SA ratings. Lower performance scores were observed as pilots' FPS diverged from the preferred FPS area and reported lower SA scores. The drop-off in mission performance is more severe when pilots launched their weapons inside the 80 to 100 percent RMAX2 area relative to launching outside this preferred area. These findings are interpreted in terms of fire point selection as one potential measure of merit for tactical situation awareness. Author

N90-28977# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
EVALUATION OF THE SITUATIONAL AWARENESS RATING TECHNIQUE (SART) AS A TOOL FOR AIRCREW SYSTEMS DESIGN
S. J. SELCON and R. M. TAYLOR *In* AGARD, Situational Awareness in Aerospace Operations 8 p (SEE N90-28972 23-53) Apr. 1990
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The Situational Awareness Rating Technique (SART) was developed as an evaluation tool for aircrew systems design. SART provides subjective estimates of attentional Demand and Supply, and ratings of Understanding, which are postulated to be the three primary components of situational awareness. While consistent with contemporary theories of cognition, the application of SART requires knowledge of performance. SART sensitivity seems likely

to depend on the contribution of skill, rule, and knowledge based behavior, and on the role of explicit and implicit knowledge in the candidate task situation. An evaluation of SART in three aircrew systems design studies with different task requirements is reported: (1) Multiple Task Compatibility Study; (2) Attitude Recovery/Attention-Switching Study; and (3) Warnings Comprehension Study. SART Demand, Supply, and Understanding ratings showed significant effects of experimental manipulations in all three studies. The relevance of the specific SART components was related to the contribution of skill, rule, and knowledge based behavior to the tasks. The SART ratings also highlighted weaknesses in the performance measures and improved their interpretation. Thus, in combination with performance measures, SART provides a powerful tool for aircrew system design. Author

N90-28978# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
ATTENTION GRADIENTS IN SITUATION AWARENESS
MARTIN L. FRACKER *In* AGARD, Situational Awareness in Aerospace Operations 10 p (SEE N90-28972 23-53) Apr. 1990
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A model of how people develop and maintain awareness was explored in a series of four experiments. These experiments focused on the role of attention allocation in situation awareness. All four experiments supported the hypothesis that attention is limited in supply contrary to recently proposed unlimited supply theories. Unlimited supply theories do not predict attention gradients in which more attention is allocated to some things than to others. Spatial awareness data from all four experiments showed that more attention was paid to enemy aircraft that directly threatened the subject than was paid to other aircraft. Experiment 2 showed that the resulting attention gradient steepened as enemy number increased: when attentional demand was increased by increasing the total number of aircraft, subjects seemed to increase the amount of attention paid to direct threats by reallocating attention previously paid to other aircraft. Experiments 3 and 4 provided additional support for the reallocation hypothesis by showing that less attention was paid to individual neutral aircraft when the number of enemy aircraft increased (even though the total number of aircraft had not changed). These data suggest that attention is allocated to objects based on the degree to which they threaten or can assist the subject's task performance. Author

N90-28984# Royal Aerospace Establishment, Farnborough (England). Human Factors Div.
THE SIMULATION OF LOCALIZED SOUNDS FOR IMPROVED SITUATIONAL AWARENESS
PETER L. N. NAISH *In* AGARD, Situational Awareness in Aerospace Operations 9 p (SEE N90-28972 23-53) Apr. 1990
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It is argued that, in everday life, the directional information available in sounds is automatically incorporated into the listener's overall awareness of the situation. The absence of such cues in the air-borne environment must inevitably impoverish the data base from which the pilot builds his appreciation of the situation. Experiments are reported, which indicate that modifying cockpit sounds, to give them a synthetic directional quality, would indeed facilitate spatial appreciation. Author

N90-28985# School of Aerospace Medicine, Brooks AFB, TX.
THE EFFECTS OF ACOUSTIC ORIENTATION CUES ON INSTRUMENT FLIGHT PERFORMANCE IN A FLIGHT SIMULATOR
TERENCE J. LYONS, KENT K. GILLINGHAM, DON C. TEAS, WILLIAM R. ERCOLINE, and CAROLYN OAKLEY *In* AGARD, Situational Awareness in Aerospace Operations 10 p (SEE N90-28972 23-53) Apr. 1990 Prepared in cooperation with Krug International, Houston, TX
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An initial version of an Acoustic Orientation Instrument (AOI)--in which airspeed was displayed as sound frequency, vertical velocity

as amplitude modulation rate, and bank angle as right-left lateralization-- was evaluated in a T-40 (Link GAT-3) motion-based simulator. Fifteen pilots and three non-pilots were taught to use the AOI and flew simulated flight profiles under conditions of neither visual nor auditory instrumentation (NO INPUT), AOI signals only (AOI), T-40 simulator instrumentation only (VISUAL), and T-40 simulator instrumentation with AOI signals (BOTH). Bank control under AOI conditions was significantly better than under the NO INPUT condition for all flying tasks. Bank control under VISUAL conditions was significantly better than under the AOI condition only during turning and when performing certain complex secondary tasks. The pilots' ability to use the AOI to control vertical velocity and airspeed was less apparent. However, during straight-and-level flight, turns, and descents the AOI provided the pilots with sufficient information to maintain controlled flight. Factors of potential importance in using sound to convey aircraft attitude and motion information are discussed.   Author

N90-28986# Los Alamos National Lab., NM.
WORKLOAD INDUCED SPATIO-TEMPORAL DISTORTIONS AND SAFETY OF FLIGHT: AN INVESTIGATION OF COGNITIVE INTRUSIONS IN PERCEPTUAL PROCESSES
CHRISTOPHER L. BARRETT and SCOTT A. WEISGERBER (Naval Weapons Center, China Lake, CA.) *In* AGARD, Situational Awareness in Aerospace Operations 9 p (SEE N90-28972 23-53) Apr. 1990 Previously announced as N90-14771
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A theoretical analysis of the relationship between cognitive complexity and the perception of time and distance is presented and experimentally verified. Complex tasks produce high rates of mental representation which affect the subjective sense of duration and, through the subjective time scale, the percept of distance derived from dynamic visual cues (i.e., visual cues requiring rate integration). The analysis of the interrelationship of subjective time and subjective distance yields the prediction that, as a function of cognitive complexity, distance estimates derived from dynamic visual cues will be longer than the actual distance whereas estimates based on perceived temporal duration will be shorter than the actual distance. This prediction was confirmed in an experiment in which subjects (both pilots and non-pilots) estimated distances using either temporal cues or dynamic visual cues. The distance estimation task was also combined with secondary loading tasks in order to vary the overall task complexity. The results indicated that distance estimates based on temporal cues were underestimated while estimates based on visual cues were overestimated. This spatio-temporal distortion effect increased with increases in overall task complexity.   Author

N90-28988#   Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
TRACKING PERFORMANCE AND INFLUENCE OF FIELD OF VIEW [PERFORMANCE DE TRACKING ET INFLUENCE DU CHAMP DE VISION]
PATRICK SANDOR and ALAIN LEGER *In* AGARD, Situational Awareness in Aerospace Operations 7 p (SEE N90-28972 23-53) Apr. 1990 In FRENCH
(AGARD-CP-478) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Eyesight with limited field of view becomes habitual with the use of optronic systems mounted on a helmet. In order to evaluate the influence of these devices on operator performance, the effect of several levels of visual restriction on the task of visual-manual tracking and on eye-head coordination, was tested. The performance is moderately reduced when the available field or view is small (20 deg), without improvement in the intermediate field (70 deg). The origin of this reduction must be researched bringing into play the adaptive neuro-sensory mechanisms needed for the limitation of the field rather than the restricted biomechanics imposed by the target motion range. This aspect obeys the analysis of the change of eye-head coordination tied to the string restriction of the field.   Transl. by E.R.

N90-28989# Italian Air Force Aerospace Medical Center, Rome. Neuropsychophysiology Group.
NEUROPHYSIOLOGICAL CORRELATES OF INFORMATION PROCESSING ABILITIES DURING DIVIDED ATTENTION SITUATIONS IN AIR TRAFFIC CONTROLLERS
S. PORCU, G. DELLERBA, L. RICCIO, M. PERONTI, and P. VENTURI (La Sapienza Univ., Rome, Italy) *In* AGARD, Situational Awareness in Aerospace Operations 9 p (SEE N90-28972 23-53) Apr. 1990
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The relationships that exist between arousal, cognitive functioning and generalized expectancy of control in a group of air traffic controllers (ATC), are studied in conditions of single and dual tasks. Furthermore, under the same conditions and based on performance outcome, evidence was sought of eventual differences in cognitive functioning which could be related to the diversity of professional ATC skills. Data show that arousal is increased in the dual-task: (1) N2 peak latency is positively correlated to arousal in both tasks; (2) correlates inversely with perceived control in the single task; (3) relates inversely with activation in the dual task; and (4) adjusted arousal correlates with perceived control. Finally, N2 peak latency appears to be sensitive to ATC skill.   Author

N90-28990#   Paris V Univ. (France). Lab. d'Anthropologie Appliquee.
LOSS OF ALERTNESS AND CONSCIOUSNESS FROM PILOT POSITION DURING LONG RANGE FLIGHT [BAISSE DE LA VIGILANCE ET CONSCIENCE DE LA SITUATION DES PILOTES AU COURS DE VOLS LONG-COURRIERS]
A. COBLENTZ, J.-P. FOUILLOT, R. MOLLARD, and PH. CABON *In* AGARD, Situational Awareness in Aerospace Operations 9 p (SEE N90-28972 23-53) Apr. 1990 In FRENCH
(AGARD-CP-478) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The variations in levels of alertness over the course of monotonous activities have been presented by many authors. In aeronautics, during long flight, these variations in alertness can reduce pilot performance and ability to an appreciable amount. After study of pilot behavior during this type of flight, ground based research was undertaken. The objective was to identify phases of hyperalertness and to evaluate their impact on pilot performance and its effect on consciousness. The method rests on the use of ambulatory techniques such as EEG, EOG, heart rate, and motor function of the pilot during flight, as well as the observation of the task. The first results in the preliminary phase, supported by eight long range flights, are presented.   Transl. by E.R.

N91-11358# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
RECRUITING, SELECTION, TRAINING AND MILITARY OPERATIONS OF FEMALE AIRCREW
Aug. 1990 173 p In ENGLISH and FRENCH Symposium held in Tours, France, 4-5 Apr. 1990
(AGARD-CP-491; ISBN-92-835-0576-X; AD-A229642) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
There are now approximately one thousand female military aviators flying within the NATO nations. The experience of each nation with recruiting, selection, training, and military operations of female aircrew was reviewed. In addition, a section was devoted to the discussion of the physiological differences between male and female aviators, pregnancy, and flying. Once selected, there appear to be no basic differences in flight capabilities between men and women. There is a requirement to develop smaller helmets, oxygen masks and NBC respirators for females; and data were presented which showed that females are more susceptible to decompression sickness. For individual titles, see N91-11359 through N91-11379.

53 BEHAVIORAL SCIENCES

N91-11359# Naval Air Station, Norfolk, VA. Fleet Logistics Support Squadron.
THE INTEGRATION OF WOMEN INTO US NAVY AIRCREW TRAINING AND SQUADRON ASSIGNMENTS
LINDA VAUGHT HUTTON   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 5 p (SEE N91-11358 02-53) Aug. 1990
(AGARD-CP-491) Copyright Avail: NTIS HC/MF A08;
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     Aviation and military service are non-traditional career choices for women. Though obvious, the fact remains crucial to the success of integration programs. Much is written and said about the average woman: size, weight, strength, mental acuity, leadership, competitiveness, and drive to excel. But discussions on the average woman are erroneous; the average woman does not seek non-traditional career paths. The woman who seeks a non-traditional military career will be an intelligent, outspoken student of above-average ability; confident, gregarious, and competitive by nature; active and athletically inclined; and routinely found in leadership positions. This dynamic over-achiever personality does not fit statistical norms for a population wide average woman. However, these attributes do fit military aviator candidate profiles; the reason for successful integration. Cultural attitudes and biases are displaced by time. However with forethought and planning, the integration of women into naval aircrew training and squadron assignments can progress smoothly. A planning outline which covers employment intentions, development of an accession model, flight training attrition, aviation retention, and addresses integration concerns and lessons learned is provided.   Author

N91-11360#   Canadian Forces Base Cold Lake, Medley (Alberta).
A CANADIAN FEMALE CF-18 PILOT'S EXPERIENCE
DEANNA MARIE BRASSEUR   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 5 p (SEE N91-11358 02-53) Aug. 1990
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     Educational experiences, early military career, flight training, advanced jet aircraft training, experience as a flight instructor, fighter aircraft training, and operational fighter squadron experience of a Canadian female CF-18 pilot are summarized.   Author

N91-11361#   Royal Netherlands Air Force, Soesterberg.
THE SELECTION, TRAINING, AND OPERATIONAL WORK OF FEMALE HELICOPTER PILOTS IN THE ROYAL NETHERLANDS AIR FORCE
MARIELLE WINNUBST   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 5 p (SEE N91-11358 02-53) Aug. 1990
(AGARD-CP-491) Copyright Avail: NTIS HC/MF A08;
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     In 1976 it was decided in the Netherlands to allow women into almost all functions within the armed forces, which included flying. Being one of the few female helicopter pilots of the 298 squadron for two years now, some of the practical problems female helicopter pilots in the R.N.L.A.F. were (and still are) faced with, are highlighted. Presently there are only 9 female helicopter pilots in the Netherlands Air Force; one female transport aircraft pilot; and one female jet aircraft pilot. Being unfamiliar with the last two categories, the experiences of myself, 8 female colleagues and the few predecessors are the focus of interest. Because of the low numbers, this is a highly personal account.   Author

N91-11362#   Air Force Human Resources Lab., Brooks AFB, TX.
COMPARISON OF MALE AND FEMALE USAF PILOT CANDIDATES
FREDERICK M. SIEM and LINDA L. SAWIN *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 7 p (SEE N91-11358 02-53) Aug. 1990
(AGARD-CP-491) Copyright Avail: NTIS HC/MF A08;
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     Female Air Force pilot candidates were compared to male candidates in terms of factors related to pilot training performance. The factors examined included selection test scores, background measures such as college academic performance and major, and ratings from a college military training program. Successful candidates of both sexes, compared to less successful candidates, had higher ratings and test scores, and also a higher percentage of technical majors and licensed private pilots. The data were analyzed for predictive equity or whether the utility of the factors for prediction of flying training outcomes differed for females and males. The results of regression analyses indicated that the factors examined were equally useful for candidates of both sexes.
                                                  Author

N91-11363# Naval Aerospace Medical Research Lab., Pensacola, FL.
NAVAL AVIATION SELECTION TEST SCORES AND FEMALE AVIATOR PERFORMANCE
DAVID J. BLOWER, DANIEL L. DOLGIN, and RONALD N. SHULL   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 5 p (SEE N91-11358 02-53) Aug. 1990
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     The majority of U.S. Navy pilots are white males. Of the 12,477 Navy pilots, only 225 (1.8 percent) are women. Navy women are prohibited from permanent assignment on ships or aircraft designated for potential combat missions. Data comparing female and male performance on aviation selection tests over the past five years is present. Female and male student naval aviator performance in primary flight training and on a cognitive/psychomotor test battery are compared. The data examined uncovered some differences in aviation selection test scores as well as differences in cognitive/psychomotor performance, but corresponding effect of these variables on success in primary flight training was discovered.   Author

N91-11364#   Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Hamburg (Germany, F.R.). Dept. of Aviation and Space Psychology.
SEX DIFFERENCES CONCERNING PERFORMANCE AND PERSONALITY TRAITS OF APPLICANTS FOR HIGHLY QUALIFIED OPERATOR FUNCTIONS IN AVIATION
KLAUS-MARTIN GOETERS and HINNERK EISSFELDT   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 6 p (SEE N91-11358 02-53) Aug. 1990
(AGARD-CP-491) Copyright Avail: NTIS HC/MF A08;
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     Today, in the West German civil aviation females apply for training as pilots as well as air traffic controllers. Female pilot applicants are still a minority of less than 10 percent. Representative data only exists in the area of air traffic control (ATC) where about 30 to 40 percent of all applicants are female. In the psychological selection of applicants for ATC training the rate of acceptance is significantly smaller for females than for males. Therefore sex differences were investigated in cognitive aptitudes as well as in aspects of personality. The results revealed clear deficiencies for the majority of female applicants in two basic operational aptitudes: spatial orientation and technical comprehension. A lower performance of females was also revealed with regard to mathematical reasoning. Advantages of the female group with respect to other aptitudes (English and perceptual speed) were found to be relatively small. Sex differences in personality were observed for aspects of emotionality, activity, and interpersonal behavior. Females scored higher in scales of

emotional instability, empathy, and achievement motivation, but lower in scales of vitality and dominance. Author

N91-11365# Institute of Aviation Medicine, Oslo (Norway).
PSYCHOLOGICAL AND SOCIOLOGICAL ASPECTS OF THE ENTRANCE OF FEMALE AIRCREW TO THE NORWEGIAN AIRFORCE
G. MYHRE, B. OVESEN, and M. MARTINUSSEN (Norwegian Defence Psychological and Educational Center, Oslo.) In AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 5 p (SEE N91-11358 02-53) Aug. 1990
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The total number of applicants for pilot screening and officer school in the Royal Norwegian Air Force (RNoAF) from 1982 to 1989 were studied in order to reveal the fate of female applicants during these years and establish if the females accepted represented a fairly constant percentage of the total number of applicants. The results from the psychological tests for 17 female applicants admitted to pilot screening and officer school were compared with those of the 173 accepted male applicants. A survey was performed in the RNoAF, in order to map the attitudes of squadron commanders and flight commanders (34 males) about their professional experience with the present female air crew in the RNoAF. In addition the females (5) answered questions regarding how they experience their situation seen from a female point of view. The results are briefly summarized. Author

N91-11366# Centro de Instruccion de Medicina Aeroespatial, Madrid (Spain).
EVALUATION OF FEMALE AND MALE AIRCREW APPLICANTS USING A COGNITIVE AND PSYCHOMOTOR TEST
MARQUEZ DELAPLATA In AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 3 p (SEE N91-11358 02-53) Aug. 1990
(AGARD-CP-491) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Spanish Institute of Aviation Medicine (CIMA) has developed a system and the equipment for the assessment of performance of complex tasks, which will be used for the evaluation of candidates cognitive and psychomotor abilities in order to become a pilot. This system also permits the investigator to evaluate the learning capability of an individual in those tasks. The equipment consists of the following: modules for the programming and emission of visual and auditory stimuli; desks with devices for transmission of stimuli (visor and headsets) and responses (two buttons and two pedals); and modules for the recording, counting, and timing of responses. The procedure requires that the subject has to give a response to the programmed stimuli according to a previous criterion established after the significant physical features of each stimulus, which were previously divided into four categories. This test was administered to a sample of 135 subjects, 115 males and 20 females; they were applicants for a commercial pilot license. The age ranged from 17 to 25 years, and nobody had any previous piloting experience. The goal of the experiment was focused on testing whether there were significant differences between men and women in the cognitive-psychomotor task assigned. In other words if the factor sex influences on the performance (R) and on the average time of response (T), considering as a null hypothesis that there are no significant statistical differences between the group of males and the group of females. The statistical analysis of the results obtained from each subject in both trials was oriented to verify the null hypothesis. The statistical analysis shows that the results obtained in the pilot applicants in the cognitive-psychomotor test proposed were not significantly different in men compared to women. Author

N91-11367# Defence and Civil Inst. of Environmental Medicine, North York (Ontario). Central Medical Board.
FEMALE AIRCREW: THE CANADIAN FORCES EXPERIENCE
R. J. HICKS In AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 6 p (SEE N91-11358 02-53) Aug. 1990
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Data collected since females first started aircrew training in Canada in 1979 is reviewed. Females are less successful than males in selective competition for training, but once into the training scheme there is no significant sex difference in achieving wings standard. Although numbers are still relatively small, female aircrew are now participating equally with their male peers in all aspects of military flying including tactical fighter operations. Author

N91-11368# Belgian Air Force, Brussels.
REVIEW OF FEMALE APPLICANT AIRCREW IN THE BELGIAN FORCES
C. VANCUTSEM and P. VANDENBOSCH In AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 5 p (SEE N91-11358 02-53) Aug. 1990 In FINNISH; ENGLISH summary
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The female applicant pilots in the Belgian Armed Forces were evaluated. In the period from January 1983 to July 1989, seventy-three female applicants were examined in the Centre of Aerospace Medicine. Only five of them were declared physically fit as a pilot, but no one could start the instruction. The physical reasons of rejection are studied according to the frequency in the total population, and ranked in accordance with the different criteria and the category of recruitment. A comparison is made between male and female applicants. The most frequent causes of rejection are: insufficient psychomotoric score, myopia, and too short legs. Author

N91-16558# Army Aeromedical Research Lab., Fort Rucker, AL.
A COMPARISON OF COMPUTERIZED MEASUREMENT OF HELICOPTER PILOT PERFORMANCE WITH ATROPINE SULFATE DURING ACTUAL AND SIMULATED FLIGHT
J. A. CALDWELL, JR. and H. D. JONES In AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 10 p (SEE N91-16553 08-54) Sep. 1990
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The requirement for aviators to operate under stressful circumstances raises concerns over both safety and effectiveness. Although appropriate countermeasures for stress induced performance deteriorations are available, the implementation of these countermeasures require that commanders know the time course and extent of the problem. For this reason, the U.S. Army has focused research on the practical assessment of helicopter pilot degradation using flight performance assessments which combine enhanced automation and objectivity with optimized data analysis procedures. Recently, the sensitivity, accuracy, and consistency of these assessment systems were demonstrated while studying the effects of atropine sulfate on aviator performance. Both simulator and helicopter systems detected atropine related performance problems across a variety of aircraft control parameters. Also, analysis of combined simulator and helicopter data showed remarkable consistency of effects across the two flight platforms. This verification of performance measurement using computerized schemes in both simulator and aircraft has substantiated a feasible methodology, and has helped the concept development of better assessment devices. Author

N91-16561# Paris V Univ. (France). Lab. d'Anthropologie Appliquee.
STUDY OF PILOT VIGILANCE DURING LONG RANGE FLIGHT [ETUDE DE LA VIGILANCE DES PILOTES AU COURS DE VOLS LONG-COURRIERS]
A. COBLENTZ, R. MOLLARD, PH. CABON, J. P. FOUILLOT, and VINCENT CARMIGNIANI (Direction Generale de l'Aviation Civile, Paris, France) *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 17 p (SEE N91-16553 08-54) Sep. 1990 In FRENCH
(AGARD-CP-490) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The various states of alertness and performance during the course of monotonous activity has been demonstrated by many authors. In transport aviation, the monotony often found associated with the cycle of irregular work and timeshift is important. The interaction of these factors contribute to the amplification of a drop in performance and vigilance. After a study of pilot behavior during long range flight, a project was started. The objective was to identify phases of hypovigilance and to evaluate the repercussions on pilot performance. The method used rest deprivation as an objective evaluation of physiological levels of pilot alertness together with an analysis of different activities of electroencephalogram (EEG), electro-oculagram (EOC), and electrocardiogram (ECG) during flight. The cardiac frequency and driving wrist activity were both recorded during flight and periods of rest. The driving wrist activity allows the acquisition of data on the activity-rest cycles of pilots. The observation of activity and of crew task is made simultaneously in this recording using a coded grid. Eight long range transmeridian flights, north-south was used during the first stage of protocol completion. The first results show large variations in the EEG spectra and in the frequency of eye movements. The alternation of phases during which the pilots show elevated vigilance with drowsiness were seen in each crew member. The deprivation of sleep during stopover show repercussions on pilot behavior. In particular, the lowest vigilance appear most pronounced during flight following a night with sleep deprivation, especially if the flight is during the next day.
Transl. by E.R.

N91-16562# Johann-Wolfgang-Goethe-Univ., Frankfurt am Main (Germany, F.R.). Zentrum der Physiologie.
COMPUTER AIDED PHYSIOLOGICAL ASSESSMENT OF THE FUNCTIONAL STATE OF PILOTS DURING SIMULATED FLIGHT
KURT OFFENLOCH and GISELA ZAHNER *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 9 p (SEE N91-16553 08-54) Sep. 1990 Sponsored by Dornier G.m.b.H. and Inspektion des Sanitaetswesens der Bundeswehr
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Multichannel (polygraphic) analysis of cardiovascular and neurophysiological parameters provides very sensitive indicators of the functional state of subjects such as pilots during real or simulated flight missions which thus can be objectively assessed. In 6 pilots flying a fighter jet simulator with ALPHA JET dynamic characteristics without self motion, systolic and diastolic blood pressure, four channel electroencephalogram (EEG), electrooculogram (EOG), and electrocardiogram (ECG) were continuously recorded during a rest-activity-rest sequence for 60 min. The activities consisted of tracking another plane flying ahead of the piloted plane with four different degrees of difficulty. The analysis of the data, especially those of the EEG by Fast Fourier Transformation (FFT), revealed task dependent, and in the case of EEG, topographically different cortical activities depending upon whether sensory and/or motor systems were involved. The physiological measures thus obtained can serve as an objective criterion to assess the functional state of pilots and may serve as part of an automatic safety network not only in the event of sudden loss of consciousness but also in cases of lowered cases of pilot vigilance due to fatigue.
Author

N91-16564# Dialogics S.A., Labege Innopole (France).
INTELLIGENT ASSISTANT SYSTEMS: AN ARTIFICIAL INTELLIGENCE APPROACH TO DETECTING PERFORMANCE DEGRADATION AND PILOT INCAPACITATION
GUY A. BOY *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 6 p (SEE N91-16553 08-54) Sep. 1990
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An artificial intelligence approach is presented to detecting performance degradation and pilot incapacitation. The motivations are discussed for Intelligent Assistant Systems in such situations. The problem of constructing procedures is shown to be a very critical issue. In particular, keeping procedural experience in both design and operation is critical. It is suggested what artificial intelligence can offer in this direction, and the concept of Integrated Human-Machine Intelligence is presented. Some crucial problems induced by this approach are discussed in detail. Finally, the various roles are analyzed that would be shared by both the pilot and the intelligent assistant system.
Author

N91-23711# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
HUMAN PERFORMANCE ASSESSMENT METHODS. ADDENDUM
ERIC FARMER, ed. Mar. 1991 78 p Lecture series held in Downsview, Ontario, 5-6 Jun. 1989; in Soesterberg, Netherlands, 12-13 Jun. 1989; and in Rome, Italy, 15-16 Jun. 1989
(AGARD-AG-308-ADD; ISBN-92-835-0600-6; AD-A235116) Copyright Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The results are presented of the second phase of AGARD Aerospace Medical Panel Working Group 12 on Human Performance Assessment Methods. The major goal of WG 12 was to develop the Standardized Tests for Research on Environmental Stressors or STRES Battery, satisfying conventional psychometric criteria such as reliability, validity and sensitivity for which an extensive data base may now be compiled among the NATO nations. The protocol for the 7 selected tests is presented. AGARDograph 308 also serves as the Lecture Series Notes for AGARD Aerospace Medical Panel Lecture Series 163, Human Performance Assessment Methods.
Author

N91-25130# Air Force Systems Command, Kirtland AFB, NM. Directorate of Aerospace Studies.
KNOWLEDGE EXTRACTION METHODS FOR THE DEVELOPMENT OF EXPERT SYSTEMS
MANUEL PEREZ, LEOPOLDO GEMOETS, and ROBERT G. MCINTYRE (Texas Univ., El Paso) *In* AGARD, Knowledge Based System Applications for Guidance and Control 10 p (SEE N91-25121 17-04) Apr. 1991
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The development of expert systems require the use of engineering techniques which can be used to efficiently and correctly extract the domain knowledge resident within the human expert. To apply these techniques, certain conditions must be met. These conditions are that the candidate expert system domain must be suitable for implementation, that there be a knowledge engineer with a certain level of domain knowledge, and that the right human domain experts be selected in the expert system development effort. A semi-sequential approach to development of techniques is presented which can be used to extract the knowledge from the human expert. Presented are both direct and indirect methods which a knowledge engineer can use to extract this knowledge.
Author

N92-13548# Centre Medical de Psychologie Clinique de l'Armee de l'Air, Paris (France).
THE PILOT FLIGHT SURGEON BOND
J. R. GALLE-TESSONNEAU *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 5 p (SEE N92-13547 04-51) Sep. 1991
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To become a physician it is necessary to learn medicine and to know diseases, but it is also necessary to have some notions about medicine psychology. To become a flight surgeon, it is necessary to know medicine and aeronautic medicine, but it is also necessary to have some notions about pilot psychology and pilot-flight surgeon relationships. Pilots are not ordinary patients; pilots present some particularities about health, diseases, medicine, and physicians. In the psychological cause, an initiation in theoretical notions and practical attitudes likely to clarify and make understandable phenomena which would otherwise risk appearing unintelligible is presented for the benefit of flight surgeons. As an introduction, three specific and important aspects in the psychology of a pilot are presented: his body, his motivation, and his environment. Author

N92-13550# Institute of Aviation Medicine, Oslo (Norway).
AVIATION PSYCHOLOGY IN THE OPERATIONAL SETTING
GRETE MYHRE *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 4 p (SEE N92-13547 04-51) Sep. 1991
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Being an aviation psychologist in a small airforce has its advantages, since one has to cover a wide spectrum of tasks, compared to the aviation psychologist in a large airforce who has to specialize in one or two fields. The main tasks of an aviation psychologist are discussed and include the following: (1) teaching flying personnel aviation psychology; (2) acting as a consultant to the aviators on personal matters; (3) performing surveys on the flying personnel's social and working conditions; (4) assisting the flight surgeons on medical boards; (5) acting as a member on aviation accident boards where human factors are involved; and (6) acting as a consultant in an operational setting. Two case histories are discussed that involve fighter pilots who ejected from their aircraft. Author

N92-13551# Jones (David R.), San Antonio, TX.
PSYCHIATRIC DISORDERS IN AEROSPACE MEDICINE: SIGNS, SYMPTOMS, AND DISPOSITION
DAVID R. JONES *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 3 p (SEE N92-13547 04-51) Sep. 1991
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The major categories of psychiatric diagnosis and how a few that are more commonly seen in aviators may affect flying duties are considered. Major psychotic disorders are always disqualifying, as are affective disorders, manic or depressive. Lesser depressive disorders may not be so, depending on the depth of symptoms, the reaction of the flyer, and his/her insight into the condition. Neurotic disorders may or may not require grounding, again depending on the degree of symptoms. Organic mental disorders are generally cause for permanent grounding, unless the cause is reversible and not likely to occur again (e.g., acute toxic reactions). Personality disorders are always troublesome, and are likely to be handled through administrative rather than medical channels. The general symptoms involved in these disorders are discussed in a later presentation. Psychiatric disorders are frequently underdiagnosed, both because operational personnel may not recognize these ailments for what they are and because of the tendency of some non-flying psychiatrists and psychologists to shield the flier from grounding by not accurately diagnosing what they see; by avoiding its proper name. This dangerous practice may allow possible dysfunctional fliers to fly, and deny them adequate treatment, specifically, medications. Author

N92-13552# Letterman Army Inst. of Research, San Francisco, CA.
PSYCHOLOGICAL FACTORS INFLUENCING PERFORMANCE AND AVIATION SAFETY, 1
JAMES J. PICANO *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 3 p (SEE N92-13547 04-51) Sep. 1991
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Two major psychological factors which can adversely affect health, flight performance, and decision making in aviation personal are discussed: stress and hazardous thought patterns. A model for understanding stress and appraising its effects on human performance in aviation is presented. Understanding the effects of stress on health and performance is essential to designing and implementing proactive preventive programs aimed at promoting and preserving the health and welfare of pilots and enhancing aviation safety. Author

N92-13554# Letterman Army Inst. of Research, San Francisco, CA.
ASSESSING ADAPTABILITY FOR MILITARY AERONAUTICS
JAMES J. PICANO *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 3 p (SEE N92-13547 04-51) Sep. 1991
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It is said that the most important sources of information regarding the potential adaptability of a pilot candidate is the flight surgeon's own response and impression regarding the individual. While this is a valid and important source of information, the flight surgeon must be careful not to rely on stereotyped or idiosyncratic ideas of what constitutes adaptability. As of yet, there is no convenient or accurate way of assessing adaptability for military aeronautics either psychometrically or by life history criteria. The information presented here serves as a guideline for the aeromedical examiner. If there is any doubt about the psychological suitability of an individual for military aeronautics, a consultation with a psychiatrist or psychologist familiar with aviation is recommended. Author

N92-13555# Institute of Aviation Medicine, Oslo (Norway).
DOMESTIC PROBLEMS AND AVIATOR FAMILY SUPPORT
GRETE MYHRE *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 3 p (SEE N92-13547 04-51) Sep. 1991
(AGARD-AG-324) Copyright Avail: NTIS HC/MF A05;
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The usefulness of wives' squadron groups in helping the wives of military pilots deal with their unique family situations is discussed. General psychology in relation to crisis situations is discussed, especially dealing with the feelings of grieving, loss, and mourning following an accident. Case studies are presented. Author

N92-13556# Centre Medical de Psychologie Clinique de l'Armee de l'Air, Paris (France).
FEAR OF FLYING
J. R. GALLE-TESSONNEAU *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 6 p (SEE N92-13547 04-51) Sep. 1991
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When a flyer talks about his apprehension about flying, it becomes a source of concern for his fellow pilots and leaders. Clinical aspects of the fear of flying are reviewed. Clinical forms with predominantly somatic expressions, forms with anxious expression, and neutoric disorders after an accident are discussed. Predisposing factors, promoting factors, triggering factors and prognosis are covered, as well as treatment. Author

N92-13557# School of Aerospace Medicine, Brooks AFB, TX. Aerospace Clinical Psychology Function.
PSYCHOMETRIC EVALUATION TECHNIQUES IN AEROSPACE MEDICINE
JOHN C. PATTERSON *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 2 p (SEE N92-13547 04-51) Sep. 1991
(AGARD-AG-324) Copyright Avail: NTIS HC/MF A05;
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The role of psychometric evaluation techniques in aerospace medicine is discussed, with emphasis on the use of psychological evaluation in making the decision of whether a pilot should return to flying after an illness. Aspects of the clinical review and psychological testing are discussed. It is argued that psychological testing should result in relevant recommendations about flying status based on the examiner's experience and the specific evaluation of the aviator. Author

N92-13558# Letterman Army Inst. of Research, San Francisco, CA.
PSYCHOLOGICAL FACTORS INFLUENCING PERFORMANCE AND AVIATION SAFETY, 2
JAMES J. PICANO *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 2 p (SEE N92-13547 04-51) Sep. 1991
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The psychological status of the pilot as it relates to performance is discussed. Two constructs related to this issue are explored: pilot judgment and hazardous thought patterns. The five basic hazardous thought patterns of anti-authority, impulsiveness, invulnerability, macho, and resignation are seen as precursors to faulty judgment. The five hazardous thought patterns represent an interesting exploration into pilot-centered processes which may mediate between an event and a pilot's decision making outcome. These constructs are in need of further validation, but education about hazardous thought patterns and the individual's appraisal of his own decision making processes could be easily incorporated into an aviator's continuing aeromedical education and training. Author

N92-13559# Jones (David R.), San Antonio, TX.
PSYCHIATRIC REACTIONS TO COMMON MEDICATIONS
DAVID R. JONES *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 2 p (SEE N92-13547 04-51) Sep. 1991
(AGARD-AG-324) Copyright Avail: NTIS HC/MF A05;
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The somatic effects of most non-prescription medications that are available to pilots usually well-known to flight surgeons, but some of the effects on mental processes may not be as well understood. Some of these are reviewed. Trifluoperazine, daizepam, chlordiazepoxide, flurazepam, triazolam, and temazepam are discussed. Author

N92-13561# School of Aerospace Medicine, Brooks AFB, TX.
THE FAILING AVIATOR
JOHN C. PATTERSON *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 2 p (SEE N92-13547 04-51) Sep. 1991
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The purpose is to increase the awareness and alertness in those who work with aviators about the early signs and symptoms of failure. Solutions can start by addressing the failure process early, by providing training in these areas of psychological functioning as parenting and marriage communication, by changing the selection process to include not only competitiveness and achievement, but also openness to emotional experience, and finally by improving the relationship between mental health providers, flight surgeons, and aviators. Author

N92-13566# Jones (David R.), San Antonio, TX.
MEDICAL OR ADMINISTRATIVE? PERSONALITY DISORDERS AND MALADAPTIVE PERSONALITY TRAITS IN AEROSPACE MEDICAL PRACTICE
DAVID R. JONES and JOHN C. PATTERSON (School of Aerospace Medicine, Brooks AFB, TX.) *In* AGARD, Neurological, Psychiatric and Psychological Aspects of Aerospace Medicine 4 p (SEE N92-13547 04-51) Sep. 1991 Submitted for publication
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Aeromedical/occupational decisions are hard enough to make when there is concrete evidence of disease, and they are even more difficult when the evidence consists of abstract symptoms rather than physical signs, as in the case of most psychiatric disorders. The behavior which is described concerns personality problems, which present as traits or as overt disorders. Author

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MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT

Includes human engineering; biotechnology; and space suits and protective clothing.

N90-14408# Forschungsinstitut fuer Anthropotechnik, Wachtberg (Germany, F.R.).
HUMAN FACTORS ASPECTS OF DECISION SUPPORT SYSTEMS
K. F. KRAISS *In* AGARD, Operational Decision Aids for Exploiting or Mitigating Electromagnetic Propagation Effects 14 p (SEE N90-14405 06-32) Sep. 1989
(AGARD-CP-453) Copyright Avail: NTIS HC A20/MF A03
Human factors aspects of decision support system (DSS) design and various relevant dimensions are identified in decision making and problems solving, followed by a discussion of characteristics and constraints in human information processing. On this basis, design goals and guidelines are identified. The implementation of DSS concerns the layout of the human computer interface, the degree of automation, as well as the selection of suitable decision aiding algorithms. It is shown that a novel systems architecture is needed to ensure cooperative task performance of the man computer team. Finally various problems of interacting with DSS and a compilation of available operational experience are addressed. Author

N90-15060# Army Aeromedical Research Lab., Fort Rucker, AL. Aviation Research and Development Activity.
IMAGING PROBABILITIES, GEOMETRY AND ERGONOMICS IN LIMITED VISIBILITY HELICOPTER OPERATIONS
ROBERT H. WRIGHT *In* AGARD, Flight in Adverse Environmental Conditions 11 p (SEE N90-15041 07-01) Sep. 1989
(AGARD-CP-470) Copyright Avail: NTIS HC A17/MF A03;
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Helicopter pilots using night vision systems have a low probability of seeing the best visual cues that are available for flight control. Even with good visual range, the forward view of current night vision systems looks where visual cues are geometrically insensitive to changes in vehicle states and motions. At terrain flight heights, best visual cues reflecting vehicle states and motions are located directly below the helicopter. As visual range attenuates, the best vision of the terrain retreats toward the same angles below the helicopter where the best flight control cues are found. Image and symbolic cues of night vision systems both preclude effective use of normal spatial-motion visual perception, which quickly processes the entire visual array in parallel with no or very low workload. Downward viewing display concepts should allow normal spatial-motion vision to function effectively, resulting in major reductions in pilot workload and training requirements, and safer flight control with poor visibility. At terrain flight heights most tactical visual cues are visually compressed in elevation angle within just a few degrees at the

horizon, but are widely dispersed in azimuth. Terrain obstacles to safe flight are also located within a few degrees of the horizon, but are well defined in azimuth by the velocity vector. It is concluded night vision systems could be improved by designing to better exploit geometric characteristics of visual cues and normal pilot spatial-motion visual processes. Author

N90-17614# Air Transport Users Committee, London (England). Air Transport Users Committee.
SMOKEHOODS DONNED QUICKLY. THE IMPACT OF DONNING SMOKEHOODS ON EVACUATION TIMES
J. H. B. VAN *In* AGARD, Aircraft Fire Safety 12 p (SEE N90-17581 10-03) Oct. 1989
(AGARD-CP-467) Copyright Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Seven hundred and sixty-five volunteers aged between 18 and 50 took part in 9 simulated emergency evacuations in clear air and smoke with and without ventilated smoke hoods. Analysis of differences between the experimental conditions, age, sex, seat location, exit, and test run showed that the key factor was seat location. While the wearing of hoods and the presence of smoke both increased the evacuation times the interaction between these separate factors was negative, indicating that the use of hoods in the presence of smoke was less than the sum of the additional times attributable to smoke and hood. A quadratic response surface model enabled the evacuation time for each seat to be predicted for each condition and show that evacuation time increases with the distance from an exit and the aisle. It was concluded that the wearing of smoke hoods should not significantly impede the ability of passengers to evacuate an aircraft cabin in an emergency. Author

N90-17616# Civil Aeromedical Inst., Oklahoma City, OK. Protection and Survival Lab.
THE RESEARCH PROGRAM AT THE CIVIL AEROMEDICAL INSTITUTE CONCERNING PROTECTIVE BREATHING EQUIPMENT FOR USE BY CREW AND PASSENGERS IN AN AVIATION SMOKE/FUME ENVIRONMENT
E. ARNOLD HIGGINS *In* AGARD, Aircraft Fire Safety 7 p (SEE N90-17581 10-03) Oct. 1989
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On June 3, 1987, a final rule defining Crew Protective Breathing Equipment (CPBE) was issued by the FAA. On September 1, 1987, Action Notice A-8150.2 (Guidelines for Approval of Crewmember Protective Breathing Equipment) established requirements and tests for certifying CPBE. The recommended method for testing contaminant leakage proved unsatisfactory when chemically-generated oxygen was used. The Civil Aeromedical Institute (CAMI) developed a new method, and has tested two candidate devices. This test method is discussed. Recent interest in reviewing the feasibility of providing passenger protective breathing equipment (PPBE) was stimulated, in part, by the British Airtours B0737 accident at Manchester, England, in August 1985. In October, 1986, the airworthiness authorities at Great Britain, France, Canada, and the United States initiated a coordinated effort to reevaluate PPBE. A history of CAMI involvement in the study of PPBE will be presented, as will the status of current activities in this program. Author

N90-20055# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Systems Div.
DEVELOPMENT OF ACCELERATION EXPOSURE LIMITS FOR ADVANCED ESCAPE SYSTEMS
JAMES W. BRINKLEY, LAWRENCE J. SPECKER, and STEPHEN E. MOSHER (DynCorp., Wright-Patterson AFB, OH.) *In* AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 14 p (SEE N90-20054 13-03) Feb. 1990
(AGARD-CP-472) Copyright Avail: NTIS HC A06/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Transient and angular accelerations significantly affect aircrew safety during emergency escape from aerospace vehicles. However, due to the scarcity of laboratory data on the response of the human body to transient, multiaxial acceleration, criteria for design and evaluation of escape systems were restricted to

relatively simplistic limits of acceleration magnitude and rate of acceleration onset for acceleration vectors acting in three orthogonal axes, with the exception of the foot-to-head direction (+Z axis). Mathematical models were only used to assess the probability of injury for acceleration acting in the +Z axis. Limits were not specified for angular acceleration. The United States Air Force is currently engaged in an advanced development program to demonstrate the feasibility of three-dimensional thrust-vector control to provide ejection seat attitude control and trajectory steering. This program has served to stimulate the development of more comprehensive design and evaluation criteria to assure that the thrust-vector control system functions without causing an unacceptable risk of injury to the escape system occupant. A method was developed to limit acceleration exposure on the basis of the computed responses of three orthogonal dynamic models. The method was initially developed using existing data from tests with human subjects and experience with operational escape systems. More extensive research is now ongoing to evaluate and improve the method. Impact experiments with volunteers were accomplished to more precisely define the properties of the dynamic response models. Escape system test data were analyzed, including measurements of linear acceleration and angular velocity. The acceleration exposure limit method is described, the results of recent impact tests accomplished with volunteers provided, and revised dynamic response model coefficients derived from the results of these tests. Recent applications of the acceleration exposure method include evaluation of the performance of the ACES II ejection seat, development of the CREST advanced escape system technologies demonstrator, and study of crew escape systems for hypersonic flight vehicles. Author

N90-20062# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Biodynamics and Bioengineering Div.
THE USAF ADVANCED DYNAMIC ANTHROPOMORPHIC MANIKIN (ADAM)
ROY R. RASMUSSEN and INTS KALEPS *In* AGARD, Implications of Advanced Technologies for Air and Spacecraft Escape 7 p (SEE N90-20054 13-03) Feb. 1990
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Ejection from aircraft at high speeds poses severe injury hazards to the crewmember. As performance characteristics of aircraft are further improved, the protection capabilities of ejection systems must also be improved to assure the safety of the crewmember. The demonstration of these ejection system improvements requires extensive testing with manikins to effectively evaluate the performance of the ejection seat and assess the injury potential to the crewmember. The United States Air Force (USAF) has embarked on a new effort to design and develop an Advanced Dynamic Anthropomorphic Manikin (ADAM) with improved human-like fidelity and data collection capability over currently available escape system testing manikins. This effort has resulted in the development and fabrication of two prototype (one small and one large) instrumented, anthropomorphic manikins for testing and evaluation and the production of ten manikins to be used in ejection and other protection system testing. Discussed will be the design objectives and resulting features of ADAM and a summary of testing results for exposure to extreme temperature and humidity environments; Gz low level vibration; and Gx, Gy and Gz whole body impacts. Author

N90-27767*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE DYNAMICS OF ORBITAL MANEUVERING: DESIGN AND EVALUATION OF A VISUAL DISPLAY AID FOR HUMAN CONTROLLERS
STEPHEN R. ELLIS (California Univ., Berkeley.) and ARTHUR J. GRUNWALD *In* AGARD, Space Vehicle Flight Mechanics 13 p (SEE N90-27741 22-18) Jun. 1990
(AGARD-CP-489) Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 05/8

An interactive proximity operations planning system, which allows on-site planning of fuel-efficient, multi-burn maneuvers in a potential multi-spacecraft environment was developed and tested. Though this display system most directly assists planning by providing visual feedback to aid visualization of the trajectories

and constraints, its most significant features include an inverse dynamics algorithm that removes control nonlinearities facing the operator and a trajectory planning technique that reduces the order of control and creates, through a geometric spread-sheet the illusion of an inertially stable environment. This synthetic environment provides the user with control of relevant static and dynamic properties of way-points during small orbital changes allowing independent solutions to the normally coupled problems of orbital maneuvering. An experiment was carried out in which experienced operators were required to plan a trajectory to retrieve an object accidently separated from a dual-keel space station. The time required to plan these maneuvers was found to be predicted by the direction of the insertion thrust and did not depend on the point of separation from the space station.   Author

N90-28979# Royal Aerospace Establishment, Farnborough (England).
TOWARDS A FUTURE COCKPIT: THE PROTOTYPING AND PILOT INTEGRATION OF THE MISSION MANAGEMENT AID (MMA)
C. P. GIBSON and A. J. GARRETT (British Aerospace Public Ltd. Co., Kingston-upon-Thames, England)   In AGARD, Situational Awareness in Aerospace Operations 9 p (SEE N90-28972 23-53) Apr. 1990
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The Mission Management Aid (MMA) Joint Venture (MMAJV) is a three phase program, the objectives of which are to: (1) establish the functional requirements and feasibility of a device(s) such as the MMA; (2) to prove the techniques for accomplishing this in a rapid prototyping environment and produce a set of functional specifications; and (3) to optimize the MMA functionality and develop the MMI on a real time Mission Capable Simulation (MCS). With the ever increasing trend towards complex integrated avionics systems and the increased level and capability of threat anticipated in future hostile scenarios, the requirement for the pilot of the single seat aircraft to maximize his situational awareness at all times must be one of the prime issues in driving the development of such systems. The requirement is outlined for the MMA and the major functional areas of sensor fusion, situation assessment, dynamic planning and the Man-Machine Interface are introduced. Some of the Human Factors issues associated with the introduction of an intelligent Mission Management Aid (MMA) and the increasing need to promote situational awareness are discussed. Issues relating to the design requirements and evaluation of such systems are also discussed.   Author

N90-28980# School of Aerospace Medicine, Brooks AFB, TX. Crew Technology Div.
THE THREE-DIMENSIONAL STRUCTURE OF VISUAL ATTENTION AND ITS IMPLICATIONS FOR DISPLAY DESIGN
FRED H. PREVIC In AGARD, Situational Awareness in Aerospace Operations 7 p (SEE N90-28972 23-53) Apr. 1990
(AGARD-CP-478) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The ability to direct attention toward far visual space while maintaining good spatial orientation is imperative for pilots of high performance fighter aircraft. In actuality, this task is quite similar to that performed during such everyday activities as reaching and locomotion. A theoretical analysis of the three-dimensional (3-D) structure of visual attention and its involvement in normal perceptual activities leads to the conclusion that far attention is: (1) biased toward the upper right visual field; (2) associated with saccadic scanning confined to the central 30 degs of the visual field; and (3) primarily utilized in performing local perceptual processes. In properly designed aircraft displays, then, far attention can be encouraged both by restricting local perceptual analyses to certain regions of the visual field, and by enabling attitude control to be performed using more global (ambient) mechanisms.   Author

N90-28981# Central Electricity Generating Board, Gloucester (England).
A REAL TIME EVALUATION OF THE USE OF A PERSPECTIVE FORMAT TO PROMOTE SITUATIONAL AWARENESS IN USERS OF AIR TO AIR TACTICAL DISPLAYS Abstract Only
D. RIDLEY In AGARD, Situational Awareness in Aerospace Operations 1 p (SEE N90-28972 23-53) Apr. 1990
(AGARD-CP-478) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Networked data systems such as JTIDS (Joint Tactical Information Distribution System) promise a substantial increase in the amount of information available to aircrew involved in air defense. This will include more detailed information regarding relative heights of hostile and friendly airborne units. Such information will be an important factor in BVR (Beyond Visual Range) air defense engagements using missiles such as AMRAAM (Advanced Medium Range Air to Air Missile). On the basis of psychological theory it was predicted that a perspective display format, would allow a greater volume of situational awareness data to be shown intuitively than would be the case with a conventional plan format. Specifically it should allow information regarding relative height to be more easily comprehended. A real time, cockpit based, air defense simulation was used to compare pilot performance using a perspective situational awareness display with performance with an equivalent plan view display. Twelve subjects were instructed to attack and destroy a constantly evading target aircraft that had to be distinguished from a number of hostile aircraft. Performance measures showed that subjects had more difficulty in learning to use the perspective display. However once they were familiar with this format their results were significantly better than those achieved using the plan display. These results are discussed with reference to requirements for air defense displays in general and networked data displays.   Author

N90-28982# Human Engineering Labs., Aberdeen Proving Ground, MD.
COUNTERAIR SITUATION AWARENESS DISPLAY FOR ARMY AVIATION
CHRISTOPHER C. SMYTH, FRANK J. MALKIN, and WILLIAM B. DEBELLIS In AGARD, Situational Awareness in Aerospace Operations 10 p (SEE N90-28972 23-53) Apr. 1990
(AGARD-CP-478) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

An air combat display concept is proposed for Army aviation helicopter cockpits. The effects of the choice of the display size, the display symbol size, and the area of coverage as a counterair situation awareness display are discussed. The display shows the tracks of aircraft about the host helicopter on a Planar Position Indicator (PPI) graph via the open broadcast radio net of the division-wide air defense radar coverage. The display is used to alert the aircrew to the presence of aircraft in the area and cue to the location of enemy threats for the counterair role. It is concluded that with the relatively small display sizes used in helicopters, an accurate determination of the position of enemy threats during air-to-air combat cannot be made by an aviator from the PPI alone. It must be interactive allowing access to detailed information about a track of interest to be useful.   Author

N90-28983# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
TARGET ACQUISITION UNDER LOAD FACTORS: ADVANTAGES AND DISADVANTAGES OF A HELMET MOUNTED SIGHT [DESIGNATION D'OBJECTIFS SOUS FACTEUR DE CHARGE: INTERET ET LIMITES DU VISEUR DE CASQUE]
A. LEGER and PATRICK SANDOR In AGARD, Situational Awareness in Aerospace Operations 10 p (SEE N90-28972 23-53) Apr. 1990 In FRENCH
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Helmet mounted viewfinders are actually considered as a possible means for improving the consciousness of the situation of combat pilots. The potential advantage of this type of device can depend on the opening up of cramped aircraft interiors, like the $+Gz$ acceleration of air to air combat. An experimental study

in a centrifuge was conducted in order to attempt an evaluation of the impact of +Gz acceleration on the designated function of the helmet mounted viewfinder. The results show that up to +5Gz, the reduction of tracking performance under delayed load factor is moderated. These are tied to biomechanical characteristics and functional method of eye-head coordination.   Transl. by E.R.

N91-11369# Defence and Civil Inst. of Environmental Medicine, North York (Ontario).
AIRCREW/COCKPIT COMPATIBILITY: A MULTIVARIATE PROBLEM SEEKING A MULTIVARIATE SOLUTION
KEITH C. HENDY   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 8 p (SEE N91-11358 02-53) Aug. 1990
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Aircrew/cockpit compatibility depends on an interaction between the anthropometry of individual aircrew members and the geometry of the cockpit. Selection criteria in the past have attempted to deal with this interaction, but the model was too simple. This is a multi-variate problem which requires a multi-variate solution. Essentially the problem is one of charging the region of intersection between the anthropometric data domain and a set of rules or criteria which define operability. The nature of this problem was demonstrated through computer simulated fitting trials of subjects in a number of cockpit-like geometries. The simulations clearly demonstrate that membership in a particular category of fit depends on interactions between workspace and anthropometry which are geometry specific. Further, the simulations show that the establishment of analytical expressions to define class membership is complex and appears to require a nonlinear approach. The consequences of these results are discussed in terms of establishing selection standards and determining design criteria for cockpits which are compatible with these standards. It is argued that cockpit design must be based on an extensive sampling of human characteristics in order that the full range of interactions, between various anthropometric dimensions and the workspace, is represented.   Author

N91-11371# Defence and Civil Inst. of Environmental Medicine, North York (Ontario).
ANTHROPOMETRIC ACCOMMODATION OF FEMALES IN CANADIAN FORCES AIRCRAFT CREW STATIONS
P. L. ROTHWELL and R. A. PIGEAU   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 13 p (SEE N91-11358 02-53) Aug. 1990
(AGARD-CP-491) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
To ensure physical accommodation of humans in aircraft crew stations, aircrew traditionally were selected on the basis of specific standards. To be effective, these standards must be based on anthropometric limitations imposed by actual crew stations. Evidence suggests this generally is not the case. Instead, selection standards have frequently evolved from (1) aircraft design recommendations, which often bear little relationship to the finished product, or (2) anthropometry of existing aircrew, which ignores the issue. Recognizing this problem, the Canadian Forces (CF) has undertaken a large-scale study known as ACCE (Aircrew/Cockpit Compatibility Evaluation). A computer-based modelling strategy was developed to determine anthropometric limitations, on a crew station by crew station basis, and their subsequent effect on accommodation of pilot and navigator populations. The approach is attractive because it encompasses possible multivariate relationships between anthropometry and crew station geometries, and it is sub-population independent; it assumes a human anthropometry but is blind to gender, nationality, and race-specific differences. The flexibility of this strategy has allowed assessments of fit for both female and male populations in two CF aircraft - the CT133 utility jet and the CH136 light observation helicopter. Results show that current CF selection standards do not represent the range of anthropometry these aircraft can accommodate. This leads to biases in selection against females and small males.   Author

N91-11372#   Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
PROBLEMS POSED BY THE ADAPTATION OF PHYSIOLOGICAL PROTECTIVE EQUIPMENT FOR FEMALE COMBAT PILOTS [PROBLEMES POSES PAR L'ADAPTATION DES EQUIPEMENTS DE PROTECTION PHYSIOLOGIQUE AUX PILOTES FEMININS D'AVIONS DE COMBAT]
D. LEJEUNE, J. C. AMICHAUD, A. TURILLON (Aerazur C.A., Issy-les-Moulineaux, France), J. M. CLERE, and H. MAROTTE   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 4 p (SEE N91-11358 02-53) Aug. 1990 In FRENCH; ENGLISH summary
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Female pilots would have to pilot fighter in the future. The problem of adaptation for flight equipment is induced by this new population of pilots. The specific female equipment functioning is studied from theoretical basis and from the literature. Operational solutions are presented for high G protection, thermal stress induced by C.W. flight equipment. Some questions are, today, without response and require further laboratory experiments.   Author

N91-11373#   Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
SOME EQUIPMENT PROBLEMS ASSOCIATED WITH THE INTRODUCTION OF FEMALE AIRCREW INTO THE ROYAL AIR FORCE
G. M. TURNER   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 3 p (SEE N91-11358 02-53) Aug. 1990
(AGARD-CP-491) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Female aircrew have been employed for several years as Air Loadmasters operating on VC10 transport aircraft. When it was required that all transport aircrew be issued with nuclear, biological and chemical (NBC) protective equipment an anthropometry and sizing exercise was conducted with 21 randomly selected female loadmasters. The problems experienced are described and related to the anthropometry data. Mention is also made of the anticipated problems with the Royal Air Force's recent decision (1989) to train female pilots and navigators.   Author

N91-11374#   Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
MORPHOLOGICAL AND FUNCTIONAL ADAPTATION OF PERSONAL EQUIPMENT DESIGNED FOR FEMALE PERSONNEL [ADAPTATION MORPHOLOGIQUE ET FONCTIONNELLE DES EQUIPEMENTS DE VOL DESTINES AUX PERSONNELS FEMININS]
H. MAROTTE, D. LEJEUNE, G. GUTMAN, R. BEAUSSANT, P. PELLOUX-GERVAIS, and R. ZAPATA (L'Air Liquide, Sassenage, France)   *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 3 p (SEE N91-11358 02-53) Aug. 1990 In FRENCH; ENGLISH summary
(AGARD-CP-491) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Personal equipment is dedicated to protecting aircrews against adverse effects during flight. The equipment operates either in close loop or in open loop. In close loop situations, there is a control of the protective device in relation to the user's demand so that such equipment creates only a few problems. It is not so with open loop equipment. In this case, there is only a statistical relationship between functional characteristics of the equipment and the user's needs. It is especially difficult to adapt the equipment to females. As far as respiratory protection equipment is concerned, such problems were noticed in open loop equipment for technical aircrews and in closed circuit smoke-hoods for cabin attendants.   Author

N91-11375# Naval Air Development Center, Warminster, PA. Dept. of Air Vehicle and Crew Systems Technology.
ACCOMMODATION OF FEMALE AIRCREW IN USN PROTECTIVE FLIGHT CLOTHING AND EQUIPMENT
S. M. REEPS, H. T. PHEENY, and J. A. BRADY (Naval Aerospace Medical Research Lab., Pensacola, FL.) *In* AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew 7 p (SEE N91-11358 02-53) Aug. 1990
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The number of United States Navy aviation designated female personnel has increased substantially over the past two decades. Along with this increase has come the ever pressing requirement to provide these aircrew members with safe and effective protective clothing and life support equipment. A variety of problems which have arisen in attempting to accommodate the female aircrew in a clothing and equipment system which was designed for a male population are discussed. Although no overall integrated approach was employed in this effort, a review of the various methods and solutions which were successfully employed to address both the particular needs of individuals and the specific items of clothing and equipment are discussed. Based on a review of problem reports and personal contacts with currently designated female aircrew personnel, many problem areas remain. These areas are discussed as they will provide the basis for future work in this continuing effort. Author

N91-12685# Ferranti Defence Systems Ltd., Edinburgh (Scotland).
PILOT MONITORING OF DISPLAY ENHANCEMENTS GENERATED FROM A DIGITAL DATA BASE
PETER J. BENNETT and JOHN J. COCKBURN *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 7 p (SEE N91-12682 04-08) Apr. 1990
(AGARD-CP-456) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A Ferranti International integrated covert mission system called PENETRATE (Passive Enhanced Navigation with Terrain Referenced Avionics) is currently undergoing flight trials on a Hunter fast-jet aircraft at the Royal Aerospace Establishment. The heart of the PENETRATE system is a digital data store housing a three dimensional model of the terrain including cultural details and tactical intelligence information. This integrated mass memory store supplies data to a Terrain Referenced Navigation System, a head-down digital map and a head-up Skeletal Perspective Terrain Image Generator. The integrity of the terrain data loaded into this covert system cannot be totally guaranteed; neither can the navigation accuracy. The pilot must, therefore, use his normal visual technique to monitor the synthetic terrain displays for acceptable correlation with the real world. The PENETRATE integrated covert mission system, the increase in operational capability it provides, and the visual monitoring requirements are described. Author

N91-12693# Royal Aircraft Establishment, Farnborough (England).
RESEARCH INTO A MISSION MANAGEMENT AID
J. R. CATFORD and I. D. GRAY (Ferranti Ltd., Chadderton, England) *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 10 p (SEE N91-12682 04-08) Apr. 1990
(AGARD-CP-456) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Pilot workload in fighter aircraft is ever increasing, driven by the need to fly low and the complexity of the systems and weapons in modern aircraft. The density and growing sophistication of Warsaw Pact anti-aircraft weapon systems greatly exacerbate the problem. The current European trend towards single seat fighter aircraft, on grounds of system and manpower costs, increases the workload problem still further. The research project, is directed to put the crew back in charge by introducing new levels of weapon systems automation. The Mission Management Aid (MMA) is scheduled for clearance into service in the first decade of the next century and although it is confidently expected that the

airborne computing power to perform the task will be available in that timescale, the complementary disciplines to design, test, and validate such a system needs to be developed. The current research program is concentrated on the timely development of these disciplines. The basic functional approach to the MMA was outlined some four years ago. Research into the MMA is being undertaken jointly by the four industrial organizations and the Royal Aerospace Establishment (RAE). The current program which was running for two years, involves seconded staff from the industrial organizations and the RAE, Farnborough where the team is located. It is very evident that current fighter aircraft systems are composed of a number of well tested evaluated and validated sub-systems and yet the integrated system tends to exhibit serious operational problems and a long time delay before modifications to clear these problems can be introduced. It is hence essential that the more complex systems of the next century exhibit characteristics that allow for rapid modification to meet changing operational needs and yet maintain essential operational integrity through these changes. Author

N91-16553# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
SAFETY NETWORK TO DETECT PERFORMANCE DEGRADATION AND PILOT INCAPACITATION
Sep. 1990 120 p In ENGLISH and FRENCH Symposium held in Tours, France, 2 Apr. 1990
(AGARD-CP-490; ISBN-92-835-0580-8; AD-A231148) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The proceedings from this conference are presented. Recent advances in technology are making feasible the concept of a Safety Net system, temporarily overriding the authority of the partially or fully incapacitated pilot until he/she is able to resume full control of the aircraft. The current status of technological developments, as well as philosophical issues which must be addressed are reviewed. For individual titles, see N91-16554 through N91-16564.

N91-16556# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Acceleration Effects Branch.
CURRENT STATUS OF AN ARTIFICIAL INTELLIGENCE-BASED LOSS OF CONSCIOUSNESS MONITORING SYSTEM FOR ADVANCED FIGHTER AIRCRAFT
WILLIAM B. ALBERY and ROBERT E. VANPATTEN (Van Patten, Robert E., Bellbrook, OH) *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 8 p (SEE N91-16553 08-54) Sep. 1990
(AGARD-CP-490) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

During the past decade, fourteen U.S. Air Force pilots lost their lives and aircraft to gravity induced loss of consciousness (GLOC). GLOC is not a new problem, it has been around for over 70 years. Because of the emergence of high performance aircraft such as the F-16 and F-15 and the fact that these aircraft can perform beyond the acceleration tolerance limits of the human, GLOC has become the U.S. Tactical Air Force's second most serious human factors problem, second only to spatial disorientation. To date, there exists no monitoring system in USAF aircraft to detect when a pilot has become incapacitated due to GLOC. The incorporation of high G onset training and a special centrifuge training facility will help reduce, but not eliminate, the GLOC problem. The current status is presented of a LOC detection and recovery system being developed. Author

N91-16557#   Defense Advanced Research Projects Agency, Arlington, VA. Tactical Technology Office.
FRAMEWORK FOR AN EFFICIENT TWO FILTER GLOC MONITOR
DENNIS K. MCBRIDE and ELIZABETH A. DAVIES (Naval Air Test Center, Patuxent River, MD.)   *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 7 p (SEE N91-16553 08-54) Sep. 1990
(AGARD-CP-490) Copyright Avail: NTIS HC/MF A06;
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A multiple filter Gravitational Loss of Consciousness (GLOC) design framework was derived. The framework recognizes the computational limitations of current and modified airborne avionics suites. The sequential gating approach minimizes load on supporting computer resources. As context and symptoms dictate, however, appropriate processing is applied. The framework is introduced as a provocative statement of design constraints inherent in 1970's jet architectures. The simplicity of design and implementation minimizes software engineering requirements, and holds hardware/interface development to but one requisite innovation; a helmet integrated, ICS capable earplug that would serve as a blood velocity, Doppler sensing and transdusing agent.
Author

N91-16559#   British Aerospace Public Ltd. Co., Bristol (England).
EEG INDICATORS OF MENTAL WORKLOAD: CONCEPTUAL AND PRACTICAL ISSUES IN THE DEVELOPMENT OF A MEASUREMENT TOOL
M. R. HICKS   *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 7 p (SEE N91-16553 08-54) Sep. 1990
(AGARD-CP-490) Copyright Avail: NTIS HC/MF A06;
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A first objective in the development of a pilot state monitor is the development of a lab tool capable of measuring mental workload. Several general performance benchmarks are identified that facilitate the evaluation of such techniques and a recent program of research is described and assessed in the light of these criteria.
Author

N91-16560#   Royal Aerospace Establishment, Farnborough (England).
OPTIMISATION OF OPERATIONAL WORKLOAD LEVELS USING NEUROPHYSIOLOGICAL AND COGNITIVE TECHNIQUES
D. W. BURGESS, J. A. CHILLERY, S. JENSEN, and A. HALL   *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 7 p (SEE N91-16553 08-54) Sep. 1990
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Extremes of operational workloads were identified and assessed using either existing measures, e.g., NASA TLX, SWAT, etc., together with neurological measurements. Data already exists from specialist labs which show a reliable increase in the DC levels of brain activity with increasing workloads. In order to optimize workloads, the objective of future missions are predicted and analyzed. Following this detailed task analysis, timeline analysis and attentional demand analysis are used to identify the extent to which particular cognitive channels, e.g., visual, auditory, and psychomotor are being used at any one time. In parallel with this analysis, evoked response techniques are developed from the lab studies towards man mountable apparatus for in-flight use. This requires the development of low noise electrically isolated DC amplifiers of high dynamic range design to obtain physiological data from the man with the minimum of operator support. An aim is to provide a high degree of perceived realism in lab tasks including the accomplishment of secondary tasks.   Author

N91-16563#   Man-Made Systems Corp., Ellicott City, MD.
DEVELOPMENT OF A TEST-BED FOR REAL-TIME MONITORING OF PILOT MENTAL STATUS
RICHARD L. HORST, DAN T. SMITH, and JOHN K. NEBEL (Advanced Resource Development Corp., Columbia, MD.)   *In* AGARD, Safety Network to Detect Performance Degradation and Pilot Incapacitation 9 p (SEE N91-16553 08-54) Sep. 1990
(AGARD-CP-490) Copyright Avail: NTIS HC/MF A06;
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AGARD/Scientific Publications Executive
The real time determination of pilot mental and physical status is a critical feature of the workload monitoring and Mindware subsystems that have been envisioned for future jet aircraft. Recent lab and simulator studies, using retrospective data analyses, have suggested the value of various behavioral and physiological indices for reflecting task performance. Software algorithms were developed to derive some of these measures in real time and to develop a test bed in which to explore the efficacy of these measures for inferring operationally relevant changes in pilot status. The project showed the feasibility and usefulness of the approach. Data processing algorithms were developed for characterizing and integrating physiological indices based on heart rate and heart rate variability, eye blinks, and single trial, scalp recorded event related po' · 'als. These physiological measures were obtained concurre   ..ith behavioral measures as subjects performed a PC based, aviation simulation task. The data processing algorithms were implemented in a distributed processing configuration, using multiple personal computers, with the derived measures being integrated by a decision maker multiprocessor.   Author

N91-18077#   Military Airlift Command, Scott AFB, IL.
AIRCREW FATIGUE COUNTERMEASURES
STEPHENS F. MCCAULEY   *In* AGARD, Progress in Military Airlift 6 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
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Since the earliest days of aviation, there have been aircraft accidents (now referred to as flight mishaps). In earlier times, mechanical malfunctions were blamed for the greater number of mishaps. Engineering and technological advances, however, have since lowered the likelihood of machine-induced mishaps. Now, the man part of the equation (in a chain of events leading to a mishap) is far more likely to be the primary cause. Thus, as aircraft are made more durable, reliable, and better able to sustain increased workloads, the humans who operate them must find ways to adapt or cope with the greater demands which result from improved machine capability. The bottom line question for today surfaces as: What causes crewmembers to commit errors in judgment, performance, or perception, and how might the influences of such causes be reduced. Progress in the field of human factors (HF) analysis has revealed some solutions while advancing the fundamental goal of flight safety - mishap prevention. The impact of HF studies on mishap prevention is clarified and summarized and how aircrew fatigue is a common denominator among HF elements is shown. Accepted techniques for combating and coping with fatigue are listed. Finally, recommendations on how to maintain operational awareness of aircrew fatigue considerations are proposed.   Author

N91-18078#   Military Airlift Command, Scott AFB, IL. Test and Evaluation Div.
AIRCREW EYE/RESPIRATORY PROTECTION: A MILITARY AIRLIFT COMMAND PERSPECTIVE
JAMES SOUSA   *In* AGARD, Progress in Military Airlift 9 p (SEE N91-18067 10-03) Dec. 1990
(AGARD-CP-495) Copyright Avail: NTIS HC/MF A14;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
The effort of the Military Airlift Command (MAC) and the Air Force System Command (AFSC) to improve aircrew eye/respiratory protection (AERP) in the chemical defence environment is summarized. The significant effort to plan the concept, manage the acquisition, design the system, test the system, and redesign the system to meet the MAC requirements is discussed. The MAC mission to conduct and support operations remains the same during war and peacetime and despite the presence of chemical agents. An effective AERP system is needed to support the worldwide

operations. The ongoing test effort has uncovered important problems and challenges to overcome. However, after hundreds of ground and over 50 flight test hours in the MAC mission environment, solutions are on the way. More challenges exist now, but the numerous hurdles already cleared have prepared a way to proceed. Author

N91-21720# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel Working Group 14.
HIGH G PHYSIOLOGICAL PROTECTION TRAINING
1991 98 p
(AGARD-AG-322; ISBN-92-835-0596-4; AD-A235181) Copyright
Avail: NTIS HC/MF A05; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
High-G physiological protection training is currently of importance to NATO Air Force operations because of a deficiency in g protection methods. This deficiency can, and on occasion does, result in G-induced Loss of Consciousness (G-LOC). Consequently, these methods are supported and supplemented by increasing their effectiveness through: increased understanding of the physiologic basis of g protection, development of advanced g protection concepts, knowledge of the system and basis of G-LOC, identification of the existence and location of human use centrifuges in NATO countries, increased physical conditioning, improved training of pilots on the centrifuge, and establishment of training goals and standards. These topics are addressed at a scientific or technical level of knowledge that is possessed by everyone involved in acceleration research, g training, flying, or designing and building high performance aircraft. At the end of each chapter is a brief summary in both English and French.
Author

N91-25602# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
OCULAR HAZARDS IN FLIGHT AND REMEDIAL MEASURES
May 1991 121 p In ENGLISH and FRENCH Symposium held in London, England, 22-26 Oct. 1990
(AGARD-CP-492; ISBN-92-835-0616-2; AD-A237593) Copyright
Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The operational use of contact lenses by military aircrew, cataract surgery and intra-ocular lenses, the correction of refractive errors by radial keratotomy, impairment of color vision in ophthalmologists using argon lasers, and the medical management of combat laser eye injuries are examined. For individual titles, see N91-25603 through N91-25619.

N91-25606# Institute of Aviation Medicine, Farnborough (England).
AIRCREW SUNGLASSES
D. H. BRENNAN In AGARD, Ocular Hazards in Flight and Remedial Measures 6 p (SEE N91-25602 17-54) May 1991
(AGARD-CP-492) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The hazards of light are now better understood and it is imperative that aircrew, who may fly in ambient illuminance levels reaching 150,000 lux or greater, be provided with adequate protection. The primary hazards are from the CIE (International Commission on Illumination) photobiological bands starting at the ultra violet-B and extend through to the infrared-A although the latter is relatively unimportant. Potentially the most serious hazard is from the visible band below 500 nm; these highly energetic photons constitute the blue light hazard to the retina. The spectral transmittance of a sunfilter must take into account these hazards while at the same time not adversely affecting color discrimination. A good sunfilter should not only protect the eyes but also improve visual acuity and contrast discrimination both in haze and glare conditions. Author

N91-25607# Army Medical Research and Development Command, Fort Detrick, MD.
LASER PROTECTION WITH IMAGE INTENSIFIER NIGHT VISION DEVICES
DAVID J. WALSH In AGARD, Ocular Hazards in Flight and Remedial Measures 7 p (SEE N91-25602 17-54) May 1991
(AGARD-CP-492) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Current military ranging and targeting technology employs high power laser systems which can seriously damage the retina of the eye. Based on eye anatomy and function, three critical central retinal regions which must be protected - fovea, macula, and peripapillary zone (1 to 2 degree annulus surrounding the optic disc) - are included in a circular area with a 25-degree radius. In the aviation community, barrier-type laser protection inherent with night vision devices (NVDs) was thought to be adequate. The NVD barrier protection exceeds the recommended 25 degree minimum only when the eyes are in the primary (straight ahead) position. With normal scanning eye movement, critical areas of the retina become exposed to laser damage. Continuous laser protection for the central retina will require either a mechanical obstruction or a laser protective spectacle or visor which covers at least 90 degrees. The mechanical laser protection provided by NVD wear alone is not adequate to protect the aviator. Author

N91-25609# British Aerospace Public Ltd. Co., Bristol (England). Human Factors Dept.
THE EFFECTS OF DAZZLE AND DAZZLE GENERATED AFTERIMAGES ON AIMING AND TRACKING PERFORMANCE
A. KELVIN DAVIES In AGARD, Ocular Hazards in Flight and Remedial Measures 8 p (SEE N91-25602 17-54) May 1991
Sponsored in part by Ministry of Defence, England
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A series of experiments was designed to collect data for the modeling of aiming and tracking performance during and after dazzle exposure. Compensatory tracking performance was measured for static targets and targets moving with a constant linear velocity using a laboratory based tracking simulator. Tracking error was recorded with a bright noncoherent dazzle source overlaid on the target and with target-dazzle separations of 0.5, 1.0, 2.0, and 3.0 degrees. There was an indication that the dazzle source caused a significant deterioration in tracking performance. Tracking errors were inversely related to the separation between target and dazzle source and were at a maximum when target and dazzle were coincident. The effects of dazzle may persist for a significant time after dazzle offset. Foveal afterimages measuring 1 degree were generated by brief exposure to an intense light source. Tracking error with an afterimage was recorded and compared to the errors recorded for normal foveal vision, and those arizing when tracking using regions of the retina 2, 4, and 6 degree peripheral to the fovea. A significant deterioration in tracking performance was evident with an afterimage. Comparable results were obtained when tracking using the peripheral retina at 4 to 6 degrees. This similarity is attributed to observers offsetting their gaze so as to image the target away from the non-functioning foveal receptors. A significant learning effect was indicated.
Author

N92-12533# Royal Aerospace Establishment, Farnborough (England). Mission Management Aid Project.
INTEGRATING MACHINE INTELLIGENCE INTO THE COCKPIT TO AID THE PILOT
E. J. LOVESEY and R. I. DAVIS In AGARD, Machine Intelligence for Aerospace Electronic Systems 8 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499) Copyright Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Combat aircraft of the 21st Century will have to be increasingly well-equipped to counter the future threat, which itself will have become far more potent. This spiralling system complexity will result in unacceptably high cockpit workloads unless some form of automation is provided to aid the pilot. United Kingdom industry and government combined to form a joint venture team to develop a Mission Management Aid which will assist the aircrew throughout

the mission. Outlined here are some of the problems to be overcome and some suggestions regarding the major functional areas which will constitute the Mission Management Aid.   Author

N92-18988#   British   Aerospace   Aircraft   Group, Kingston-upon-Thames (England).
THE MILITARY AIRCREW HEAD SUPPORT SYSTEM (MAHSS)
A. A. MARSHALL   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 5 p (SEE N92-18972 09-52)   Oct. 1991
(AGARD-CP-516)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The Military Aircrew Head Support System (MAHSS) is designed to give the pilot extra support to his head and torso by means of cables under the control of a microprocessor. This calculates the expected tension on the cables under the prevailing G forces. It then compares these values with the actual strain on the cables. Any differences in tension to those calculated should be as a result of the pilot trying to move, and the cables will be adjusted to assist him. The MAHSS should offer benefits in terms of less fatigue (biology) and injury and the ability of the pilot to move his head while maneuvering without the danger of getting stuck in a slumped position during high G. It could also be useful during the ejection sequence, by reeling in the cables and this stabilizing the pilot's body and spine in the line of the ejection force. A simplified system was tested to 6 G in a human centrifuge with manual control of the cable lengths. The development of the system is described, including biomechanical modeling and a study into its acceptability to pilots, and other human factors issues.   Author

N92-18993#   Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
PHYSIOLOGICAL REQUIREMENTS FOR PARTIAL PRESSURE ASSEMBLIES FOR ALTITUDE PROTECTION
A. J. F. MACMILLAN   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 7 p (SEE N92-18972 09-52)   Oct. 1991
(AGARD-CP-516)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    Partial pressure assemblies using an oronasal mask and garments providing counter pressure to the torso and lower limbs may be used to provide protection against a short term exposure (1 to 2 minutes) to altitudes up to 60,000 to 65,000 feet. The performance characteristics of the delivery system used in such emergency exposures must be at least as good as that required during routine operations. Mask cavity pressure of up to 80 mmHg may be tolerated for a short period, provided adequate chest and lower limb counter pressure is provided. When upper body counter pressure is limited to the chest, then anti-G suit pressure should be at least 3 times the breathing pressure. Further tradeoffs of breathing pressure and counter pressure against absolute oxygen pressure with the use of gas mixtures with less than 100 percent oxygen should be defined by examining the effect of these tradeoffs on performance, arterial gas tensions and cardiovascular responses.   Author

N92-18994#   Laboratoire   de   Medecine   Aerospatiale, Bretigny-sur-Orge (France). Centre d'Essais en Vol.
FRENCH EQUIPMENT FOR INTEGRATED PROTECTION OF COMBAT AIRCRAFT CREWS: PRINCIPLES AND TESTS AT HIGH ALTITUDES [L'EQUIPEMENT FRANCAIS DE PROTECTION INTEGREE POUR EQUIPAGES D'AVIONS DE COMBAT MODERNE: PRINCIPES ET ESSAIS EN HAUTE ALTITUDE]
HENRI MAROTTE, HENRI VIEILLEFOND (Service de Sante des Armees, Paris, France), DAMIEN LEJEUNE, and JEAN-MICHEL CLERE   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 11 p (SEE N92-18972 09-52)   Oct. 1991   In FRENCH; ENGLISH summary
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    Personal flight equipment, manufactured and tested in France, to be used to protect aircraft crews against the risk of loss of pressurization at high altitudes is discussed. Slow decompression tests up to 60,000 feet showed that the altimetric positive pressure

schedule was badly adapted for this kind of equipment. Specific schedules for altimetric dilution and positive pressure were established and tested with a series of rapid decompression experiments (in 2 seconds). Some explosive decompression tests were also performed. The homologation was obtained for the maximum altitude of 65,000 feet, maximum duration above 40,000 feet of 2 to 3 minutes, and an aircraft pressurization schedule of 35 kPa.   Author

N92-18995#   Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE EXPERIMENTAL ASSESSMENT OF NEW PARTIAL PRESSURE ASSEMBLIES
D. P. GRADWELL   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 5 p (SEE N92-18972 09-52)   Oct. 1991
(AGARD-CP-516)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    A new generation of partial pressure assemblies were assessed with particular reference to the optimization of counter-pressure relationships. A system of non-invasive assessment of the physiological consequences of using such assemblies during pressure breathing and following rapid decompression to altitudes between 45,000 and 60,000 feet were developed. The methods used are described and an outline of the results achievable with this system are discussed. The physiological benefits of enhanced lower body counter-pressure compared with uniform levels of pressure garment inflation are described. Suggestions for further research are given.   Author

N92-18996#   Laboratoire   de   Medecine   Aerospatiale, Bretigny-sur-Orge (France). Centre d'Essais en Vol.
PHYSIOLOGICAL PROTECTION EQUIPMENT FOR COMBAT AIRCRAFT: INTEGRATION OF FUNCTIONS, PRINCIPAL TECHNOLOGIES [PROTECTION PHYSIOLOGIQUE DES EQUIPAGES D'AVIONS DE COMBAT: INTEGRATION DE FONCTIONS, PRINCIPES TECHNOLOGIQUES]
HENRI MAROTTE, RAYMOND BEAUSSANT, RICHARD ZAPATA (L'Air Liquide, Sassenage, France), JEAN-MICHEL CLERE, and DAMIEN LEJEUNE   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 8 p (SEE N92-18972 09-52)   Oct. 1991   In FRENCH; ENGLISH summary
(AGARD-CP-516)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    New generation combat aircraft crews are submitted to many kinds of constraints during flight. New technologies were developed, such as the molecular sieve oxygen concentrator (MSOC) or the electronic technology for command and/or control of regulation systems. The equipment developed allows a survey of data from the unlimited oxygen supply, with low pressure oxygen regulation systems, to anti-G protection, thanks to the assisted positive pressure breathing (APPB) apparatus. These systems are orderly integrated into the same multiple equipment systems with both respiratory and anti-G functions. New perspectives were developed: altimetric dilution schedules usable with a partial pressure suit; compatibility of the flight equipment with non-integrated functions; and thermal (cold) protection in case of accidental immersion or nonbattle casualty (NBC) protection equipment.   Author

N92-18997#   Toronto Univ. (Ontario). Dept. of Mechanical Engineering.
MODEL OF AIR FLOW IN A MULTI-BLADDER PHYSIOLOGICAL PROTECTION SYSTEM
P. S. E. FARRELL, D. F. JAMES, and A. A. GOLDENBERG   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 5 p (SEE N92-18972 09-52)   Oct. 1991
(AGARD-CP-516)   Copyright   Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    New physiological protection systems are needed in order to keep the pilot in control of the aircraft during high G and high altitude maneuvers. A model was developed for air flow in a multi-bladder physiological protection system. Each bladder of the protection system is modeled as a flexible pressure vessel. The governing equations are derived for fluid flow from one vessel to another. The equations are simplified by five assumptions which

are based on the fluid being compressible and inviscid. The result is a set of nonlinear differential equations which describe the isentropic pressure variation within the vessels. The equations are integrated numerically and yield the thermodynamic quantities within each vessel as a function of time. Based on the differential equations, a computer simulation of the flexible pressure vessel model was performed. The simulation allows for many possible configurations and scenarios. Five basic configurations are discussed here.   Author

N92-18998# Royal Aircraft Establishment, Farnborough (England). Aircrew Integration Section.
THE DESIGN AND DEVELOPMENT OF A FULL-COVER PARTIAL PRESSURE ASSEMBLY FOR PROTECTION AGAINST HIGH ALTITUDE AND G
A. E. HAY and JUDY E. APLIN   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 6 p (SEE N92-18972 09-52) Oct. 1991
(AGARD-CP-516) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   A partial pressure assembly comprising a chest counter pressure garment (CCPG) and full-cover trousers (FAGTS) were designed and constructed. The CCPG is a simple two-layer outer garment located under the life preserver and supplied with breathing gas from the demand regulator. The FAGTS comprise a single bladder which covers the abdomen, legs, and feet, retained by an outer inextendable layer of Nomex, with the ability to be donned quickly by employing zips and low friction lacing for final fit adjustment. Gas supplied from a suitably programmed G-valve inflates the garment to provide protection. Details of the design approach and the developmental stages to date are given together with an outline of the anthropometric considerations required to provide a snug fitting assembly from a limited size roll.   Author

N92-18999#   Normalair-Garrett Ltd., Yeovil (England). Military Breathing Systems.
ADVANCES IN THE DESIGN OF MILITARY AIRCREW BREATHING SYSTEMS WITH RESPECT TO HIGH ALTITUDE AND HIGH ACCELERATION CONDITIONS
NIGEL P. J. LOVETT   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 4 p (SEE N92-18972 09-52) Oct. 1991
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   It was concluded that for future aircraft systems the combining of an anti-gravity valve and a breathing regulator into one unit provides the most compact and effective system. The advances made by the research establishments in the development of new aircrew garments reduces the need for quick response, electronically controlled valves, thus suggesting that mechanically controlled systems still provide the optimum protection for aircrews under high acceleration conditions.   Author

N92-19000#   Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
HIGH ALTITUDE HIGH ACCELERATION AND NBC WARFARE PROTECTIVE SYSTEM FOR ADVANCED FIGHTER AIRCRAFT: DESIGN CONSIDERATIONS
A. J. F. MACMILLAN   *In* AGARD, High Altitude and High Acceleration Protection for Military Aircrew 7 p (SEE N92-18972 09-52) Oct. 1991
(AGARD-CP-516) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   The physiological, technical and flight safety aspects of the design of an integrated system providing protection against high sustained acceleration, short duration exposure to high altitude and nuclear-biological-chemical (NBC) warfare agents are discussed. The proposed system employs a molecular sieve oxygen concentrator and seat mounted demand regulator and anti-gravity valve together with a source of clean filtered air and an emergency gaseous oxygen supply. The personal equipment assembly comprises counter pressure garments worn external to the NBC protective layer and a man-mounted filter. The filter assembly is used on the ground with a portable ventilator, in the air connected

to the breathing gas supply, and post escape as part of a lung powered respirator system.   Author

N92-19008#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).   Aerospace Medical Panel.
HELMET MOUNTED DISPLAYS AND NIGHT VISION GOGGLES
Dec. 1991   121 p   In ENGLISH and FRENCH   Symposium held in Pensacola, FL, 2 May 1991
(AGARD-CP-517; ISBN-92-835-0645-6) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   Papers covered basic and applied issues related to human factors and device integration. Three papers considered the ergonomics of helmet design and the snugness of fit to the head and the integration of new helmet mounted devices with existing equipment. Two papers considered the effects of novel helmet designs on the pilot's ability to control head position and avoid fatigue. Two papers reported in-flight testing of human performance using novel devices. Several papers considered the human factors of visual performance related to such topics as degree of binocular overlap, overall field of view, and the ability to maintain level flight. Other papers considered issues of the nature of information displayed, including data fused from multiple sources and the design of abstract symbologies that present parameters of flight. For individual titles, see N92-19009 through N92-19023.

N92-19009#   IBIS Aerosystems Ltd., Sharnbrook (England).
FIXED WING NIGHT ATTACK EO INTEGRATION AND SENSOR FUSION
LES EVANS   *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 5 p (SEE N92-19008 09-54) Dec. 1991
(AGARD-CP-517) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   Discussed here are some of the aeromedical aspects of the development of fixed wing night attack using electro-optic sensors. Addressed are some of the problems encountered when night vision goggles (NVG's) and Forward Looking Infra-Red (FLIR) equipment were integrated into a complete airborne system. The aeromedical problems encountered when NVG's were used in fast jet aircraft are discussed. It was found that helmet fit had to be tight to ensure that the high helmet rotational forces produced by normal accelerations were contained, and also that when wearing NVG's while pulling 'g', a tumbling sensation could be induced in the pilot by head movements.   Author

N92-19010# Royal Aircraft Establishment, Farnborough (England). Flight Systems Dept.
THE DESIGN AND EVALUATION OF FAST-JET HELMET MOUNTED DISPLAYS
A. KARAVIS and G. J. N. CLARKSON   *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 8 p (SEE N92-19008 09-54) Dec. 1991
(AGARD-CP-517) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
   The design philosophy adopted by the Flight Systems Department of the Royal Aerospace Establishment (RAE), Farnborough for its fast-jet helmet display program is discussed. Details are given on the development of two devices and the tests and methods used to meet flight safety measurements. The devices, a Helmet Mounted Sight (HMS) and an Oxygen Mask Mounted Sight (OMMS), each posed different problems due to their inherently dissimilar concepts. Modifications to these devices as a result of ground and air testing to meet flight safety and operational requirements are covered. The ergonomic considerations applicable to the use of these and other head mounted devices when employed as integral components of the weapon system are also discussed. A brief account is given of display design considerations. Two helmet devices were successfully produced for evaluation in a combat environment.
                                                        Author

N92-19011# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter Div.
HELICOPTER INTEGRATED HELMET REQUIREMENTS AND TEST RESULTS
HANS-DIETER VONBOEHM and HERBERT SCHREYER *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 17 p (SEE N92-19008 09-54) Dec. 1991 Previously announced as N92-12422
(AGARD-CP-517) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Integrated Helmet (IH) requirements for helicopter applications and some test results are given. A modern IH consists of two Image Intensifier Tubes (IIT) and two Cathode Ray Tubes (CRT) with an optical system, including combiners to present binocular images. Additional symbology can be superimposed on the CRT or IIT image. An IH is a further development of a helmet mounted display. A Helmet Mounted Sight (HMS) can steer a sensor platform with a thermal camera, or an air to air missile system. The main helicopter requirements of such a system are given. Author

N92-19012# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
AN EVALUATION OF THE PROTECTIVE INTEGRATED HOOD MASK FOR ANVIS NIGHT VISION GOGGLE COMPATIBILITY
MARY M. DONOHUE-PERRY and JOSEPH T. RIEGLER (Logicon Technical Services, Inc., Dayton, OH.) *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 4 p (SEE N92-19008 09-54) Dec. 1991
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An evaluation was conducted to determine potential compatibility problems found while using the Protective Integrated Hood Mask (PIHM) with the Aviator's Night Vision Imaging System (ANVIS). The evaluation consisted of field tests performed at Pope Air Force Base using qualified C-130E crewmembers, and laboratory tests conducted at Wright-Patterson Air Force Base. Examinations of horizontal and vertical intensified fields of view, cockpit lighting compatibility, and a subjective evaluation of fit were conducted at Pope Air Force Base. Visual acuity through the ANVIS/PIHM, and distortion and transmissivity of the PIHM visor were determined Wright Patterson Air Force Base. Acuity through ANVIS with and without PIHM was assessed under quarter moon and starlight illuminations. Acuity was tested using 20 percent and 90 percent Landolt C targets depicted in one of four orientations. Overall conclusions were that potential compatibility problems of ANVIS and PIHM can be reduced or eliminated with proper fit and adjustment of the ANVIS/PIHM. Author

N92-19013# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE RAF INSTITUTE OF AVIATION MEDICINE PROPOSED HELMET FITTING/RETENTION SYSTEM
JOHN V. BARSON and ROGER J. CROFT *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 5 p (SEE N92-19008 09-54) Dec. 1991
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The role of the protective flying helmet has expanded from being a device for protecting the flyer from impact and noise hazards to include mounting platforms for vision enhancement devices as well as target sighting and designation systems. A new helmet fitting and/or retention system is described that has the potential to provide a quick and effective method of rendering a good, safe, and stable helmet fit using a minimum number of helmet sizes. The fitting or retention system also provides a relatively consistent eye position for optical systems and allows rapid donning of a chemical defense respirator. Also, the fitting or retention system can be used for a 'one size fits all' helmet while retaining all the features for personnel who are only flying on specific missions and normally are not issued a flight helmet. The system uses a series of straps and an occipital pusher plate to accommodate head length. The height adjustment is provided by a specifically shaped and contoured pad in the top of the helmet which contacts the head in such a way and over a large area to

correctly position the helmet vertically on the head for a wide range of pupil-vertex heights. Author

N92-19014# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France). Centre d'Essais en Vol.
BIOMECHANICAL RESPONSE OF THE HEAD TO G+ ACCELERATIONS: BENEFIT FOR STUDIES IN COMBAT SIMULATORS [REPONSE BIOMECANIQUE DE LA TETE AUX ACCELERATIONS+ GZ: INTERET POUR LES ETUDES EN SIMULATEUR DE COMBAT]
A. LEGER, P. SANDOR, C. BOURSE, and A. ALAIN *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 9 p (SEE N92-19008 09-54) Dec. 1991 In FRENCH Prepared in cooperation with Centre d'Electronique de l'Armement, Bruz (France)
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Fixed base simulators cannot provide the effect of biomechanical constraints resulting from accelerations, which can pose problems in interpreting studies of helmet mounted sights. One study, in a human centrifuge, of the biomechanical response of the head during an orientation task was conducted for different gradients of variation of acceleration (0.3, 0.6, and 1 G/s). Terminal acceleration in every case plateaued at +5 G. The results obtained show that the stability of the orientation (Mean Quadratic Deviation) on an infinitely collimated target varied from 0.8 deg at 0.3 G/s to more than 2 deg at 1 G/s. The characteristics of the biomechanical response of the head were analyzed. Practical recommendations are made for modeling the effect of the biomechanical constraint at the time of combat simulator studies.
Transl. by M.G.

N92-19015# New Orleans Univ., LA. Dept. of Mathematics.
A KINEMATIC MODEL FOR PREDICTING THE EFFECTS OF HELMET MOUNTED SYSTEMS
TERRY A. WATKINS, M. S. WEISS, D. W. CALL, and S. J. GUCCIONE, JR. (Naval Biodynamics Lab., New Orleans, LA.) *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 7 p (SEE N92-19008 09-54) Dec. 1991
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A statistical study was made using head kinematic response data from a set of 79 human -X impact acceleration tests. Five volunteer subjects were tested successively in three configurations: (1) no helmet; (2) helmet only; and (3) helmet with weights. The peak acceleration levels ranged from 3 to 10 g. Three kinematic responses, the X and Z components of the linear acceleration and the Y axis angular acceleration, were analyzed These acceleration curves were fitted with polynomial splines using least squares techniques. The fitted peaks and times to peak were then regressed against sled acceleration, initial head orientation and head/neck anthropometric parameters. Statistical measures of goodness of fit were highly significant. The regression equations were used to simulate the effects of varying individual parameters (such as total head mass, peak sled acceleration, neck length, etc.). The results show an analytical approach for extrapolating human neck/head kinematics to levels and types of exposure where injury would be expected. Future applications of this modeling technique include analysis of the effects of mass distribution parameters on head/neck dynamic response to +Z vertical impact acceleration. Author

N92-19016# British Aerospace Public Ltd. Co., Bristol (England). Human Factors Dept.
THE EFFECTS UPON VISUAL PERFORMANCE OF VARYING BINOCULAR OVERLAP
G. K. EDGAR, K. T. CARR, M. WILLIAMS, J. PAGE, and A. L. CLARKE *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 15 p (SEE N92-19008 09-54) Dec. 1991
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In a helmet mounted display, there is a tradeoff between the binocular overlap of the images presented to each eye and the total field of view. It is therefore desirable to see whether decreasing the binocular overlap (and thus making possible a large total FOV)

adversely affects performance. The results are reported of four experiments examining the effects of different binocular overlaps upon performance on a visual search task, and the factors that may explain any differences in the results obtained with different overlap conditions. The results indicated that performance was poorer in all non-100 pct. overlap conditions, and suggested that this decrement in performance could be explained by the presence of depth boundaries introduced by a disparity between the images presented to each eye.   Author

N92-19017#   Laboratoire   de   Medecine   Aerospatiale, Bretigny-sur-Orge (France).
RESTRICTION OF THE FIELD OF VISION: INFLUENCE ON EYE-HEAD COORDINATION DURING ORIENTATION TOWARDS AN ECCENTRIC TARGET [RESTRICTION DU CHAMP DE VISION: INFLUENCE SUR LA COORDINATION OEIL-TETE PENDANT L'ORIENTATION VERS UNE CIBLE EXCENTREE]
PATRICK SANDOR and ALAIN LEGER   In AGARD, Helmet Mounted Displays and Night Vision Goggles 6 p (SEE N92-19008 09-54) Dec. 1991 In FRENCH
(AGARD-CP-517) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
        Vision in a limited field of vision deviates more and more frequently with use of optronic helmet-mounted systems. The consequences of restricted field on the characteristics of eye-head coordination were studied during a task of orientation toward an eccentric pinpoint target. Three sizes of binocular fields were tested (20 degree, 70 degree, and free field). A pinpoint target is projected onto a round screen in a horizontal plane passing in front of the subject's eyes. The target is presented with three different eccentricities: 45, 65, and 85 degrees. The tests are carried out in two modes: expected and semi-expected, where only the side (left or right) is indicated. The unexpectedness increases the time to acquisition. It is accompanied by an increase in the number of eye motions. The mean and maximum rates of eye motion seem to be maintained constant by means of continual adjustment of eye and head speeds. Amplitude limitation of the eye movements linked to vision restriction is not compensated by use of the entire available field. Generally, only the half-field of vision of the same side as the displacement is used. In conclusion, the results show that restriction of the field of vision modifies the motor behaviors involved in eye-head coordination, especially when the placement of the target is unexpected. An understanding of these mechanisms can eventually contribute to optimizing the use of hement-mounted optronic devices.   Author

N92-19018#   Aerospace   Medical   Research   Labs., Wright-Patterson AFB, OH. Human Engineering Div.
THE EFFECT OF FIELD-OF-VIEW SIZE ON PERFORMANCE OF A SIMULATED AIR-TO-GROUND NIGHT ATTACK
ROBERT K. OSGOOD and MAXWELL J. WELLS (Logicon Technical Services, Inc., Dayton, OH.) In AGARD, Helmet Mounted Displays and Night Vision Goggles 7 p (SEE N92-19008 09-54) Dec. 1991
(AGARD-CP-517) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
        Five experienced fighter pilots flew a simulated, night attack, pop-up bomb delivery, with a flight simulator that had a head-mounted display. The mission was conducted with an aircraft-fixed forward looking infrared sensor (FLIR) or a head-steered FLIR. With the head-steered FLIR, the sensor image was viewed on a helmet-mounted display, whereas, the aircraft-fixed FLIR was presented on a heads-up display (HUD). With both types of sensor, the field of view (FOV) size may affect performance, and to provide data for the determination of the minimum FOV size for helmet-mounted displays (HMD's). With a head-steered sensor, subjects acquired the targets earlier in the mission and released their bomb at a higher altitude. Increasing the size of the FOV also resulted in earlier target acquisition. It is explained how early target acquisition allowed subjects to modify their flight paths and position their aircraft for higher releases. Using criterion, HMD FOV's of 20 and 30 degrees were significantly worse than FOV's of 40, 60, or 80 degrees.   Author

N92-19019#   Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France). Div. Vision et Ergonomie.
DOES THE FUTURE LIE IN BINOCULAR HELMET DISPLAY? [L'AVENIR EST-IL AU VISUEL DE CASQUE BINOCULAIRE?]
CORINNE ROUMES, JUSTIN PLANTIER, and JEAN-PIERRE MENU   In AGARD, Helmet Mounted Displays and Night Vision Goggles 9 p (SEE N92-19008 09-54) Dec. 1991 In FRENCH
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        The introduction of a binocular capability in helmet displays can be considered as a rebalancing of visual stimuli between the two eyes, given the specific properties of human vision. The potential advantage of binocular helmets rests with the transposition of visual processing capabilities to the conditions of image generation and reconstruction in the helmet's display. Several problems resulting from this transfer are envisaged: some require experimental investigation, especially determining the tolerance of partial binocularity and to the constraints of the aeronautical environment. In view of these difficulties, the role of binocularity in the display can be envisaged differently in the presentation of real world images through sensors or synthesized input, in the framework of an actual flight or of simulation.   Author

N92-19020#   Center for Night Vision and Electro-Optics, Fort Belvoir, VA.
DESIGN OF HELICOPTER NIGHT PILOTAGE SENSORS: LESSONS LEARNED FROM RECENT FLIGHT EXPERIMENTS AND FIELD ASSESSMENTS Abstract Only
RICHARD VOLLMERHAUSEN, TRANG BUI, and CAROLYN NASH   In AGARD, Helmet Mounted Displays and Night Vision Goggles 1 p (SEE N92-19008 09-54) Dec. 1991
(AGARD-CP-517) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
        The Army requirement to fly helicopters at low level at night led to the development and fielding of night vision pilotage sensors. These sensors have included image intensifiers (I sup 2) operating in the near infrared as well as 8 to 12 micron thermal imagers. The design of current pilotage sensors was driven by available technology. There were no clear data for optimum pilotage sensor design, to enable the designer to trade off sensor field of view (FOV) and resolution or to predict the performance sensitivity. The Center of Night Vision and Electro-Optics (CCNVEO) is establishing design criteria for night pilotage sensors. Our program included flight experiments to define sensor characteristics which optimize flight tasks as well as assessments of the performance of fielded systems. We conclude that terrain flight can be accomplished with reasonable pilot workload using a head-tracked sensor with 40 degree FOV and 0.6 cycles per milliradian (cy/mrad) resolution. Larger FOV or better resolution will lessen workload and improve confidence; however, the ability to resolve scene detail of 0.6 cy/mrad is essential and should not be traded for increased FOV. Furthermore, a pilotage system which provides both thermal and I sup 2 imagery will significantly enhance system capability to support a variety of flight tasks under a wide range of environments. We also conclude that solid state cameras with detector dwell time equal to the standard video field rate are not suitable for use in helicopter pilotage systems. The long dwell time leads to image blur due to the head and scene motion associated with many pilotage tasks.   Author

N92-19021# Royal Aircraft Establishment, Farnborough (England), Flight Systems Dept.
HELMET MOUNTED DISPLAYS: HUMAN FACTORS AND FIDELITY
PETER L. N. NAISH and HELEN J. DUDFIELD   In AGARD, Helmet Mounted Displays and Night Vision Goggles 5 p (SEE N92-19008 09-54) Dec. 1991
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        Helmet mounted display (HMD) systems, of the kind able to present what has been termed virtual reality, will not be able to present a completely faithful rendering of the world. This paper shows how non-HMD technology may be used to assess the effects of this deficiency. Three aspects of the helmet mounted system are considered, and experiments are reported, which were designed

to determine the degree of reality required in flyable equipment. The areas covered are time lag in the display, the need for color, and the use of 3-D sound. It is concluded that, for the parameters considered, currently available technology is able to produce stimuli which are adequate for the anticipated use of HMDs. **Author**

N92-19022# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
ATTITUDE MAINTENANCE USING AN OFF-BORESIGHT HELMET-MOUNTED VIRTUAL DISPLAY
ROBERT K. OSGOOD, ERIC E. GEISELMAN, and CHRISTOPHER S. CALHOUN (Logicon Technical Services, Inc., Dayton, OH.) *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 7 p (SEE N92-19008 09-54) Dec. 1991
(AGARD-CP-517) Copyright Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Helmet mounted displays (HMDs) enable flight information to be displayed within the pilot's field of view, regardless of head position in the cockpit. The present research investigates an off boresight HMD (OBHMD), which appears when the pilot's head position is greater than 20 deg from the aircraft's boresight. Nine subjects flew a simulated, low level, high speed, airborne surveillance/reconnaissance mission, while monitoring a hostile adversary aircraft. The results indicate pilots were able to spend more time and look further off boresight with an OBHMD than without one. In addition, missions with an OBHMD produced fewer terrain impacts. **Author**

N92-19023# Sextant Avionique, Saint Medard en Jalles (France). Div. Visualisation Interface.
DESIGN METHODOLOGY FOR A HELMET DISPLAY: ERGONOMIC ASPECTS [METHODOLOGIE DE CONCEPTION D'UN VISUEL DE CASQUE: LES ASPECTS ERGONOMIQUES]
J. M. KRAUS, P. LACROUX, and A. LEGER *In* AGARD, Helmet Mounted Displays and Night Vision Goggles 6 p (SEE N92-19008 09-54) Dec. 1991 In FRENCH
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Purely from the standpoint of vision, the design of a helmet display presents relatively few differences from that of a more classic visualization device such as a head-up display. For the engineer, one of the major difficulties encountered in designing a head mounted system rests in the fact that the carrying structure is far from being as well defined as are the usual supports. The diversity of anatomical and functional specifications of the pilot's head constitutes the source of ergonomic constraints that must be taken into account. The first part of this study addressed the precise identification of the limiting constraints encountered: antropometric and biomechanical constraints as well as those of secureness, comfort, manipulation, and environment. The data from previous research, computer aided design (CAD), and the simultaneous development of ergonomic and physical models permit a global approach to these different problems. The second part of the study exposes the essential aspects of the methodological principles used. In conclusion, reflection on the design development for helmet displays makes apparent the need for early integration of the vision aspects and physical ergonomic requirements. This is a major and indispensable asset that will lead to the creation of a device that will satisfy the requirements imposed by weapon systems and their users. **Transl. by M.G.**

N92-21972# Naval Weapons Center, China Lake, CA.
FIXED WING NIGHT CARRIER AEROMEDICAL CONSIDERATIONS
J. C. ANTONIO *In* AGARD, Aircraft Ship Operations 3 p (SEE N92-21951 12-05) Nov. 1991
(AGARD-CP-509) Copyright Avail: NTIS HC/MF A15; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Discussed here are the emerging use of night vision devices (NVDs) in the United States Navy/United States Marine Corps fixed wing aircraft, a description of the NVD environment, and the identification of aeromedical concerns associated with night carrier operations. Enhancements to the F-18 night strike mission provided by NVDs include increased situational awareness, enhanced night navigation, threat avoidance, multi/mixed aircraft tactics, nighttime

use of daytime tactics, and the significant expansion of night air-to-air tactics, including escort missions. **Author**

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COMPUTER OPERATIONS AND HARDWARE

Includes hardware for computer graphics, firmware, and data processing.

N91-12695*# Draper (Charles Stark) Lab., Inc., Cambridge, MA. Fault-Tolerant Systems Div.
A BYZANTINE RESILIENT PROCESSOR WITH AN ENCODED FAULT-TOLERANT SHARED MEMORY
BRYAN BUTLER and RICHARD HARPER *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 12 p (SEE N91-12682 04-08) Apr. 1990
(Contract NAS1-18565)
(AGARD-CP-456) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 09/2
The memory requirements for ultra-reliable computers are expected to increase due to future increases in mission functionality and operating-system requirements. This increase will have a negative effect on the reliability and cost of the system. Increased memory size will also reduce the ability to reintegrate a channel after a transient fault, since the time required to reintegrate a channel in a conventional fault-tolerant processor is dominated by memory realignment time. A Byzantine Resilient Fault-Tolerant Processor with Fault-Tolerant Shared Memory (FTP/FTSM) is presented as a solution to these problems. The FTSM uses an encoded memory system, which reduces the memory requirement by one-half compared to a conventional quad-FTP design. This increases the reliability and decreases the cost of the system. The realignment problem is also addressed by the FTSM. Because any single error is corrected upon a read from the FTSM, a faulty channel's corrupted memory does not need realignment before reintegration of the faulty channel. A combination of correct-on-access and background scrubbing is proposed to prevent the accumulation of transient errors in the memory. With a hardware-implemented scrubber, the scrubbing cycle time, and therefore the memory fault latency, can be upper-bounded at a small value. This technique increases the reliability of the memory system and facilitates validation of its reliability model. **Author**

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COMPUTER PROGRAMMING AND SOFTWARE

Includes computer programs, routines, and algorithms, and specific applications, e.g., CAD/CAM.

N89-10049# Raytheon Co., Bedford, MA. Missile Systems Div.
COMPARISON OF STATISTICAL DIGITAL SIMULATION METHODS
PAUL ZARCHAN *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 16 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Copyright Avail: NTIS HC A07/MF A01
The various statistical digital simulation methods used in the preliminary analysis and synthesis of a homing missile guidance system are compared. A unifying example is used to illustrate the advantages and computer costs of each of the methods. **Author**

61 COMPUTER PROGRAMMING AND SOFTWARE

N89-10050# Dynetics, Inc., Huntsville, AL.
A GENERIC SEEKER SIMULATION FOR THE EVALUATION OF ACTIVE RF GUIDANCE SYSTEMS
FRANK T. CAMPOS   *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 9 p (SEE N89-10048 01-08) Jul. 1988
(Contract F08635-83-C-0123)
(AGARD-AG-273) Copyright Avail: NTIS HC A07/MF A01
The essential features of a generic simulation of an active radio frequency (RF) air-to-air missile seeker is described. The concept of generic simulations is supported by the need for a common test-bed of system models and simulation technology capable of supporting advanced seeker development programs. An extensive library of target, environment, and RF seeker models was incorporated within a modular program structure featuring tri-level hierarchy of program control that allows the selective management of program options for specifying the fidelity and functional implementation of models used at the component, subsystem, and system levels. The Generic Seeker Simulation offers considerable flexibility for simulating a broad range of RF seeker configurations and has a significant potential for supporting the evaluation of competitive designs and advanced seeker technologies.   Author

N89-10051# Magnavox Electronic Systems Co., Fort Wayne, IN. Control Systems Operation.
DIGITAL SIMULATION TECHNIQUES FOR END GAME PHENOMENA
MARTIN E. TANENHAUS and DUANE J. CART   *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 37 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Copyright Avail: NTIS HC A07/MF A01
This report is based on efforts to develop a color graphics based analytical methodology for determining end game performance of smart sensors on missiles and projectiles. These sensor systems defend against present and future target threats. The development of a computer based methodology to define and test weapon system sensor performance requirements, predict end game sensor and fuze burst point distributions, assess weapon system effectiveness, and evaluate advanced weapons design concepts is presented. A graphics driven target modeling methodology is presented, together with verification, correlation, and validation techniques. A complex radar target model with detailed graphics, radar cross section (RCS), glint, imagery analysis, and target Doppler signature output was developed. A sensor system signal processor model is developed and exercised with the target model to provide system performance assessments. Verifiable correlation between system model performance and real hardware was obtained. End game system function results are utilized in a weapons effectiveness simulation and appraisal.
                                           Author

N89-10052# Raytheon Co., Bedford, MA.
DESIGN CRITERIA FOR HARDWARE-IN-THE-LOOP SIMULATION FACILITIES
S. J. POWERS and M. E. SISLE   *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 10 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Copyright Avail: NTIS HC A07/MF A01
The criteria used in the design of a Hardware-in-the-Loop (HIL) simulation facility are outlined. Although dealing with a missile interceptor facility, the criteria are directly applicable to any electronic weapon system simulation facility. The first step in the process is defining the role that the facility will play in the development cycle. Facility requirements which drive the model and data requirements are then defined and the facility design follows from the requirements. Following completion of the facility development is the conduct of system integration tests. Verification/validation criteria are established and met, the process is complete, allowing the facility operation to begin. Facility operation and maintenance become ongoing functions.   Author

N90-20998# Princeton Univ., NJ.
AERODYNAMIC DESIGN VIA CONTROL THEORY
ANTONY JAMESON   *In* AGARD, Computational Methods for Aerodynamic Design (Inverse) and Optimization 32 p (SEE N90-20976 14-05) Mar. 1990
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The purpose is to demonstrate by representative examples that control theory can be used to formulate computationally feasible procedures for aerodynamic design. The cost of each iteration is of the same order as two flow solutions, since the adjoint equation is of comparable complexity to the flow equation, and the remaining auxiliary equations could be solved quite inexpensively. Provided, therefore, that one can afford the cost of a moderate number of flow solutions, procedures of this type can be used to derive improved designs. The approach is quite general, not limited to particular choices of the coordinate transformation or cost function, which might in fact contain measures of other criteria of performance such as lift and drag. For the sake of simplicity certain complicating factors, such as the need to include a special term in the mapping function to generate a corner at the trailing edge, have been suppressed from the present analysis. Also it remains to explore the numerical implementation of the design procedures proposed.   Author

N90-21987# Politecnico di Torino (Italy). Dept. of Aerospace Engineering.
THREE-DIMENSIONAL ADAPTIVE GRIDS WITH LIMITED SKEWNESS
RENZO ARINA   *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 8   (SEE N90-21975 15-34) Mar. 1990
(AGARD-CP-464) Copyright Avail: NTIS HC A14/MF A02;
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A grid generation technique for curved surfaces and three-dimensional regions is presented. In the two-dimensional case the set of solutions of the proposed grid generator belongs to the class of quasiconformal mappings, and it is shown that under appropriate conditions, it represents unfolded orthogonal coordinates. The isothermic coordinates are a particular case of this wider family of mappings. In three dimensions the solution of the mapping system is harmonic. Different kinds of stretching including an adaptive control of the mesh clustering are presented.   Author

N90-21995# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.
UNSTRUCTURED MESH GENERATION BY A GENERALIZED DELAUNAY ALGORITHM
TIMOTHY J. BAKER   *In* AGARD, Applications of Mesh Generation to Complex 3-D Configurations 10 p (SEE N90-21975 15-34) Mar. 1990 Sponsored in part by IBM
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A method for generating tetrahedral meshes will be described. The algorithm is based on the Delaunay triangulation and can treat objects of essentially arbitrary complexity. In order to preserve the surface triangulation of solid objects, it is necessary to override the Delaunay property and redefine the triangulation when points are introduced close to solid boundaries. Details of the generalized algorithm are presented and an efficient implementation of the triangulation method is described.   Author

N91-10986# National Aerospace Lab., Amsterdam (Netherlands).
THE APPLICATION OF TRAJECTORY PREDICTION ALGORITHMS FOR PLANNING PURPOSES IN THE NETHERLANDS ATC-SYSTEM
J. N. P. BEERS, T. B. DALM, J. M. TENHAVE, and H. VISSCHER (Department of Civil Aviation, An Hoofddorp, Netherlands) *In* AGARD, Aircraft Trajectories: Computation, Prediction, Control, Volume 2: Air Traffic Handling and Ground-Based Guidance of Aircraft. Part 4: Air Traffic Handling. Part 5: Guidance of Aircraft in a Time-Based Constrained Environment. Surveillance. Part 7: Meteorological Forecasts. Part 8: Aircraft Operation in Air Traffic Handling Simulation 11 p (SEE N91-10981 02-05) May 1990
Previously announced as N89-20115
(AGARD-AG-301-VOL-2-PT-4-8) Copyright Avail: NTIS HC/MF A20; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Netherlands ATC-environment, the basic set-up of the trajectory prediction module, improvements realized, and the performance figures are presented. Applications of the trajectory prediction results in the system are listed, including data distribution rules, presentation of estimated times of arrival, boundary estimates, and, in particular, long term detection of conflicts for overflying aircraft, planning of inbound traffic for Schiphol airport, and planning of departure times for an efficient engine start-up procedure. Author

N91-12697# Centre d'Etudes et de Recherches, Toulouse (France). Dept. d'Etudes at de Recherches en Informatique.
FORMALIZING DEVELOPMENTS: FROM THEORY TO PRACTICE
KARIM BECHANE and MICHEL LEMOINE *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 9 p (SEE N91-12682 04-08) Apr. 1990
(AGARD-CP-456) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The need to support the whole process of system development with available and really efficient environments is a major challenge of the software technology. The old paradigms in use is briefly examined. Then a new one is introduced which is well supported by an environment under consideration. in this environment the use of the DEVA language is emphasized which aims at: expressing formal developments; expressing and using development methods; and finally, re-using formal developments for the derivation of new developments and consequently new programs. A realistic example based on the JSP method is introduced, then formalized and expressed in terms of DEVA. The correctness of the run guarantees that the resulting programs satisfies their initial specifications. Author

N91-12699# Royal Signals and Radar Establishment, Malvern (England).
FAULT TOLERANCE VIA FAULT AVOIDANCE
B. D. BRAMSON *In* AGARD, Fault Tolerant Design Concepts for Highly Integrated Flight Critical Guidance and Control Systems 10 p (SEE N91-12682 04-08) Apr. 1990
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A safety-critical system is proposed whose architecture is based upon software components that have diverse specifications and diverse implementations. It is claimed that a proof of correctness of one of the components implies a proof of safety of the system. The claim is illustrated using the MALPAS intermediate language as a design language and compliance analysis as a verification technique. Author

N91-15715# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
COMPUTER AIDED SYSTEM DESIGN AND SIMULATION
Aug. 1990 388 p In ENGLISH and FRENCH Symposium held in Cesme/Izmir, Turkey, 22-25 May 1990
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Papers from the workshop are presented. The following guidance and control topics are addressed: computer aided system design, simulation technology for missile applications, simulation technology for aircraft applications, hardware-in-the-loop simulation, systems applications, and pilot-in-the-loop simulations. For individual titles, see N91-15716 through N91-15746.

N91-15716# Aerospatiale, Marignane (France). Div. Helicopteres.
ALGORITHMS DEVELOPMENT METHODOLOGY FOR PERFORMANCE-OPTIMIZED MULTICYCLIC ROTOR COMMANDS
S. GERMANETTI and BERNARD J. GIMONET *In* AGARD, Computer Aided System Design and Simulation 14 p (SEE N91-15715 07-61) Aug. 1990 In FRENCH
(AGARD-CP-473) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

It is now necessary to use simulation between the conception of an idea and its realization in the domain of control laws. The attempts to measure classically simple models focus attention on the limited but important aspects of the many problems posed by control and the necessity of minimizing the volume of calculations. Simulations now used, so that the calculations are realistically creditable and flexible, are a more integral part of actual components, theory, and equipment. Wind tunnel tests and flight tests are not the ultimate phase of simulation. Numerical simulation allows a choice of complexity of landing phenomena. This data allows a change of analytic and verification tools thanks to the effectiveness of the available interactive means. The precise approach is given of simulation tools during development of control laws for optimization of helicopter performance. Transl. by E. R.

N91-15717# Bilkent Univ., Ankara (Turkey).
A DECENTRALIZED CONTROLLER FOR HIGHLY AUGMENTED AIRCRAFT
KONUR ALP UNYELIOGLU and A. BULENT OZGULER *In* AGARD, Computer Aided System Design and Simulation 10 p (SEE N91-15715 07-61) Aug. 1990
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The design is considered of a decentralized controller for the yaw pointing/lateral translation control of the Flight Propulsion Control Coupling (FPCC) aircraft, to increase the reliability of the closed loop system with respect to absolute sensor failures. It is shown that better robustness results concerning absolute sensor failures with fixed zero output can be achieved by using decentralized dynamic compensator with high gain in the canard loop, at the expense of reduced phase and gain margins. Author

N91-15718# Naples Univ. (Italy). Dipartimento di Informatica and Sistemistica.
PARAMETER SPACE DESIGN OF ROBUST FLIGHT CONTROL SYSTEMS
A. CAVALLO, G. DEMARIA, and L. VERDE (Italian Aerospace Research Center, Capua.) *In* AGARD, Computer Aided System Design and Simulation 13 p (SEE N91-15715 07-61) Aug. 1990
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Generally, high performance requirements in terms of better efficiency (reduction in fuel consumption) and maneuverability, impose intrinsic instability on the aircraft. Then a Stability Augmentation System is required for its stabilization. Moreover, the aircraft must be safely controllable without any exceptional piloting skill. The requirements of stability and control are referred in literature as handling qualities. According to handling quality

specifications, a feedback controller must be designed with robustness criteria with respect to flight conditions and sensor failure. A new design procedure of feedback controllers which allows the achievement of simultaneous stabilization, and provides some kind of fault tolerance with respect to sensor failure, are proposed. An application to the F4-E military aircraft is also presented. Author

N91-15719# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Aircraft Div.
COMPUTER AIDED DESIGN AND SIMULATION OF THE AUTOMATIC APPROACH AND LANDING PHASE OF A COMBAT AIRCRAFT
F. D. LANGER *In* AGARD, Computer Aided System Design and Simulation 10 p (SEE N91-15715 07-61) Aug. 1990
(AGARD-CP-473) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Complex control systems like those used in modern aircraft can be efficiently designed and simulated with the aid of artificial intelligence tools. It is discussed how a symbolic manipulation program can be used to automate the steps which are necessary to design and simulate a control system. The landing phase of the MRCA Tornado is taken as an example. The automation of the development phase of a control system can reduce the workload of designers by doing repetitive, tedious, time consuming, and error prone tasks on the computer while letting the respective designers concentrate on more important issues. In the initial design phase, a six degree of freedom model is derived for the approach and landing mode of the aircraft configuration under consideration. The resulting nonlinear equations of motion are linearized around suitably spaced points of the flight trajectory. Next, control systems design methods are applied to the linearized set of equations to generate a control algorithm that satisfies prespecified goals. It is shown that a symbolic manipulation program can be employed as an integrated tool to derive the equations of motion, linearize them around a operating point, and produce a code for digital computer simulation. Author

N91-15720# Thomson-CSF, Malakoff (France). Div. Electronique de Missiles.
CONCEPTUAL DESIGN OF STRAPDOWN SEEKERS
F. BERTRAND and M. BREUZET *In* AGARD, Computer Aided System Design and Simulation 18 p (SEE N91-15715 07-61) Aug. 1990 In FRENCH
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The development of infrared sensor imagery over the last years, like image processing techniques, lead to the use of seeker optronics in which the optomechanics part is more simplified. The specification of strapdown seekers (with optronic stabilization of the line of sight) necessitate a global simulation of the missile behavior, because it is this which assures the angular homing in on the target. A digital simulation was employed, which permits the definition of the principal sensor parameters (the range, resolution, integration time) taking into account the characteristics of the missile, target, and the mission. The missile guidance is entirely assured by the algorithms which are represented by a behavior model. Transl. by E.R.

N91-15721# Societe d'Applications Generales d'Electricite et de Mecanique, Cergy-Pontoise (France). Missile and Space Guidance Systems Unit.
COMPUTER SIMULATIONS FOR THE DEVELOPMENT OF MISSILE NAVIGATION SYSTEMS
D. BERTON, D. DUHAMEL, and G. CUVELIER *In* AGARD, Computer Aided System Design and Simulation 18 p (SEE N91-15715 07-61) Aug. 1990
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An overview is given of general aspects of conception and utilization of simulators for the development of missile navigation systems. First, specific needs for simulators arising during the various stages of a project (concept definition, specifications, algorithms development, software validation, mission requirements analysis) are detailed. Then, the simulators currently operational

in SAGEM, and used to assist engineers in the development of modern missile guidance systems, are described. The utilization philosophy, as well as the different methods and tools available to exploit the vast amount of data delivered by simulators are detailed. Particular emphasis is given to the obtaining of true and accurate models of the systems being simulated. Finally, an example of the use of a simulator is given. It deals with the development of a new algorithm for automatic alignment of an airborne missile navigation system, before the launching of the missile. Author

N91-15722# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain).
GUIDED WEAPON SIMULATION: THE SBGL DEVELOPMENT EXPERIENCE
JOSE LUIS QUESADA RODRIGUEZ, RICARDO MINGUEZ, and PEDRO SEGUROLA (Sener Ingenieria y Sistemas S.A., Madrid, Spain) *In* AGARD, Computer Aided System Design and Simulation 10 p (SEE N91-15715 07-61) Aug. 1990
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The work in the simulation area carried out in the development of a laser guided weapon system (SBGL) is discussed. Simulation was used on two levels. First, computer integral simulation, with all subsystems algorithmically simulated, was made. A remarkable point is the use of the same high level software which was afterwards embedded in the SBGL real time processor. This allowed early testing of both design and codification of the software, independently of the hardware development, and a considerable reduction of the hardware - software integration problems. Secondly, simulation was done in a testing facility, for testing and validating the different subsystems and the whole system. The simulation facilities and the software tools used for their adjustment and validation are described, as well as the data reception and analysis capabilities. Finally, the flight data and simulation results are compared. It seems that the model developed is accurate, and that the complete simulation facility is a powerful tool for the design and validation of guided weapons. Author

N91-15723# Royal Military Coll. of Science, Shrivenham (England). Control and Guidance Group.
GWSIM: A COMPUTER BASED DESIGN AND SIMULATION PACKAGE FOR LAND BASED AND AIR WEAPON SYSTEMS
P. M. G. SILSON and B. A. WHITE *In* AGARD, Computer Aided System Design and Simulation 11 p (SEE N91-15715 07-61) Aug. 1990
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A weapon system design and simulation package is described and demonstrated. The package was developed for use both as a research and development design tool as well as a computer aided learning/demonstration package. The package is currently used in projects as diverse as guided weapon systems, VTOL aircraft control systems, helicopters, and autonomous land vehicle systems. The use of the package in design and simulation of a medium range ground to air missile is described and demonstrated. Author

N91-15724# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
THE MICROCOMPUTER AS A TOOL FOR GUIDANCE AND CONTROL VISUALIZATION
PAUL ZARCHAN *In* AGARD, Computer Aided System Design and Simulation 16 p (SEE N91-15715 07-61) Aug. 1990
(AGARD-CP-473) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

It is shown how real time simulation output can be generated and enhanced with the computational horsepower and graphics visualization technology which is currently available with microcomputers. Examples are presented which demonstrate how microcomputer based technology offer the designer a visualization which not only gives a deeper insight into the problem being solved, but in addition allows and encourages rapid iteration in order to get an acceptable design. Author

N91-15725# Litton Technische Werke, Freiburg (Germany, F.R.).
A UNIFIED APPROACH TO SIMULATION SOFTWARE AND OPERATIONAL SOFTWARE
A. MATTISSEK *In* AGARD, Computer Aided System Design and Simulation 10 p (SEE N91-15715 07-61) Aug. 1990
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Development of avionic software typically requires extensive simulation of avionic specific algorithms during system analysis phase. Usually these programs are written in FORTRAN. For the development of operational software the same algorithms are re-coded in assembly or a high level programming language. An approach is described where the application software is only coded once, using ADA as the language, and the same code is then used for simulation as well as for the operational program. To ease the translation from the existing FORTRAN simulation environment to ADA, a FORTRAN to ADA translator was applied to automatically generate ADA versions of existing FORTRAN packages. The experience with such a translator is also presented. Author

N91-15726# Forschungsinstitut fuer Anthropotechnik, Wachtberg (Germany, F.R.).
A SIMULATION STUDY FOR ANALYSING PILOT'S RULE-BASED BEHAVIOR
BERNHARD DOERING *In* AGARD, Computer Aided System Design and Simulation 19 p (SEE N91-15715 07-61) Aug. 1990
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In modern highly automated aircraft, the pilot still plays an important role. He has, e.g., to monitor automated flight processes and to compensate malfunctions of the equipment. If he is trained to identify work situations and consciously relate them to the appropriate action sequences, he exhibits rule based behavior. To permit this type of training, work situations and appropriate action sequences have to be known in advance and the cockpit-interface must be designed to facilitate them. A simulation study was made to establish the task knowledge required by the pilot to make a correct automated landing approach and to identify data flow requirements for the pilot-cockpit interface. The various steps of the study are described, starting with the definition of the problem and the development of a functional model. The model comprises a description of pilot behavior in terms of IF-THEN rules of a production system and of aircraft flight processes in the form of difference equations. Simulation generates the behavior of the pilot and the aircraft during approach. Simulation results are analyzed concerning data transmitted to the pilot and his control outputs. Methods for validating the models are discussed. Author

N91-15727# Universite Catholique de Louvain (Belgium).
SYMBOLIC GENERATION OF AIRCRAFT SIMULATION PROGRAMMES
P. MAES and P. Y. WILLEMS *In* AGARD, Computer Aided System Design and Simulation 9 p (SEE N91-15715 07-61) Aug. 1990
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The main features are presented of a multipurpose computer program which provides aircraft equations of motion in symbolic form and can be used in various testing and simulation procedures. The entries of the program are compatible with ISO standards. Various possibilities are given to the users and, when appropriate, standard choices are suggested. Both kinematical and dynamical equations are derived. They permit the motion of a reference point fixed to the aircraft to be determined as well as the orientation of the system; they relate the variables which describe the motion to the controls and the interactions and perturbations acting on the system. The program is written in C language, but its output is a standard FORTRAN subroutine which can be used as such by the user. Among other things, this program can be used for simulation and design purposes for the vehicle and its control and navigation systems. It can also be used for air traffic control simulation and trajectory optimization; coupled with a numerical

linearization subroutine, it also proves useful for stability analysis. Author

N91-15728# Avions Marcel Dassault, Saint-Cloud (France). Div. Systemes Avioniques.
FORMAL TOOLS AND SIMULATION TOOLS: A COHERENT WORKSHOP
PATRICK SCHIRLE *In* AGARD, Computer Aided System Design and Simulation 12 p (SEE N91-15715 07-61) Aug. 1990 In FRENCH
(AGARD-CP-473) Copyright Avail: NTIS HC/MF A17;
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Avionics systems today have become very complex and represent a large part of aircraft costs. The increasing cost over the last decade can be realized from the operational plans, technology, and methodology. Effective operations research and polyvalence carry an integration of many close functions, which are expressed by the optimization of physical and human resources (sensory fusion, human factors engineering, expert systems). For improvements in their efficiency, these methods rest on a number of information tools collected from coherent workshops. According to their place in the cycle of development, they represent the creative activities, verification, validation, or quality control. During some stages of development, the simulation allows verification to continue from the limited techniques of different specs. The simulation characteristics are from a different stage of development. The more upstream simulation allows hypothetical development to demonstrate their operability. Lastly, a simulation of system behavior is realized beginning with functional specs of the components. The methods and means are described which were used by the AMD-BA Society for the development of avionics systems from an industrial architecture viewpoint. The accent is placed on the different techniques and tools of simulation and their integration in a complete and coherent workshop. Transl. by E.R.

N91-15729# Aeronautica Macchi S.p.A., Varese (Italy). Air Vehicle Technology Div.
AIRCRAFT CONTROL SYSTEM DESIGN, SYNTHESIS, ANALYSIS, AND SIMULATION TOOLS AT AERMACCHI
L. MANGIACASALE, L. V. CIOFFI, and C. A. BONATTI *In* AGARD, Computer Aided System Design and Simulation 10 p (SEE N91-15715 07-61) Aug. 1990
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Three phases of an aircraft control system design are presented and discussed. From the preliminary synthetic design to the nonlinear simulation, the various steps proceed through the computational methods currently exploited at Aermacchi. Optimal and suboptimal methods are used in the first phase in order to get information about control strategies; accurate linear analysis is then performed with complex linear models for the continuous and sampled data design. The design is completed with three and six degrees of freedom nonlinear simulations in which the complete aircraft is simulated with an even more complex modelization. Author

N91-15730# Electronic System G.m.b.H., Munich (Germany, F.R.).
COCKPIT MOCK UP (CMU): A DESIGN AND DEVELOPMENT TOOL
CHRISTOPH WEBER *In* AGARD, Computer Aided System Design and Simulation 9 p (SEE N91-15715 07-61) Aug. 1990
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Designing a modern helicopter cockpit, ergonomics, operational, and technical aspects have to be considered. To ensure a low cost development schedule the Cockpit Mock-Up (CMU) is a flexible, inexpensive design and development tool for optimization of the Man Machine Interface (MMI). The ESG CMU, realized in close cooperation with the user, is a full size model cockpit of future helicopters such as NH 90 and PAH-2. The future user is integrated in the experimental closed loop simulation with the CMU. Author

N91-15731# Royal Aerospace Establishment, Bedford (England). Dept. of Flight Management.
COMPUTER-AIDED CONTROL LAW RESEARCH: FROM CONCEPT TO FLIGHT TEST
B. N. TOMLINSON, G. D. PADFIELD, and P. R. SMITH *In* AGARD, Computer Aided System Design and Simulation 15 p (SEE N91-15715 07-61) Aug. 1990
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Active control technology (ACT) has changed the way aircraft can be designed and flown. The challenge for flight control research is, given the potential of ACT, to define what is required. In order to answer this question, a flyable implementation is needed, whether for a piloted flight simulator or for full scale flight. The need for implementation introduces issues of software design and management and possibly conflict with the needs of research. A domain is described for flight control law research being developed to provide a rigorous yet flexible framework. A comprehensive life cycle is defined for the evolution of flight control laws from concept via piloted simulation to flight test which, in its current form, has four major phases: conceptual design, engineering design, flight clearance, and flight tests. Conceptual design covers off-line simulation. Engineering design is the process of full control law design. Flight clearance consolidates results from earlier stages and achieves a verified implementation for the target flight control computer. Flight test evaluates the control system in full scale flight. A description of all these phases is presented. Control law life cycle examples are given. Author

N91-15732# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.
REAL-TIME HARDWARE-IN-THE-LOOP SIMULATION FOR ATTAS AND ATTHES ADVANCED TECHNOLOGY FLIGHT TEST VEHICLES
PETER SAAGER *In* AGARD, Computer Aided System Design and Simulation 12 p (SEE N91-15715 07-61) Aug. 1990
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Applications are given of the real time simulations used by DLR, and are followed by the presentation of the implemented hardware concept and some special aspects with regard to the simulation computers AD10 and AD100. This includes considerations of the analog and digital input/output handling with connected hardware in the loop (HIL). The advantage of higher simulation languages (CSSL based ADSIM, MPS10) as software tools for the development, modification, and implementation of complex and extensive software modules under real time simulation aspects is also considered. Based on this discussion is the description of problems with the correlation between the simulation frame time and the actual integration stepsize. Suitable integration algorithms and other supporting methods used within real time simulations to compute the dynamics of stiff systems are described. The presented helicopter's mainrotor simulation model serves as an example of the complexity of software modules, incorporated into the real time simulations. Finally, the actual method for the verification and validation of the simulation results and the principle diagnostic and test software application concept is explained. Author

N91-15733# Naval Weapons Center, China Lake, CA. Missile Simulation Branch.
HARDWARE-IN-THE-LOOP SIMULATION AT THE NAVAL WEAPONS CENTER
R. A. LICKLIDER, A. B. GALLOWAY, F. SCHIAVONE, E. J. BEVAN, and W. WILLIAMS *In* AGARD, Computer Aided System Design and Simulation 7 p (SEE N91-15715 07-61) Aug. 1990
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Hardware in the loop (HWIL) simulation as it is practiced at the Naval Weapons Center is described along with its use in tactical missile development. Computational aspects of HWIL are discussed along with the types of simulations that form system analysis efforts. Target generation techniques in the radio frequency and infrared domains are presented with some comments on utility and cost. Author

N91-15734# Naval Weapons Center, China Lake, CA.
SIMULATION OF MULTIPATH FOR SEMIACTIVE MISSILES
RICHARD M. SMITH, JOE Y. YEE, CHONG S. AN, and ALLEN L. HAUN *In* AGARD, Computer Aided System Design and Simulation 14 p (SEE N91-15715 07-61) Aug. 1990
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High fidelity modeling of the multipath environment is required to properly test the performance of software tracking algorithms in a semiactive missile. Examples of multipath models are presented. Simulation data is compared to flight test data and the underlying signal mechanisms are explained. Author

N91-15735# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.
A NEW APPROACH TO HARDWARE-IN-THE-LOOP SIMULATION (FALKE SHUTTLE)
C.-H. OERTEL, K. ALVERMANN, R. GANDERT, and B. GELHAAR *In* AGARD, Computer Aided System Design and Simulation 19 p (SEE N91-15715 07-61) Aug. 1990
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System simulation is an important task in the development procedure of new and improved flight test vehicles. In addition to typical off-line and non-real time system simulations, special requirements for real time computation speed exists for flight simulators. Another application of real time simulation is the so called hardware in the loop (HIL) simulation, where real parts like new closed loop controllers or complete on-board systems are tested under realistic conditions. The progress in computer science shows a trend to distributed systems where multiple processors are running in parallel to improve the performance dramatically. At DLR a computer system, based on the TRANSPUTER was designed to achieve real time simulation capabilities for the FALKE Shuttle. This flight vehicle is a reduced size model of a reentry body which is used for a new aerodynamic flight test technique. The characteristics of the HIL simulation is presented along with an introduction to the FALKE flight test technique. Then an introduction to TRANSPUTERS is given along with a description of the hardware for simulation including all the interfaces to the FALKE. The simulation model is described and its mathematical formulation. Author

N91-15736# Naval Weapons Center, China Lake, CA. Missile Simulation Branch.
COMPUTER GRAPHICS IN HARDWARE-IN-THE-LOOP MISSILE SIMULATION
B. J. HOLDEN *In* AGARD, Computer Aided System Design and Simulation 11 p (SEE N91-15715 07-61) Aug. 1990
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Performance of computer graphics workstations has increased dramatically in recent years. These machines are currently being applied to a wide variety of scientific and engineering problems, and can be used very effectively in hardware in the loop (HWIL) simulation. The architecture of these machines is briefly explained and their current capabilities summarized. The application of graphics workstations to simulation visualization is discussed along with its application to the difficult problem of computer generated imagery for HWIL simulation of imaging missile systems. Author

N91-15737# Royal Aerospace Establishment, Farnborough (England).
MODELLING OF LAND BASED AIR DEFENCE SYSTEMS IN RESEARCH AND PROCUREMENT SUPPORT
K. A. HURST and S. FLYNN *In* AGARD, Computer Aided System Design and Simulation 11 p (SEE N91-15715 07-61) Aug. 1990
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The ADVOCATE (Air Defence Verification of Options by Computer Analysis of Target Engagements) land based air defence simulation program is described. The key features of the simulation program are given together with a description of how weapon systems and threats are modeled. The way in which ADVOCATE

is used is discussed and several weaknesses and strengths are identified as well as key program enhancements presently under way. The role of ADVOCATE as part of a wider weapon assessment process is also given some consideration throughout.   Author

N91-15738# European Organization for the Safety of Air Navigation, Brussels (Belgium). Engineering Directorate.
INTEGRATION OF A REALISTIC AIRLINE/AIRCREW/AIRCRAFT COMPONENT IN ATC SIMULATIONS
ANDRE BENOIT and SIP SWIERSTRA *In* AGARD, Computer Aided System Design and Simulation 10 p (SEE N91-15715 07-61) Aug. 1990
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Present trends indicate that air traffic density will double over the next few years. The level of automation achieved in the aircraft itself allows a flight to be programmed and then conducted with little or no subsequent human intervention. In contrast, at the executive level, the air traffic authorities handle each flight as a succession of individual short segments and are not in a position to take much account of aircraft capabilities. The work done by EUROCONTROL is described with a view to integrating airline requirements, crew reactions, and aircraft capabilities in simulations aimed at assessing future air traffic handling procedures. Such procedures involve the 4-D guidance of aircraft which may possess the entire range of 2-D, 3-D, and 4-D navigation capabilities. Emphasis is placed on specific aspects such as (1) assessment of future 4-D ground/air guidance procedures under realistic conditions, and (2) assessment of the overall air traffic control loop. The solutions proposed in the two areas were tested and were presented to controllers, pilots, and pseudopilots.   Author

N91-15739# Honeywell Advanced Technology Centre, Markham (Ontario).
NAVPACK: SIMULATION TOOLS FOR DESIGN OF HIGH PERFORMANCE INTEGRATED NAVIGATION SYSTEMS
JAN Z. ZYWIEL, JOHN S. A. HEPBURN, and BRUNO M. SCHERZINGER *In* AGARD, Computer Aided System Design and Simulation 6 p (SEE N91-15715 07-61) Aug. 1990
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The NAVPACK Software Package for navigation systems simulation and analysis is described. The fundamental concept of NAVPACK is to create as modular a structure for the software as possible, with standard interfaces between separate programs and within individual programs. Therefore NAVPACK consists of distinct computer programs that perform individual simulation tasks. These programs are combined as needed at the operating system level to perform the required processing. The NAVPACK software was successfully used for supporting a number of programs. It was used in the development of the Helicopter Integrated System (HINS). HINS requirements called for a high performance, robust, and fault tolerant integrated navigation system. Elements of NAVPACK were used for the development of a very high precision motion compensation system for high resolution, long range synthetic aperture radar. The package was also used in some work on a recently completed Marine Attitude Reference System (MARS), comprising an Inertial Navigation System (INS) capable of in motion alignment without aiding sensors.   Author

N91-15740# Contraves G.m.b.H., Stockach (Germany, F.R.).
APPLICATION OF MODELLING AND SIGNAL PROCESSING IN AIR DEFENCE
N. MURTY VEPA and WOLFGANG KREUZER *In* AGARD, Computer Aided System Design and Simulation 21 p (SEE N91-15715 07-61) Aug. 1990
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Modeling plays an important role in improving the performance of air defence systems. Simple and effective models that match the real world are necessary, to process sensor signals and to estimate/predict flight path trajectories of air targets in real time, to the accuracy needed by the air defence fire control systems. The scope in air defence consists of modeling of sensors and

effectors, noise and errors of sensors, flight path profiles of targets, target noise, and ballistics. Models and actual measurements form the basis for fire control algorithms design. Based on the experience gained in the development of a number of air defence systems, the techniques are described of modeling and sensor signal processing in real time. Critical problems that will be faced in land based, land vehicle mounted and ship based air defence systems are pointed out. Modeling of target types and target maneuvers is discussed. Methods of using modeling and stochastic optimal estimation techniques to estimate and predict target flight trajectory in real time are explained. A novel concept for an integrated sensor (WHISS) is briefly described. Use of multisensor data fusion and results of multisensor synergism are presented.   Author

N91-15741# Deutsche Airbus G.m.b.H., Hamburg (Germany, F.R.).
THE USE OF SYSTEM SIMULATION DURING THE DEFINITION PHASE OF THE PASSENGER TRANSPORT AIRCRAFT MPC75
DIETER DEY and AUGUST KROEGER *In* AGARD, Computer Aided System Design and Simulation 13 p (SEE N91-15715 07-61) Aug. 1990
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Some general remarks are presented concerning the tasks to be performed during the definition phase of a civil passenger aircraft and the importance is given of the use of simulation as a design tool. A more detailed differentiation of the terms systems and simulation is given with the emphasis on real time simulation. The present use of simulation in four areas is described: for systems engineering and know-how accumulation; for aircraft systems automation, monitoring, and handling in failure cases; for tests of programmed avionic boxes, specially the fly-by-wire system; and for flight simulation with and without pilot in the loop.   Author

N91-15742# Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (Germany, F.R.).
COMTESS: COMBAT MISSION TRAINING EVALUATION AND SIMULATION SYSTEM
W. KRAFT, U. KROGMANN, H. P. MUELLER, and E. PLATT *In* AGARD, Computer Aided System Design and Simulation 12 p (SEE N91-15715 07-61) Aug. 1990
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NATO air forces need to achieve and maintain combat readiness of their air crew against increasing challenge and complexity of expected combat scenarios and, at the same time, decreasing availability of training sorties. ACMI (Air Combat Maneuvering Installation) is of great training quality benefit for air forces, specially for air-to-air tactics training. However, there are disadvantages. COMTESS was designed against the requirements for ACMI and uses GPS (Global Positioning System) for accurate and continuous position determination, leading to registration of trajectories and maneuvers. COMTESS provides accurate visual mission reconstruction and playback for detailed evaluation and debriefing of both air-to-air and ground attack missions, range independent and daily available at squadron level worldwide. The system allows for various combination of live flown missions with complex simulator flying. COMTESS is low cost, easy handling, and fits any Sidewinder compatible and/or MIL STD 1760 interface aircraft without any need of modification.   Author

N91-15743# Boeing Co., Seattle, WA.
INTEGRATED TECHNOLOGY DEVELOPMENT LABORATORIES
DONALD E. DEWEY *In* AGARD, Computer Aided System Design and Simulation 7 p (SEE N91-15715 07-61) Aug. 1990
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New integrated avionics technologies are capable of providing the performance improvements needed for current military aircraft. However, integrated laboratory facilities are needed to fully realize the potential of these technologies. The Boeing Co. has developed such a facility, a single laboratory capable of studying high

integrated avionics systems from research through full scale development. Author

N91-15744*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SIMULATION OF NAP-OF-EARTH FLIGHT IN HELICOPTERS
GREGORY W. CONDON *In* AGARD, Computer Aided System Design and Simulation 17 p (SEE N91-15715 07-61) Aug. 1990
(AGARD-CP-473) Copyright Avail: NTIS HC/MF A17; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 09/2

NASA-Ames in conjunction with U.S. Army has conducted extensive simulation investigations of rotorcraft in the nap-of-the-Earth (NOE) environment and has developed facility capabilities specifically designed for this flight regime. The experience gained to date in applying these facilities to the NOE flight regime are reported along with the results of specific experimental investigations conducted to understand the influence of both motion and visual scene on the fidelity of NOE simulation. Included are comparisons of results from concurrent piloted simulation and flight research investigations. The results of a recent simulation experiment to investigate simulator sickness in this flight regime is also discussed. Author

N91-15745# Royal Aerospace Establishment, Farnborough (England).
RESULTS OF MAN IN THE LOOP SIMULATOR EXPERIMENTS USING AIR-TO-AIR MISSILE MODELS
NEILL SEAVERS *In* AGARD, Computer Aided System Design and Simulation 1 p (SEE N91-15715 07-61) Aug. 1990
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Short Range Air-to-Air Missiles (SRAAMS) are an essential part of any modern fighter aircraft's weapon system. The high success rate of InfraRed (IR) SRAAMS, e.g., Sidewinder class missiles in aerial conflict, have made a considerable impact on modern aerial combat tactics and to some extent on aircraft and weapon system designs. Some of the experiences and results gained from two man in the loop experimental trials using the RAE Combat Simulator are detailed. Various types of air-to-air missiles and aircraft weapon systems were used against a variety of threat aircraft. Author

N91-15746# Test Squadron (6515th), Edwards AFB, CA.
THE DEVELOPMENT OF AVIONICS-INTENSIVE, MULTI-SENSOR COCKPITS: SIMULATION DOES NOT ALWAYS EQUAL SUCCESS
C. G. KILLBERG *In* AGARD, Computer Aided System Design and Simulation 8 p (SEE N91-15715 07-61) Aug. 1990
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Simulation provides a critical foundation for the design and development of advanced aircraft. Present day wind tunnels and aerodynamic computer models are generally accurate to within a few percentages of actual performance. Simulators appear to provide a very accurate model of the environment for large transport category aircraft, which operate in comparatively benign conditions. Although the past decade has brought significant changes to the design of commercial airline cockpits, one may recall that for many years major commercial aircraft manufacturers tried in vain to modernize airline cockpits with significant improvements in instrument and display design. The use of simulation in the design and development of the cockpit man-machine interface for advanced multisensor aircraft is not always successful. Certainly simulation has been useful in the development of fighter/attack aircraft with high integrated cockpits. Some of the reasons for the failure of simulation to highlight some of these problems before a highly integrated fighter flys for the first time are examined. Author

N91-19731# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
TECHNICAL EVALUATION REPORT OF THE GUIDANCE AND CONTROL PANEL 50TH SYMPOSIUM ON COMPUTER AIDED SYSTEM DESIGN AND SIMULATION
GEORGE T. SCHMIDT (Draper, Charles Stark Lab., Inc., Cambridge, MA) Nov. 1990 25 p
(AGARD-AR-283; ISBN-92-835-0596-6; AD-A230433) Copyright Avail: NTIS HC/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The 50th symposium of the AGARD Guidance and Control Panel was held in Cesme, Turkey, from May 22 to 25, 1990. The goal of the symposium was to provide a valuable opportunity to highlight the possibilities, problems, and solutions associated with the use of computers for system design and simulation. This technical evaluation report evaluates the presentations in each of the six formal sessions of the symposium and summarizes the round table discussions and reactions of symposium participants. The technical sessions addressed the following areas: computer aided systems design, simulation technology for missile and aircraft applications, hardware-in-the-loop simulations, systems applications, and pilot-in-the-loop simulations. B.G.

N91-25131# Royal Aircraft Establishment, Farnborough (England).
A METHODOLOGY FOR PRODUCING VALIDATED REAL-TIME EXPERT SYSTEMS
S. A. CROSS and M. GRISONI (Logica Ltd., Cambridge, England) *In* AGARD, Knowledge Based System Applications for Guidance and Control 11 p (SEE N91-25121 17-04) Apr. 1991
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VORTEX (Validation Of Real Time EXpert systems) is an experimental methodology for building validated expert systems. It considers validation to be an exercise in building confidence in a system in the users, procurers, experts, and developers. It identifies the components of validation concerning each participant and techniques for achieving validation and embeds them in a life cycle suitable for a new technology. The essential points are presented of the methodology along with some experiences from the airborne Antisubmarine (ASW) application developed in parallel with it. Author

N91-25134# Royal Aircraft Establishment, Farnborough (England).
AN ADA FRAMEWORK FOR THE INTEGRATION OF KBS AND CONTROL SYSTEM SIMULATIONS
M. J. CORBIN and G. F. BUTLER *In* AGARD, Knowledge Based System Applications for Guidance and Control 6 p (SEE N91-25121 17-04) Apr. 1991
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The application of Ada and an object oriented approach to the design and construction of advanced defence systems are both attracting increasing attention. The Ada language contains some support for object oriented programming but has some notable deficiencies. How to overcome these deficiencies is shown by providing a library for object oriented development in Ada (OODA) which contain facilities to create and manipulate objects and provides support for more general relationships between objects. One of the initial applications of this library was to design a framework for integrating Knowledge Base System (KBS) with control system simulations comprising mixed continuous and discrete time elements. Using this framework it is possible to study the interactions between a Knowledge Based controller and the other more conventional elements of the closed loop to any level of detail required. Author

N92-12449# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
SOFTWARE FOR GUIDANCE AND CONTROL
Sep. 1991   243 p   In ENGLISH and FRENCH   The 24th symposium was held in Thessaloniki, Greece, 7-10 May 1991
(AGARD-CP-503; ISBN-92-835-0629-4) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

This volume contains the 23 unclassified papers presented at the Guidance and Control Panel Symposium. The papers were presented covering the following headings: tools and methods from a user's viewpoint; general requirements on software; integrated program support environments; software requirements; design methods for real-time software; Ada applications; and automated software generation approaches. For individual titles, see N92-12450 through N92-12469.

N92-12450# GEC-Marconi Ltd., Stanmore (England).
A SURVEY OF AVAILABLE TOOLS AND METHODS FOR SOFTWARE REQUIREMENTS CAPTURE AND DESIGN
D. J. THEWLIS   In AGARD, Software for Guidance and Control 7 p (SEE N92-12449 03-61)   Sep. 1991
(AGARD-CP-503) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The contribution of the tools and methods to software development are discussed. These tools and methods are currently available to assist with the early part of the software development life cycle: that is tools and methods for requirements capture and design. The discussion of methods and their contribution to software development comes from experience gained using a Hierarchical Object Oriented Design (HOOD) tool.   Author

N92-12451# Federal Ministry for Defence, Bonn (Germany, F.R.).
TOOL SUPPORTED SOFTWARE DEVELOPMENT EXPERIENCES FROM THE EFA PROJECT
WERNER M. FRAEDRICH   In AGARD, Software for Guidance and Control 7 p (SEE N92-12449 03-61) Sep. 1991
(AGARD-CP-503) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The European Fighter Aircraft (EFA) Project is a multinational project. Agreement had to be reached between the partner nations (industry and government) with respect to pertinent data processing support. It is shown that general agreements were worked out by arriving at the lowest common denominator since none of the participating nations were prepared to accept standards established by another partner nation; an attempt to solve this problem is presented. The following topics are addressed: (1) some general information on the EFA Project, including important determinations; (2) the status of the software tool selection and procurement in the EFA Project; and (3) a comparison between required and actual availability of software tools in the EFA Project.   Author

N92-12452# Smiths Industries Aerospace and Defence Systems Ltd., Cheltenham (England).
MILITARY AND CIVIL SOFTWARE STANDARDS AND GUIDELINES FOR GUIDANCE AND CONTROL
K. W. WRIGHT   In AGARD, Software for Guidance and Control 13 p (SEE N92-12449 03-61) Sep. 1991
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The two most widely used standards covering the development of software in the military and civil avionics industries are DOD-STD-2167A and the Radio Technical Commission for Aeronautics (RTCA) DO.178A/European Organization for Civil Aviation Electronics (EUROCAE) ED-12A, respectively. This latter document is currently undergoing extensive update by RTCA Special Committee (SC) 167 and EUROCAE Working Group (WG) 12, with a planned document re-issue date of the end of 1991. A comparison of DOD-STD-2167A with the work currently being undertaken by SC 167/WG.12.   Author

N92-12453# Marconi Underwater Systems Ltd., Weybridge (England).
REQUIREMENTS AND TRACEABILITY MANAGEMENT
G. M. CROSS   In AGARD, Software for Guidance and Control 5 p (SEE N92-12449 03-61) Sep. 1991
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The contribution of requirements traceability to the system development process in risk reduction and rework avoidance and the impact on all phases of project development from requirements capture to customer acceptance and subsequent maintenance is explained. By update of the traditional lifecycle model, it is shown how the requirements of traceable management (RTM) product builds a system development environment addressing these issues and improving the benefits to users of many of todays leading computer aided software engineering (CASE) tools by more effective integration, with a total lifecycle coverage.   Author

N92-12454# Naval Weapons Center, China Lake, CA.
COPROCESSOR SUPPORT FOR REAL-TIME ADA
R. K. PAGE   In AGARD, Software for Guidance and Control 7 p (SEE N92-12449 03-61) Sep. 1991
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The purpose is to propose the basic elements of a real-time clock that would be suitable for use with the tasking mechanism of the Ada programming language and other real-time concurrency management systems. A real-time application needs such a clock for several reasons: (1) to relieve the processor of some of the overhead burden of time and task management; (2) to provide adequate granularity for the representation of time; and (3) to provide sufficient range for the representation of time. A more complete solution to the overhead problem is suggested: move both the clock and the task scheduling functions normally implemented in software into a concurrency management coprocessor.   Author

N92-12455# Dornier Luftfahrt G.m.b.H., Friedrichshafen (Germany, F.R.).
SOFTWARE DESIGN CONSIDERATIONS FOR AN AIRBORNE COMMAND AND CONTROL WORKSTATION
P. KIELHORN, P. KUEHL, B. MUTH, and R. VISSERS   In AGARD, Software for Guidance and Control 16 p (SEE N92-12449 03-61) Sep. 1991
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Some basic concepts are presented of the software design for a command and control workstation for airborne applications. Not only are theoretical considerations reported, but also practical experience, which was gained during the development process of a prototype command and control workstation at DORNIER. Special emphasis is put on software architecture, data structures, and tasking with respect to Ada. In order to get a firm basis and to ease understanding, a description is given of the tasks and the components of a command and control workstation, which includes a short description of the aforementioned DORNIER prototype workstation MODOS.   Author

N92-12457# GEC Avionics Ltd., Rochester (England). Technology and Systems Research Lab.
FORMAL VERIFICATION OF A REDUNDANCY MANAGEMENT ALGORITHM
JONATHAN DRAPER   In AGARD, Software for Guidance and Control 6 p (SEE N92-12449 03-61) Sep. 1991
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Work is described on mathematical formal verification of a redundancy management algorithm that was carried out in two stages. The first stage used the specification language Z and verified the specification with hand written rigorous proofs. The second stage used a proof tool to produce formal proofs and specified the system with the language of that proof tool. The system specified was part of a safety critical software section of an avionic system. A section is included that presents the

theoretical concepts of formal methods, concentrating on specification and proof. These ideas are illustrated with extracts from the formal specifications. Some of the benefits and problems of using mathematical proof for verification are described in the illustration of the redundancy management example. Author

N92-12459# Forschungsinstitut fuer Funk und Mathematik, Wachtberg (Germany, F.R.).
NETWORK PROGRAMMING: A DESIGN METHOD AND PROGRAMMING STRATEGY FOR LARGE SOFTWARE SYSTEMS
L. SCHUBERTH, J. KUTSCHER, and W.-J. GRUENEWALD *In* AGARD, Software for Guidance and Control 15 p (SEE N92-12449 03-61) Sep. 1991
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Network Programming (NP) is a methodology for the evolutionary development and life cycle support of large data processing systems. It uses a fully decentralized approach. A given DP task is first realized as an operable network of sequential processes, communicating via typed channels. It serves as a base for logical testing, data flow measurements, and assessment of system behavior. Runtime requirements and the mapping of processes to processors are taken care of in a separate final step. A remote procedure call illustrates the concept of a channel's operation mode. The NP method is neither confined to a certain programming language nor to a certain kind of machinery. A short introduction is given to NP and its main features. Then the Network Programmer's Workbench will be shown in some detail and some of its tools are described. Particular attention is paid to the Network Monitor. An example illustrates the use of these software instruments. Finally, a defense oriented simulation is examined.
Author

N92-12460# British Aerospace Dynamics Group, Stevenage (England).
THE DATA ORIENTED REQUIREMENTS IMPLEMENTATION SCHEME
CHRISTINE THOMAS *In* AGARD, Software for Guidance and Control 9 p (SEE N92-12449 03-61) Sep. 1991 Sponsored in part by Ministry of Defence in the UK
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A need has been identified for a generalized approach to the specification, design, and development of real time embedded systems. There are many tools that cover different parts of the life cycle. Some of these are integrated to various degrees, but for real time systems it is probably true to say that there is not a set of integrated tools which covers all the phases of the life cycle. Described here is the way that the Data Oriented Requirements Implementation Scheme (DORIS) attempts to remedy this situation. Author

N92-12461# Electronic System G.m.b.H., Munich (Germany, F.R.).
PROCESS/OBJECT-ORIENTED ADA SOFTWARE DESIGN FOR AN EXPERIMENTAL HELICOPTER
K. GRAMBOW *In* AGARD, Software for Guidance and Control 7 p (SEE N92-12449 03-61) Sep. 1991
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Discussed here is the software design method for real-time applications written in Ada. It proves that even time critical systems can be implemented in pure Ada. The design method is based on the Ada tasking model in conjunction with object oriented (OOD) principles. Special purpose graphs, derived from Yourdon/DeMarco data flow diagrams (DFDs), illustrate the method, while Ada program design language (PDL), as a counterpart to the graphs, serves as a basis for the software implementation. No global executive is used to schedule the concurrent threads of execution. Instead, a rendezvous-based interaction of Ada tasks provides the scheduling. This is automatically generated from an Ada compiler. This software design technique is illustrated by the development of the operational flight software for an experimental helicopter. Author

N92-12462# Digital Signal Processing and Control Engineering G.m.b.H., Paderborn (Germany, F.R.).
CODE GENERATION FOR FAST DSP-BASED REAL-TIME CONTROL
H. HANSELMANN, A. SCHWARTE, and H. HENRICHFREISE *In* AGARD, Software for Guidance and Control 9 p (SEE N92-12449 03-61) Sep. 1991
(AGARD-CP-503) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Digital single chip signal processors (DSP) are powerful devices to implement closed-loop controllers for highly dynamic mechanisms. However, code production is not that easy, particularly with DSP offering only fixed-point arithmetic. Described here are key issues and a toolset which builds on automatic code generation to complement existing control design tools so as to close the gap between design and implementation or experiment. Author

N92-12463# Thomson-CSF, Bagneux (France).
COMPUTER AIDED DESIGN OF WEAPON SYSTEM GUIDANCE AND CONTROL WITH PREDICTIVE FUNCTIONAL CONTROL TECHNIQUE
DIDIER CUADRADO and S. ABUELATADOSS (Association pour le Developpement de l'Enseignement et de la Recherche en Systematique Appliquee, Verrieres-le-Buisson, Franc) *In* AGARD, Software for Guidance and Control 16 p (SEE N92-12449 03-61) Sep. 1991
(AGARD-CP-503) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Predictive Functional Control (PFC), a Mode Based Predictive Control (MBPC) technique, is a control strategy based on the use of a model to predict the process output over a long range time period. This technique, fully compatible with the computer aided design (CAD) based integrated plan, is presented. The link between the specification and the control law tuning parameters is made and the benefits of the use of a CAD tool is demonstrated. Two industrial applications are detailed. The first one concerns the guidance of an air defence short range missile. The second one consists in the control of the two axis turret of a very short range air defence weapon system. Author

N92-12464# Naval Weapons Center, China Lake, CA.
ANALYST WORKBENCH
THOMAS F. REESE and FRANK ARMOGIDA *In* AGARD, Software for Guidance and Control 12 p (SEE N92-12449 03-61) Sep. 1991
(AGARD-CP-503) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The Analyst Workbench was developed at the Naval Weapons Center (NWC) to provide analysts with the ability to interactively visualize flight test and simulation results in the study of missile performance and effectiveness. This technology integrates tools and utilities into one software package that not only assists analysts in gathering data, but provides the means to analyze and assimilate the data. The Analyst Workbench helps eliminate the large portion of time analysts now spend just searching for the data so that this valuable time can be spent analyzing the data. Using these technologies to increase personnel productivity and organization communications will ensure the reliability and effectiveness of current and future guidance and control systems throughout the North Atlantic Treaty Organization (NATO). Author

N92-12465# Dassault (E. M.) Co., Saint Cloud (France). Dassault Electronique.
A PRACTICAL EXPERIENCE OF ADA FOR DEVELOPING EMBEDDED SOFTWARE
CHRISTOPHE GOETHALS and CLAUDE GRANDJEAN *In* AGARD, Software for Guidance and Control 4 p (SEE N92-12449 03-61) Sep. 1991
(AGARD-CP-503) .Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The general purpose programming language Ada is discussed. Some important reflections are proposed regarding design methods, real-time aspects, and tools needed, considering the experience with combat aircraft embedded software. Author

N92-12467# Lucas Aerospace Ltd., Birmingham (England).
SOFTWARE METHODOLOGIES FOR SAFETY CRITICAL SYSTEMS
W. C. DOLMAN, A. M. ASHDOWN, and T. C. MOORES (Ministry of Defence, London, England) *In* AGARD, Software for Guidance and Control 21 p (SEE N92-12449 03-61) Sep. 1991
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UK MOD (PE) identified Ada as a single preferred high level language for the implementation of defence real-time operational systems. UK MOD (PE) decided iu invite proposals for the High Order Language Demonstrator (HOLD) to examine the applicability of Ada to aero gas turbine FADEC. The work carried out to date is described. *Author*

N92-12468# Air Force Armament Lab., Eglin AFB, FL.
COMMON ADA MISSILE PACKAGES (CAMP)
BARRY E. MULLINS *In* AGARD, Software for Guidance and Control 6 p (SEE N92-12449 03-61) Sep. 1991
(AGARD-CP-503) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The Common Ada Missile Packages (CAMP) program is developed to ease the software crisis via a high-payoff remedy - reuse of real-time embedded (RTE) software. CAMP is a pathfinding effort designed to investigate the feasibility of RTE software reuse by actually developing reusable Ada parts, compiler benchmarks, and a parts engineering system. The following topics are described: the genesis of CAMP, structure of the CAMP program, evaluation results, and CAMP products. *Author*

N92-12469# LITEF, Freiburg (Germany, F.R.).
DEVELOPMENT AND VERIFICATION OF SOFTWARE FOR FLIGHT SAFETY CRITICAL SYSTEMS
H. AFZALI and A. MATTISSEK *In* AGARD, Software for Guidance and Control 4 p (SEE N92-12449 03-61) Sep. 1991
(AGARD-CP-503) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
In Flight Safety Critical System errors in the Computer Software components can have a catastrophic impact on the safety. For the development of the equipment software, a set of development standards and additional procedures for the implementation of Safety Critical Functions are defined. The standards and procedures were applied for the development of the Inertial Measurement Unit which is a part of the Flight Control System and Seat Sequencer Unit which is part of the Ejection Seat. Some critical technology needs for supporting the development and verification process of such systems and activities which have to be performed during the development phases for identifying, assessing, and eliminating or minimizing hazards in a systematic way are described. *Author*

N92-17498# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
TECHNICAL EVALUATION REPORT ON THE 52ND SYMPOSIUM ON SOFTWARE FOR GUIDANCE AND CONTROL
DONALD E. DEWEY (Boeing Military Airplane Development, Seattle, WA.) Dec. 1991 41 p Symposium held in Thessaloniki, Greece, 7-10 May 1991
(AGARD-AR-302; ISBN-92-835-0647-2; CP-503) Copyright Avail: NTIS HC/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A review is presented of some of the symposium sessions. The papers presented covered some of the following headings: tools and methods for a user's viewpoint; general requirements on software; integrated programs support environments; software requirements; design methods for real time software; ADA applications; and automated software generation approaches. *Author*

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CYBERNETICS

Includes feedback and control theory, artificial intelligence, robotics and expert systems.

N91-25122# Lockheed Aeronautical Systems Co., Thousand Oaks, CA.
THE PILOT'S ASSOCIATE: EXPLOITING THE INTELLIGENT ADVANTAGE
DOUGLAS I. HOLMES and JOHN P. RETELLE, JR. (Lockheed Missiles and Space Co., Calabasas, CA.) *In* AGARD, Knowledge Based System Applications for Guidance and Control 8 p (SEE N91-25121 17-04) Apr. 1991
(AGARD-CP-474) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The Pilot's Associate program has provided a series of technology demonstrations of the potential of integrating intelligent systems and artificial intelligence technology into modern avionics systems. The Defense Advanced Research Projects Agency and the United State Air Force have provided funding and program management to determine the potential increases in mission effectiveness from such a system. The Pilot's Associate effort pursued by Lockheed and its partners has produced not only prototypes for advanced systems, but also new insights into the nature of the systems themselves as well as new approaches for quickly producing software for these systems. The rapid prototyping methods that have been utilized have also provided the ultimate consumers (the pilots) with significant awareness of the operation of the Pilot's Associate, and with many opportunities to improve the requirements for such a system. The evolution of Lockheed's Pilot's Associate System approach leading to the current system configuration is described. Also described are some lessons learned from managing a large software development team assembled to produce an unprecedented system. *Author*

N91-25132# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain).
A REVIEW OF SOME ASPECTS ON DESIGNING FUZZY CONTROLLERS
E. TRILLAS, M. DELGADO, J. L. VERDEGAY, and M. A. VILA (Granada Univ., Spain) *In* AGARD, Knowledge Based System Applications for Guidance and Control 12 p (SEE N91-25121 17-04) Apr. 1991
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Theoretical and practical aspects are examined of the fuzzy control systems according to the following scope. First, foundations of the fuzzy controllers, and the different ways for implementing them, are described. Second, the management of the information is studied, i.e., the way in which the inferences are made from the expert's knowledge. Usually this is carried out by means of the Generalized Modus Ponens for which, the so-called implication function, is the main tool used to handle it. Hence, depending on the selected type of implication, one has a different version of inference. Finally, the possible implications functions and the consequences of its use are analyzed and discussed. *Author*

N91-25133# Vanderbilt Univ., Nashville, TN.
A NEURAL NETWORK FOR THE ANALYSIS OF AIRCRAFT TEST DATA
J. B. GOLDEN and B. A. WHITEHEAD (Tennessee Univ. Space Inst., Tullahoma.) *In* AGARD, Knowledge Based System Applications for Guidance and Control 13 p (SEE N91-25121 17-04) Apr. 1991
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With the advent of the USAF's Advanced Tactical Fighter and NASA's National Aerospace Plane, demands for concise test data reduction and interpretation will increase beyond the capabilities of current methodologies. As mission complexity increases it becomes apparent that real time data analysis for flight safety,

mission control and test conduct becomes a necessary tool. A neural network is a biologically inspired mathematical model, which can be represented by a directed graph, that has the ability to learn through training. They are excellent for parameter estimation and pattern recognition in signal data. A prototype system is discussed which was designed and implemented to discover patterns in test data from an engine test cell in order to determine if any part of the system is in failure. The results show that a neural net can be used for fault diagnosis in an engine test cell when the problem of fault monitoring and diagnosis is seen as one of pattern recognition. A two layer semilinear feedforward neural net is able to separate simulated sensor data into normal and abnormal classes and the addition of a hidden layer makes the network more resistant to noise and improves its network classifying ability.   Author

N91-25906# Copenhagen Univ. (Denmark).
FIELDS OF APPLICATION OF THE PROCESSING OF NATURAL LANGUAGES WITH THE HELP OF ARTIFICIAL INTELLIGENCE
BENTE MAEGAARD   *In* AGARD, Bridging the Communication Gap 5 p (SEE N91-25902 17-82) Feb. 1991
(AGARD-CP-487) Copyright Avail: NTIS HC/MF A06;
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    Two very important areas of Natural Language Processing (NLP) application are described in some detail, machine translation and computer assisted instruction. Both fields are extremely important, and of growing importance. Artificial Intelligence techniques are only starting to be used in applications. At the same time an alternative model for artificial intelligence has emerged: neural networks. Neural networks are interesting from a theoretical point of view, because they can be said to take into account the biology of human information processing. It is not possible at present to evaluate the potential of neural networks for application in the Language Industries.   Author

N92-12517#   Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
MACHINE INTELLIGENCE FOR AEROSPACE ELECTRONIC SYSTEMS
Sep. 1991   301 p   In ENGLISH and FRENCH   Symposium held in Lisbon, Portugal, 13-16 May 1991
(AGARD-CP-499; ISBN-92-835-0628-6; AD-A242025) Copyright
Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
    The papers presented at the Avionics Panel Symposium are compiled. The results of efforts applying Machine Intelligence (MI) technology to aerospace electronic applications are discussed. The symposium focused on application research and development to determine the types of MI paradigms which are best suited to the wide variety of aerospace electronic applications. For individual titles, see N92-12518 through N92-12544.

N92-12518# Rome Air Development Center, Griffiss AFB, NY.
MACHINE INTELLIGENCE FOR SURVIVABLE COMMUNICATIONS NETWORK MANAGEMENT
NICK P. KOWALCHUK   *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 7 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499) Copyright Avail: NTIS HC/MF A14;
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    The development of communication networking technologies that increase the survivability of services provided to military users was an important goal in Air Force programs over the past several years. This enhanced survivability is a result of work that focused on two areas: the development of more robust communication equipment, and the development of a management system that coordinate the use of this equipment. The role of machine intelligence in the design of such a network management system is discussed. Emphasis is placed on the intelligent network management decision making capabilities that are required in a military environment, and the design tradeoffs which must be made in developing a system that can optimize the system-wide use of resources without the need of human intervention.   Author

N92-12519# Rome Air Development Center, Griffiss AFB, NY.
A DISTRIBUTED ENVIRONMENT FOR TESTING COOPERATING EXPERT SYSTEMS
JEFFREY D. GRIMSHAW   *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 11 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499) Copyright Avail: NTIS HC/MF A14;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The Advanced Artificial Intelligence Technology Testbed (AAITT) is discussed. Its purpose is to provide a powerful environment for integrating dissimilar software systems including expert systems, conventional software, databases, and simulations distributed over a network. It also will provide measurement and analysis tools for evaluating the results of the various user-supplied software components. The AAITT will be based on the ABE (A Better Environment) module-oriented system and on the Cronus distributed computing environment. This will allow the various components to communicate transparently over a heterogeneous network. Generic database and simulation capabilities will be provided to support the development, integration, and testing of new software components.   Author

N92-12520# Rome Air Development Center, Griffiss AFB, NY.
HEURISTIC ROUTE OPTIMIZATION: A MODEL FOR FORCE LEVEL ROUTE PLANNING
JANET L. BARBOZA   *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 6 p (SEE N92-12517 03-63) Sep. 1991
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    A major shortcoming of tools and methods currently employed for route planning is that they do not incorporate force-level factors, or, if they do, the representation is inadequate. Many important factors necessary for approaching the best possible route are ignored. Heuristic Route Optimization, or HERO, is a model for automated route generation for force-level mission planning. Object Oriented techniques and a dynamic threat representation allow detailed analysis of multiple planning variables in producing effective, survivable mission plans.   Author

N92-12522# Phillips Lab., Kirkland AFB, NM.
A SYNERGISTIC APPROACH TO REASONING FOR AUTONOMOUS SATELLITES
JAMES M. SKINNER and GEORGE F. LUGER (New Mexico Univ., Albuquerque.)   *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 8 p (SEE N92-12517 03-63) Sep. 1991
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    Based on our earlier research, we are convinced that the best way to approach problem solving tasks is not through any single method of reasoning, but by a method that will allow several reasoning methods to be blended together. The thrust of this effort is to develop a synergistic approach to reasoning that will allow a system to rely on multiple reasoning methodologies, thus benefiting from the strength of each of the reasoning methods, while minimizing their respective weakness. The following steps are discussed that were taken towards developing such a system: (1) the categorization of reasoning methods; (2) the selection of reasoning approaches to blend; (3) design of a framework to blend the systems; and (4) proposed tasks to investigate the result.
                                    Author

N92-12524# British Aerospace Public Ltd. Co., Preston (England). Software Technology Dept.
TACAID: A KNOWLEDGE BASED SYSTEM FOR TACTICAL DECISION MAKING
K. ROBERTS   *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 6 p (SEE N92-12517 03-63) Sep. 1991
(AGARD-CP-499) Copyright Avail: NTIS HC/MF A14;
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    TACAID (TACtical AID) is a research tool to explore the use of AI idea in Mission Management Aids and investigate the potential benefits of coupling between AI and more convenient modules. TACAID is developed using the tool MUSE, a blackboard based

system which possesses many of the generic features used in AI, namely: object oriented knowledge representation; object hierarchy; object relations; forward production rules; backward chaining goals; symbolic list manipulation; and knowledge source scheduling.

Author

N92-12527# Smiths Industries Aerospace and Defense Systems, Inc., Grand Rapids, MI.
NEURAL NETWORK SOLUTIONS TO MATHEMATICAL MODELS OF PARALLEL SEARCH FOR OPTIMAL TRAJECTORY GENERATION
LYLE A. REIBLING *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 9 p (SEE N92-12517 03-63) Sep. 1991
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AGARD/Scientific Publications Executive

Research was performed in neural network technology for vehicle management system applications of optimal trajectory generation in embedded systems. The problem and solution method is described in envisioning massively parallel architectures which incorporate mathematical physics models for trajectory generation applications. A difficult problem in search applications is computing the optimal aircraft trajectory in real time onboard an aircraft, where the objective is to increase the aircraft survivability and mission effectiveness by penetrating enemy threats and minimizing threat radar exposure. The mathematical model which is the basis for the architecture is based on an application of electrostatic field theory. It describes the problem of finding the best path through a region which contains a variable cost function as a problem in mathematical physics. This research studied computer architecture and algorithms characterized by massive parallelism which can solve trajectory generation problems.

Author

N92-12528*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A NASA/RAE COOPERATION IN THE DEVELOPMENT OF A REAL-TIME KNOWLEDGE BASED AUTOPILOT
COLIN DAYSH, MALCOLM CORBIN, GEOFF BUTLER, EUGENE L. DUKE, STEVEN D. BELLE, and RANDAL W. BRUMBAUGH (PRC Systems Services Co., Edwards, CA.) *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 10 p (SEE N92-12517 03-63) Sep. 1991 Sponsored in part by Ministry of Defence
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As part of a US/UK cooperative aeronautical research program, a joint activity between NASA-Ames and the Royal Aerospace Establishment on Knowledge Based Systems (KBS) was established. This joint activity is concerned with tools and techniques for the implementation and validation of real-time KBS. The proposed next stage of the research is described, in which some of the problems of implementing and validating a Knowledge Based Autopilot (KBAP) for a generic high performance aircraft will be studied.

Author

N92-12542# Wright Lab., Wright-Patterson AFB, OH.
ENGINEERING GRAPHICAL ANALYSIS TOOL (EGAT) DEVELOPMENT PROGRAM
VICTOR R. CLARK and JOSEPH R. DIEMUNSCH *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 10 p (SEE N92-12517 03-63) Sep. 1991
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The Air Force Avionics Laboratory has sponsored many efforts to develop real-time Artificial Intelligence (AI) systems. One of these systems, the Adaptive Tactical Navigation (ATN) Program, developed a prototype system to intelligently control a future tactical fighter's integrated navigation sensors. ATN was developed using a distributed communicating expert object architecture called the Activation Frame (AF). Using the AF architecture, ATN was able to achieve real-time execution. Real-time execution was primarily achieved due to the AF's distributed control scheme which eliminates many of the bottlenecks associated with centralized schedulers. Unfortunately, with these increased benefits, there is increased complexity associated with correctly setting the distributed control parameters. The Engineering Graphical Analysis

Tool (EGAT) was developed to overcome these limitations by providing a user friendly, graphical AF development tool. EGAT provides the capability to dynamically monitor and modify the AF control parameters. The AF architecture, and the development and implementation of the EGAT are described. The EGAT system is used to dynamically monitor and modify the decentralized control parameters of the AF architecture, a communicating expert object paradigm.

Author

N92-12544# National Aerospace Lab., Amsterdam (Netherlands).
REASONING WITH UNCERTAIN AND INCOMPLETE INFORMATION IN AEROSPACE APPLICATIONS
J. C. DONKER *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 16 p (SEE N92-12517 03-63) Sep. 1991
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In many real-life application areas such as aerospace, decisions have to be made based on imperfect knowledge. If decision makers are to be supported by computer systems, it is desirable that this type of knowledge can be represented. Methods have been developed to represent various kinds of imperfections, such as incompleteness, inexactness, or uncertainty. The development of methods to represent and reason with uncertain or incomplete information is studied. The applicability of the Dempster-Shafer Theory is investigated. Parts of the initiation and identification problems in multi-radar tracking are modeled, and the application is described. It is shown that the Dempster-Shafer Theory promises improvements over the Bayesian approach; however, the latter theory is currently more advanced than the former.

Author

N92-14673# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
ARTIFICIAL NEURAL NETWORK APPROACHES IN GUIDANCE AND CONTROL
Sep. 1991 183 p Lecture series held in Monterey, CA, 8-9 Oct. 1991, in Kjeller, Norway, 14-15 Oct. 1991, and in Neubiberg, Fed. Republic of Germany, 17-18 Oct. 1991
(AGARD-LS-179; ISBN-92-835-0635-9; AD-A244247) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Ever increasing operational and technical requirements have led to highly integrated flight, guidance and control, and weapons delivery systems. The effective implementation of these functions makes the fusion and interpretation of sensor data and the multifunctional use of sensor information inevitable. Neural networks, consisting of parallel microcomputing elements, hold great promise for guidance, navigation, and control applications because of their ability to learn and acquire knowledge. The objective of this lecture series, sponsored by the Guidance and Control Panel of AGARD, was to present both the fundamentals of neural networks and a number of guidance, navigation, and control (GNC) applications. Some specific topics addressed include neural network architectures and design methodologies, target detection and recognition, vision systems, robots, and multisensor data fusion. For individual titles, see N92-14674 through N92-14682.

N92-14674# Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (Germany, F.R.). Intelligent Systems Div.
INTRODUCTION TO NEURAL COMPUTING AND CATEGORIES OF NEURAL NETWORK APPLICATIONS TO GUIDANCE, NAVIGATION AND CONTROL
UWE K. KROGMANN *In* AGARD, Artificial Neural Network Approaches in Guidance and Control 24 p (SEE N92-14673 05-63) Sep. 1991
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The creation of artificial neural networks (ANN) is directed towards the realization of capabilities and characteristics such as self-organization, learning, and associative memory. This is achieved by the particular structure of neural networks where a large number of simple processor elements are interconnected with uni-directional signal channels to single- or multi-layer networks. All processing elements are working in parallel as

compared to one central, extremely efficient computer for sequential arithmetic and/or symbolic information processing. Artificial neural networks are not programmed but trained and l⁻ ⁻rn like their biological paradigm, the brain. This is done by changing the intensity of the connections between processor elements and by generating or eliminating structural connections. A brief introduction to the architecture and functional characteristics of neural networks is presented. In addition, the general structure of guidance and control problems is described and the application of ANNs to guidance and control tasks is examined. Example applications relate to the fault tolerant measurement of the proprio-specific motion of an air vehicle and neural target classification.   M.G.

N92-14675#   General Dynamics/Electronics, San Diego, CA.
NEURAL NETWORK PARADIGMS
PATRICK K. SIMPSON   *In* AGARD, Artificial Neural Network Approaches in Guidance and Control 33 p (SEE N92-14673 05-63) Sep. 1991
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    A review is given of what neural networks are and why they are so appealing. A typical neural network is introduced to illustrate several of the key features. Then the fundamental elements of a neural network such as input and output patterns, the processing element, connections, and threshold operations are described, followed by descriptions of neural network topologies, learning algorithms, and recall dynamics. Next, a taxonomy of neural networks is presented that uses two of their key characteristics: learning and recall. Finally, a comparison of neural networks and similar non-neural information processing methods is presented.
                                                Author

N92-14676#   CompEngServ Ltd., Ottawa (Ontario).
**A NEURAL NETWORK DESIGN METHODOLOGY:
CONSIDERATIONS AND ISSUES FOR DESIGN AND PROJECT
MANAGEMENT**
B. ARCHIE BOWEN   *In* AGARD, Artificial Neural Network Approaches in Guidance and Control 20 p (SEE N92-14673 05-63) Sep. 1991
(AGARD-LS-179) Copyright Avail: NTIS HC/MF A09;
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    An artificial neural network (ANN) is a software implementation of a neural paradigm, and, therefore, such projects yield to many of the disciplines of software engineering. On the other hand, many issues that must be faced, as the project proceeds, are unique and require specialized knowledge to address. The concern here is mainly with the management of such projects. However, in order to propose the management issues, it seems necessary to understand, at least superficially, the process of the design and implementation of a neural-based system. Therefore, a proposal is given for a methodology for the conduct of a project involving the choice, design, and implementation of a neural-based system. The issues that should be considered and resolved at each step of the project are outlined. Based on this methodology, a project management plan can be put in place. Such a plan calls for a set of milestones and design reviews for various levels of management (and the customer) and a corresponding document set designed to prove a milestone has been reached, and finally, that the original requirements have been met.   Author

N92-14677#   Hecht-Nielsen Neurocomputer Corp., Inc., San Diego, CA.
**PROCESSING COMPLEXITY OF TWO APPROACHES TO
OBJECT DETECTION AND RECOGNITION**
TODD GUTSCHOW and ROBERT HECHT-NIELSEN   *In* AGARD, Artificial Neural Network Approaches in Guidance and Control 12 p (SEE N92-14673 05-63) Sep. 1991 Prepared in cooperation with California Univ., San Diego, La Jolla
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    The computational complexity of a processing function is a driving factor in the implementation of that function in an operational system. Artificial neural networks offer the potential for significant improvements in the computational complexity of a number of

guidance and control functions. To illustrate such an improvement, a comparison is considered between two different approaches to object detection and recognition: a traditional approach using a wide field of view and constant spatial resolution throughout the image sensing and processing chain; and a foveal approach using a roving eyeball circularly symmetric sampling grid with a radially variant resolution in the processing chain. The rationale and characteristics of these two approaches are described and compared. Quantitative evaluations of the processing loads and data transfer rates are then carried out for both approaches. These processing requirements are then compared and the operational implications of this comparison are discussed. While the efficacy of the foveal approach is not explicitly discussed, references are provided to relevant research results in this regard.   Author

N92-14678#   Mimetics, Chatenay Malabry (France).
NEURAL NETWORKS FOR TARGET RECOGNITION
BERNARD ANGENIOL   *In* AGARD, Artificial Neural Network Approaches in Guidance and Control 12 p (SEE N92-14673 05-63) Sep. 1991
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    Neural networks are a very promising technique for target recognition, because of their adaptability, their fault tolerance, and their real time potential due to their parallelism. If, as in most of the applications of neural networks, data base availability, choice of preprocessing, and feature extraction are important to keep the amount of time necessary for learning within reasonable limits, the key factors for the success of the applications are multi-resolution recognition capabilities, invariance of recognition by translation, rotation, scaling, and movement detection capability. The integration of neural modules in weapon systems requires new validation processes, as well as a careful study to make the neural modules compatible with the sequence of functionalities of the system. Backpropagation is the most often used neural algorithm, because of its ability of extracting features. Various comparisons of performance with classical methods were made on some examples.   Author

N92-14679#   CompEngServ Ltd., Ottawa (Ontario).
**VISION SYSTEMS FOR GUIDANCE AND CONTROL: A
TUTORIAL OVERVIEW**
B. ARCHIE BOWEN   *In* AGARD, Artificial Neural Network Approaches in Guidance and Control 14 p (SEE N92-14673 05-63) Sep. 1991
(AGARD-LS-179) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    Vision systems are finding wide-spread use in such areas as autonomous robotics and in more mundane situations for the interpretation and/or identification of objects in images generated by various sensors. An overview of the various areas in which such systems have proven successful and and introduction to the underlying theory are presented. The human vision system seems to be composed of a set of pre-attentive filters located in the retina which do an immediate data reduction by computing a set of features (a feature vector). These features are transmitted to the brain for interpretation as images. Synthetic vision systems are based on the same functional decomposition of feature extraction followed by interpretation. The use of pre-attentive filters for synthetic vision systems had gained wide acceptance and produced some impressive results. The concept of pre-attentive filters is introduced and the Gabor and the Fourier-Mellin filter are shown as typical examples. Several types of neural nets, given the appropriate input data, can be trained as interpreters to classify, complete, and identify patterns. Several architectures are explored for these applications. The first class of applications exploits the mapping characteristics of neural networks. This ability leads to a set of applications in pattern classification, pattern completion, and pattern recognition. The second is in the more difficult field of object (target) recognition. Experimental results in image compression and target identification are drawn from the literature. It is suggested that the techniques for creating vision systems appear to be applicable to a very large class of problems not normally associated with seeing as we normally consider it.
                                                Author

N92-14680#   British Aerospace Public Ltd. Co., Bristol
(England).
NEURAL NETWORKS FOR MILITARY ROBOTS
W. A. WRIGHT *In* AGARD, Artificial Neural Network Approaches
in Guidance and Control 22 p (SEE N92-14673 05-63)   Sep.
1991   Sponsored in part by Procurement Executive, Ministry of
Defence (England)
(AGARD-LS-179) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   A short review of mobile robotic research is presented through
the use of three case studies. These case studies describe, in
brief, current research undertaken at three establishments and
indicate the role that neural networks are playing in this process.
Hence, the impact that neural networks may have on the military
environment is also indicated. Three case studies are chosen to
illustrate the advantage, in terms of speed, compactness, and
adaptability, of the use of these systems in what are defined as
the three essential functional areas for mobile robot control: (1)
localization; (2) path planning; and (3) obstacle avoidance.
                                                                Author

N92-14681#   General Dynamics/Electronics, San Diego, CA.
**MULTISENSOR DATA FUSION AS APPLIED TO GUIDANCE
AND CONTROL**
PATRICK K. SIMPSON   *In* AGARD, Artificial Neural Network
Approaches in Guidance and Control 10 p (SEE N92-14673
05-63) Sep. 1991
(AGARD-LS-179) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   Multisensor data fusion (MDF) is the synergistic application of
data from several sources, typically sensors, toward a specific
task. In the area of guidance and control, data fusion plays an
important role. Several methods of applying neural networks to
data fusion, including: self organizing hierarchical neural systems,
multi layer error correction learning networks, and single layer
pattern completion systems, are described. Application case studies
will be examined to determine how researchers have applied neural
networks to data fusion. Additionally, a discussion of feature
representation and feature weighting will be provided.   Author

N92-14682#   Hecht-Nielsen Neurocomputer Corp., Inc., San
Diego, CA.
**ADVANCE NEURAL NETWORK ARCHITECTURES FOR
GUIDANCE AND CONTROL**
TODD GUTSCHOW and ROBERT HECHT-NIELSEN *In* AGARD,
Artificial Neural Network Approaches in Guidance and Control 12
p (SEE N92-14673 05-63) Sep. 1991 Prepared in cooperation
with California Univ., San Diego, La Jolla
(AGARD-LS-179) Copyright Avail: NTIS HC/MF A09;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
   Several advanced neural network architectures are expected
to be of significant value in guidance and control. Three advanced
neural network architectures (the graded learning network, the
recurrent backpropagation network, and the hierarchical matched
filter network) are discussed.   Author

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STATISTICS AND PROBABILITY

Includes data sampling and smoothing; Monte Carlo method; and
stochastic processes.

N91-25129*#   Princeton Univ., NJ. Dept. of Mechanical and
Aerospace Engineering.
**KNOWLEDGE ACQUISITION FOR EXPERT SYSTEMS USING
STATISTICAL METHODS**
BRENDA L. BELKIN and ROBERT F. STENGEL   *In* AGARD,
Knowledge Based System Applications for Guidance and Control
17 p (SEE N91-25121 17-04) Apr. 1991
(Contract NGL-31-001-252; DAAG29-84-K-0048)
(AGARD-CP-474) Copyright Avail: NTIS HC/MF A12;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive   CSCL 09/2
   A common problem in the design of expert systems is the
definition of rules from data obtained in system operation or
simulation. A statistical method for generating rule bases from
numerical data, motivated by an example based on aircraft
navigation with multiple sensors is presented. The specific objective
is to design an expert system that selects a satisfactory suite of
measurements from a dissimilar, redundant set, given an arbitrary
navigation geometry and possible sensor failures. The systematic
development of a Navigation Sensor Management (NSM) Expert
System from Kalman Filter covariance data is described. The
development   method   invokes   two   statistical   techniques:
Analysis-of-Variance (ANOVA) and the ID3 algorithm. The ANOVA
technique indicates whether variations of problem parameters give
statistically different covariance results, and the ID3 algorithm
identifies the relationships between the problem parameters using
probabilistic knowledge extracted from a simulation example set.
                                                                Author

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SYSTEMS ANALYSIS

Includes mathematical modeling; network analysis; and operations
research.

N90-27438#   Advisory Group for Aerospace Research and
Development, Neuilly-Sur-Seine (France). Avionics Panel.
TACTICAL APPLICATIONS OF SPACE SYSTEMS
May 1990   150 p   Symposium held in Colorado Springs, CO,
16-19 Oct. 1989
(AGARD-CP-460; ISBN-92-835-0553-0; AD-A226344) Copyright
Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests
available only from AGARD/Scientific Publications Executive
   The benefits, indeed the necessity of space systems to military
operations have increased considerably in the past few years.
Military   communications   satellites   have   demonstrated   their
effectiveness as elements of military command and control
systems. The various weather satellites are providing more accurate
and timely weather forecasting and have become important to all
military operations. The 18 satellite-Global Positioning System may
revolutionize weapon systems navigation guidance over the next
decade. New remote sensing systems such as the Space Based
Radar and other systems are in study on various stages of
development. While the importance of space systems is becoming
better appreciated, the full potential has not been realized. The
intent was to bring into focus and to characterize the attributes
which contribute to the effectiveness of tactical military operations.
For individual titles, see N90-27439 through N90-27454.

N90-27439# Air Force Systems Command, Norton AFB, CA.
Defense Meteorological Satellite Program.
**TACTICAL APPLICATIONS OF DEFENSE METEOROLOGICAL
SATELLITE PROGRAM (DMSP) ENVIRONMENTAL DATA**
JURI RANDMAA *In* AGARD, Tactical Applications of Space
Systems 9 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

Timely knowledge of weather conditions through the use of
meteorological satellites is one of the major force multipliers for
the United States and NATO countries. How the Defense
Meteorological Satellite Program meets this need for timely data
will be described. The Defense Meteorological Satellite Program
(DMSP) has for over fifteen years supplied tactical meteorological
data to Air Force, Navy, and Army units. This fully operational
system consists of at least two satellites, a command and control
system, a strategic data processing system, and tactical processing
systems. Specifically, the DMSP mission is to provide global visible
and infrared cloud data and other specialized meteorological,
oceanographic, and solar-geophysical data in support of worldwide
DOD operations. Environmental data is acquired by various sensors
aboard the DMSP satellites in two modes. In the first mode, the
data are stored on board for relay to the strategic centers at the
Air Force Global Weather Central and at the Navy Fleet Numerical
Oceanography Center. The second mode is the real-time direct
broadcast of the environmental data to the land and sea-based
tactical processing systems. All the environmental data are
combined into one data stream and are broadcast in an encrypted
mode on S band frequencies. The primary sensor carried on each
satellite is the Operational Linescan System (OLS), which provides
global cloud imagery in the visible and infrared bands. This data
can be sent to the tactical user with a resolution of .6 km in one
channel and 2.8 km is the other channel. This data are normally
displayed in real time as the data from the sensor are taken. In
the future, a variety of secondary mission sensors will be used to
provide a complementary quantitative measure of the
environment. Author

N90-27440# Air Force Systems Command, Norton AFB, CA.
Air Weather Service.
**APPLICATION OF METEOROLOGICAL SATELLITE (METSAT)
DATA TO SUPPORT UNITED STATES FORCES IN THE
NORTH ATLANTIC TREATY ORGANIZATION (NATO)**
ALAN L. ADAMS *In* AGARD, Tactical Applications of Space
Systems 5 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

Meteorological satellites play an important role in observing
the environment and predicting how the environment will change
with time. Such knowledge is absolutely crucial to military
operations whose success or failure can often be directly influenced
by changing environmental conditions. United States forces in
NATO receive METSAT data from several sources and routinely
use these data for operational decision making. The types of data
available and the application of these data to United States Air
Force and Army tactical military operations in NATO is discussed.
Author

N90-27443# Air Force Systems Command, Norton AFB, CA.
BLOCK 6: THE FUTURE DMSP SPACE SYSTEMS
RAYMOND G. BONESTEELE and RUSTY O. BALDWIN *In*
AGARD, Tactical Applications of Space Systems 5 p (SEE
N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

The acquisition strategy and anticipated capabilities of the
Defense Meteorological Satellite Program (DMSP) Block 6 satellite
system are described. It includes brief discussions of previous
satellites and the requirements which drove the Block 6 system
acquisition. The first three phases of acquisition are discussed:
concept study, risk reduction, and full scale development. Strategy
and concept of each phase are described in detail. The use of
total quality management in each phase is discussed. Author

N90-27444# Air Force Systems Command, Norton AFB, CA.
Space Systems Div.
**SPACE-BASED WIDE AREA SURVEILLANCE SYSTEM
STUDIES**
CHARLES E. HEIMACH and CHESTER L. WHITEHAIR (Aerospace
Corp., El Segundo, CA.) *In* AGARD, Tactical Applications of
Space Systems 12 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

The U.S. Department of Defense (DoD) is vigorously exploring
and evaluating alternative concepts for conducting global wide
area surveillance using space-based assets. The objective is to
provide for the detection, identification, and tracking of atmospheric,
ocean surface and ground targets on a 24-hour basis, worldwide
and under all weather conditions. Candidate concepts include radar
systems, infrared systems, and a combination of both. The current
effort is based on a series of engineering concept studies and
designs. The primary evaluation tool is an in-depth computer
simulation that is being used to model each concept in a simulated
operational environment. This simulation is described with several
example operational missions and alternative space-based
surveillance systems. The U.S. Department of Defense (DoD) is
conducting Cost and Operational Effectiveness Analyses (COEA)
of the Space-Based Wide Area Surveillance System (SBWASS)
concepts in preparation for a decision to start the
demonstration/validation phase. The principal goal of the COEA
effort is to develop detailed information about the ability of
space-based systems to satisfy surveillance needs of operational
forces beyond the range of existing sensors in an afforable,
cost-effective manner. The SBWASS will provide global,
all-weather, day/night, near-real-time tactical and strategic warning
of air and surface attacks directly to operational forces. Author

N90-27445# MacDonald, Dettwiler and Associates Ltd., Richmond
(British Columbia).
**COMMAND AND CONTROL IN THE AGE OF SPACE-BASED
SURVEILLANCE**
MURRAY MACDONALD *In* AGARD, Tactical Applications of
Space Systems 5 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

The Canadian and United States defense departments are
currently investigating requirements and technologies appropriate
to a constellation of radar satellites providing global surveillance
against targets such as cruise missiles, long-range bombers,
strategic fighters, and surface ships. Command and Control of
Canadian forces using data obtained from this space-based radar
(SBR) satellite system will pose an intricate set of problems,
complicated by data transfer requirements and the potential number
of agencies involved with different aspects of SBR operations.
Since extensive on board processing is unlikely during the early
years of SBR, data will need to be downlinked to a central facility,
processed, and distributed to appropriate regional stations.
Operational tasking requirements from regional stations will have
to be coordinated by the central control station and uplinked to
the satellite. All of these processes will need to be carried out
within the real-time constraints of a surveillance operation. Data
transfer and processing constraints are discussed in the context
of the command and control issues that will arise with the advent
of SBR. Author

N90-27450# Aerospace Corp., Los Angeles, CA.
**TACTICAL USES OF THE DSCS 3 COMMUNICATIONS
SYSTEM**
A. T. FINNEY *In* AGARD, Tactical Applications of Space Systems
7 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

Originally conceived and designed in the late 1970's, the DSCS
3 Communications System was primarily oriented toward long haul,
point-to-point service for strategic users who desired a high degree
of antijam capability combined with physical survivability. The
satellite portion of the system was designed under the auspices
of the United States Air Force Space Systems Division. Overall
responsibility for the DSCS system rests with the Defense

Communications Agency (DCA), which has developed much of the tactical philosophy discussed in subsequent paragraphs. Although primarily conceived as a strategic support system, a significant portion of the total resource was allocated to tactical uses. In subsequent paragraphs, some of the tactical concepts that evolved for the present design, as well as some new ideas concerning possible tactical uses for the system, will be described. Author

N90-27451# Naval Space Surveillance System, Dahlgren, VA.
TACTICAL APPLICATIONS OF THE UHF SATELLITE COMMUNICATIONS SYSTEM
PHILIP J. LATULIPPE, WILLIAM C. CLAIR, and JOSEPH L. K. CORCORAN In AGARD, Tactical Applications of Space Systems 5 p (SEE N90-27438 21-66) May 1990
(AGARD-CP-460) Copyright Avail: NTIS HC A07/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Information on how the U.S. Navy uses the UHF Communications Satellite Systems to support its tactical operations is provided. It identifies shortfalls associated with the existing UHF SATCOM System and shows how these shortfalls are overcome. It presents methods which are used to operationally increase the number of satellite accesses available by implementing FDM and TDM techniques. New space communications initiatives are also discussed. Author

N91-25136# Grumman Aerospace Corp., Bethpage, NY. Technology Development Section.
DESIGN AND SIMULATION OF AN ADVANCED AIRBORNE EARLY WARNING SYSTEM
CHIEN Y. HUANG and MANIKANT D. LODAYA In AGARD, Knowledge Based System Applications for Guidance and Control 10 p (SEE N91-25121 17-04) Apr. 1991
(AGARD-CP-474) Copyright Avail: NTIS HC/MF A12; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The results of the design and simulation of an advanced airborne early warning (AEW) system are presented. The approach is based on modeling operator's reasoning and decision processes as well as battlefield strategies. The tasks are divided into threat assessment and tactical planning. The implementation of these subsystems is carried out in a generic expert system shell developed specifically for this purpose. The AEW crew is provided with an advanced display that monitors all transactions. The functionalities of this prototype AEW system are demonstrated using an advanced simulation facility. Simulation results show that decision automation can be accomplished in real time and can prove to be a valuable tool in an AEW environment. Author

N91-25750# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics and Aerospace Medical Panel.
MISSION PLANNING SYSTEMS FOR TACTICAL AIRCRAFT (PRE-FLIGHT AND IN-FLIGHT)
May 1991 51 p Original contains color illustrations
(AGARD-AR-296; ISBN-92-835-0615-4; AD-A237855) Copyright Avail: NTIS HC/MF A04; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The concept of planning a mission for a military aircraft is probably as old and well established as that of the military aircraft itself, but until recently the methodology and technology associated with mission planning had received only limited attention from scientists and engineers. The last few years have, however, seen a marked increase in the attention given to mission planning both by the users, who are demanding improved facilities, and by the suppliers, who are able to provide increasingly more capable systems. As a result, the air forces of many of the NATO countries are procuring new and advanced mission planning systems that have capabilities far in advance of those previously available. Author

ACOUSTICS

Includes sound generation, transmission, and attenuation.

N91-24843# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
AGARD FLIGHT TEST TECHNIQUES SERIES. VOLUME 9: AIRCRAFT EXTERIOR NOISE MEASUREMENT AND ANALYSIS TECHNIQUES
H. HELLER (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany, F.R.) Apr. 1991 201 p
(AGARD-AG-300-VOL-9; ISBN-92-835-0612-X; AD-A237358) Copyright Avail: NTIS HC/MF A10; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Testing and analysis techniques to measure aircraft noise primarily for purposes of noise certification as specified by the 'International Civil Aviation Organization', ICAO are described. The relevant aircraft noise certification standards and recommended practices are presented in detail for subsonic jet aircraft, for heavy and light propeller-driven aircraft, and for helicopters. The practical execution of conducting noise certification tests is treated in depth. The characteristics and requirements of the acoustic and non-acoustic instrumentation for data acquisition and data processing are discussed, as are the procedures to determine the special noise measures - effective perceived noise level (EPNL) and maximum overall A-weighted noise level (L sub pA,max) - that are required for the noise certification of different types of aircraft. The AGARDograph also contains an extensive, although selective, discussion of test and analysis techniques for more detailed aircraft noise studies by means of either flight experiments or full-scale and model-scale wind tunnel experiments. Appendices provide supplementary information. Author

OPTICS

Includes light phenomena; and optical devices.

N90-10853# Air Force Inst. of Tech., Wright-Patterson AFB, OH. Dept. of Electrical and Computer Engineering.
ADAPTIVE TRACKING OF MANEUVERING TARGETS BASED ON IR IMAGE DATA
PETER S. MAYBECK In AGARD, Kalman Filter Integration of Modern Guidance and Navigation Systems 18 p (SEE N90-10847 02-04) Jun. 1989
(AGARD-LS-166) Copyright Avail: NTIS HC A09/MF A01

The capability of tracking dynamic targets from forward looking infrared (FLIR) measurements was improved substantially by replacing standard correlation trackers with adaptive extended Kalman filters or enhanced correlator/Kalman filter combinations. A tracker able to handle multiple hot-spot targets, in which digital and/or optical signal processing is employed on the FLIR data to identify the underlying target shape is investigated. Furthermore, multiple model adaptive filtering is investigated as a means of changing the field-of-view as well as the tracker bandwidth when target acceleration can vary over a wide range. Enhancements are developed and analyzed: (1) allowing some of the elemental filters within the adaptive algorithm to have rectangular fields-of-view and to be tuned for target dynamics that are harsher in one direction than others; (2) considering both Gauss-Markov acceleration models and constant turn-rate models for target dynamics; and (3) devising an initial target acquisition algorithm to remove important biases in the estimated target template to be used within the tracker. The performance potential of such a tracking algorithm is shown to be substantial. Author

N90-15929# Ferranti Defence Systems Ltd., Edinburgh (Scotland). Dept. of Electro-Optics.
ELECTRO-OPTIC SENSORS FOR SURVEILLANCE AND TARGET ACQUISITION
J. W. JACK and A. HOUSTON *In* AGARD, Guidance and Control of Unmanned Air Vehicles 20 p (SEE N90-15924 08-08) Aug. 1989
(AGARD-CP-436) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The synthesis of a compact electro-optical payload suitable for tactical reconnaissance, target spotting and fire control is described. The selection criteria for the electro-optical sensors comprizing an imaging sensor, lens, and laser are discussed and the performance of an actual system is predicted. The predicted performance is compared with the results of flight trials in which an equipment was used to acquire, range and designate ground targets. Finally the experience of using the equipment against ground targets in collaboration with fixed wing aircraft is discussed. Author

N91-15167# Thomson-CSF, Orsay (France).
SPECIAL OPTICAL FIBRES AND SENSORS FOR AERONAUTICS
JEAN-PIERRE LEPESANT and MARC TURPIN *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 10 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The primary motivations for using fiber optics for onboard communications, flight, and engine control in aircrafts, are immunity from electromagnetic interference and lightnings, lighter weight, smaller size, and a high degree of data formatting flexibility. The present status of the optical fiber fabrication technologies is presented along with some of the applications currently accessible for optical fibers in terms of inflight communications, navigation, and physical data collection and optical power transmission. Typical values are given of the characteristics made achievable by the evolution of the technologies. Author

N91-15168# Marconi Space Systems Ltd., Portsmouth (England).
THE USE OF OPTICAL METHODS FOR MICROWAVE SIGNAL DISTRIBUTION AND CONTROL
IAN MCMILLAN *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 5 p (SEE N91-15154 07-06) Sep. 1990
(AGARD-CP-482) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

It has now become practical to distribute radio frequency signals with GHz frequencies along optical fibers and to use optical power splitters and filters as one might use their microwave equivalents. Lower mass designs are therefore possible and the low transmission loss of optical fibers means that loss due to distances of up to 50 meters may be ignored. The inherent wide bandwidth and stable phase characteristics of optical components as well as their possible parallel channel capacity can also be readily exploited. A signal distribution system was designed which when coupled with a novel high speed data transmission method was used to control a ground demonstrator of a spaceborne phased array synthetic aperture radar. Such a radar requires the low mass and high quality distribution of a 5 GHz signal to around 500 individual transmit-receive modules as well as the collection and summation of the dual polarization receive signals and the high speed control of the array. The design choices are discussed and the practical realization of such an all optical distribution system is presented together with the resultant measured performance. Author

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SOLID-STATE PHYSICS

Includes superconductivity.

N91-14030# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
APPLICATIONS OF SUPERCONDUCTIVITY TO AVIONICS
Oct. 1990 164 p Meeting held in Bath, England, 7-8 May 1990
(AGARD-CP-481; ISBN-92-835-0586-7; AD-A229161) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Recent advances in developing high temperature superconductors have renewed interest in the entire superconductivity field. Modern techniques in materials preparation are making it possible to fabricate a number of new superconducting components which promise significant improvements in the performance of avionics systems. The almost daily revelation of advances in this area attests to its importance as an emerging technology. Device scientists and avionics engineers explore the possibilities for exploiting all aspects of superconductivity in avionics systems. For individual titles, see N91-14031 through N91-14046.

N91-14031# Royal Signals and Radar Establishment, Malvern (England).
PROGRESS IN HIGH TC SUPERCONDUCTORS
R. G. HUMPHREYS, N. G. CHEW, S. W. GOODYEAR, J. A. EDWARDS, J. S. SATCHELL, and S. E. BLENKINSOP *In* AGARD, Applications of Superconductivity to Avionics 7 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The high temperature superconductor materials are introduced, and their properties relating to applications reviewed, with particular reference to the prospects for fabrication of devices. Recent results on the factors relating to the growth of smooth high quality $YBa_2Cu_3O_7$ thin films are presented. Author

N91-14032# Royal Military Coll. of Canada, Kingston (Ontario). Dept. of Science.
PHYSICS AND APPLICATIONS OF LOW TEMPERATURE SUPERCONDUCTIVITY
D. C. BAIRD *In* AGARD, Applications of Superconductivity to Avionics 25 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A historically-based introduction to low temperature superconductivity is provided. Those aspects of the basic physics that underlie the practical applications of superconductors and that are significant for understanding the properties of the new high temperature superconductors are emphasized. Author

N91-14033# Laboratoire Central de Recherches Thomson-CSF, Orsay (France).
HIGH TEMPERATURE SUPERCONDUCTING THIN FILMS FOR MICROELECTRONICS: PREPARATION AND PROPERTIES
G. CREUZET, R. CABANEL, and A. SCHUHL *In* AGARD, Applications of Superconductivity to Avionics 8 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The discovery of high temperature superconductors (HTSC) has generated a great deal of activity, both fundamental and towards applications. For the latter, low current devices appear to be particularly interesting. The fundamental building block of superconducting electronics is the Josephson junction, in which two superconducting electrodes are isolated by a thin metallic (SNS) or insulating (SIS) barrier. Due to the extreme low value of the coherence length in these compounds, one has to achieve very thin (a few nm) barriers with sharp interfaces with the superconducting material. This leads first to the major challenge

of producing HTSC epitaxial films controlled at the atomic level. For HTSC thin film preparation, reasonable good films are now available routinely using the laser ablation technique. In particular, these films present high frequency characteristics which are good enough to develop superconducting components like microstrips for delay lines. For Josephson junction electronics, the requirements, especially for the barrier thickness control, are much more ambitious. In this context, molecular beam epitaxy, and furthermore atomic layer epitaxy, appear to be very promising.

Author

N91-14034# American Superconductor Corp., Watertown, MA.
SUCCESS CRITERIA FOR OXIDE SUPERCONDUCTOR WIRES: MEASURING THE PRESENT, PREDICTING THE FUTURE
CARL J. RUSSO *In* AGARD, Applications of Superconductivity to Avionics 7 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

Successful application of oxide superconductor wires to large-scale applications requires: high critical current in long lengths at high fields; adequate mechanical properties for handling; a process technology scalable to production quantities; corrosion resistance; adequate strength at low temperatures in high fields; superconducting joints; cryostability; and low ac losses. The present state of conductor development is discussed in terms of several figures of merit. Historical data is evaluated, technology challenges is investigated, and predictions for the future of oxide superconductor wire development are examined. Author

N91-14036# Birmingham Univ. (England). Dept. of Electronic and Electrical Engineering.
PASSIVE MICROWAVE DEVICES USING HIGH TEMPERATURE SUPERCONDUCTORS
M. J. LANCASTER, T. S. M. MACLEAN, Z. WU, C. E. GOUGH, and N. MCN. ALFORD *In* AGARD, Applications of Superconductivity to Avionics 6 p (SEE N91-14030 05-76) Oct. 1990
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Passive microwave devices that benefit from the inclusion of a superconducting element are listed. Three devices out of the list; a superconducting loop antenna, a superconducting filter, and a cavity resonator were designed, built, and tested. The advantages of each of these components are reviewed and results of their performance are presented. Author

N91-14037# Laboratoire Central de Recherches Thomson-CSF, Orsay (France).
MICROWAVE SUPERCONDUCTING ELECTRONIC DEVICES
P. HARTEMANN *In* AGARD, Applications of Superconductivity to Avionics 7 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08;
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The present and future applications of superconductors to the small-scale microwave electronics are reviewed by taking into account the results obtained with the conventional superconductors and the potentialities of the new high-temperature superconductors. The signal transmission by superconductive planar waveguides is surveyed. Then the effect of the electrode thickness on the propagation loss and velocity along superconductive microstrip waveguides is pointed out. The use of Josephson junctions in mixers or amplifiers or generators of periodic signals is considered. Examples of signal processing devices including linear or nonlinear superconducting elements are given. Their main characteristics are compared to those feasible by other techniques. Author

N91-14038# Laboratoire Central de Recherches Thomson-CSF, Orsay (France).
HIGH TC SUPERCONDUCTORS FOR MICROWAVE FILTERS
J. C. MAGE and D. DIEUMEGARD *In* AGARD, Applications of Superconductivity to Avionics 8 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08;
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Passive microwave components will probably be the first application of high Tc superconductors. Devices such as multi-pole filters, delay lines, transversal filters with improved performances can easily be developed as soon as reliable high quality superconducting thin films are available. The basic constituent of these devices is a microwave line which consists of a superconducting layer deposited on a dielectric substrate then patterned. At the present time, the accurate characterization of both superconducting and dielectric materials is the main topic of the research activities in cooperation with the improvement of deposition techniques. Author

N91-14039# Hitachi Ltd., Tokyo (Japan). Superconducting Electronics Research Center.
THE STATUS-QUO AND PROSPECT OF SUPERCONDUCTING DIGITAL DEVICES
USHIO KAWABE *In* AGARD, Applications of Superconductivity to Avionics 12 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08;
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Superconducting digital devices, featuring high-speed, small size, and low power dissipation, are expected to be one of key components of future computer system. Currently, research and development are continued to demonstrate the possibility of the superconducting computer system above 1 GHz clock using highly reliable Nb/AlO(x)/Nb Josephson junctions with small size and high current density and further to explore new digital devices capable with higher speeds and higher levels of integration. The striking feature is that superconducting digital devices have a small switching energy below 0.1 fJ and that they can be connected with a lossless superconducting wiring. From this good performance, a giga-scale integration type parallel-processing computer is promising through the heat flux and cooling power in cryogenic environment are taken into consideration. The status-quo and prospect of superconducting digital devices are discussed. Author

N91-14047# Varian Associates, Palo Alto, CA.
A LIQUID NITROGEN COOLED SUPERCONDUCTIVE ELECTRON BEAM FOCUSING SYSTEM FOR IMPROVED PERFORMANCE ECM HELIX TRAVELING WAVE TUBES
M. C. GREEN *In* AGARD, Applications of Superconductivity to Avionics 6 p (SEE N91-14030 05-76) Oct. 1990
(AGARD-CP-481) Copyright Avail: NTIS HC/MF A08;
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In avionics, the focus of attention in recent years has been upon the development of solid state devices for low-level signal processing. Device development based upon the new high-temperature superconductors has mirrored this, with concentration upon thin film systems as a basis for the eventual fabrication of delay lines, resonators and the like. However, large numbers of avionics systems, particularly in the electronic countermeasures (ECM) area, employ traveling wave tubes (TWTs) as final power amplifiers. Broadband ECM helix TWTs utilizing periodic permanent magnet (PPM) focusing systems are particularly suitable for the application of superconductive focusing systems, since despite the relatively low magnetic fields employed along the electron beam axis in a typical PPM stack, the PPM configuration is limited to less-than-optimum axial fields by the local saturation of polepiece material between the adjacent ring magnets of the stack. In a typical I-J band ECM helix TWT, the axial field does not exceed 2.5 KG despite the use of exotic polepiece materials, which in turn means a lower-than-optimum perveance electron beam. This impacts adversely upon TWT bandwidth, stability, and gain. The relatively low field requirement for this application means that a solenoidal field generated by a

high-temperature superconductor flux trap is potentially practical with today's level of materials development.   Author

N91-14048# Naval Surface Weapons Center, Silver Spring, MD. Dept. of Research and Technology.
SYNTHESIS AND CHARACTERIZATION OF HIGH TEMPERATURE SUPERCONDUCTOR MATERIALS
W. A. FERRANDO, A. P. DIVECHA, S. D. KARMARKAR, A. N. MANSOUR, and P. W. HESSE   *In* AGARD, Applications of Superconductivity to Avionics 10 p (SEE N91-14030 05-76)   Oct. 1990   Sponsored by NRL
(AGARD-CP-481)   Copyright   Avail: NTIS HC/MF A08; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
High temperature superconductors are oxides and, therefore, inherently brittle. A process involving thermal decomposition of silver nitrate in the presence of YBa2Cu3O7 (123) powder was developed which shows promise for synthesis of fine diameter wires. The silver deposits uniformly on the 123 powder as indicated by optical and scanning electron microscopy. The composite powder can be formed into rods via drawing and swaging through conical converging dies. Finer diameter wires were produced by slurry extrusion of the composite powder in a polymeric vehicle. The current carrying capacity, Jc, continues to rise due to better understanding of the Ag/superconductor interface. Jc values of a typical wire has now reached 400 A/sq cm at 77 K and zero magnetic field, with a superconducting transition temperature of 93 K. In addition, the AgNO3 decomposition process can be employed with fine HTS powder and ethylene glycol as a suitable vehicle to produce an adherent, stable high temperature superconducting paint. The composition, chemistry, and uniformity of dispersion of Ag was investigated by x ray diffraction, x ray photoelectron spectroscopy, and scanning electron microscopy.
                                        Author

N91-15157# Royal Signals and Radar Establishment, Malvern (England).
MULTIPLE QUANTUM WELL NIR OPTICAL MODULATORS: A REVIEW OF THE POTENTIAL FOR OPTICAL SIGNAL PROCESSING USING III-V SEMICONDUCTORS
DAVID R. P. GUY, DAN D. BESGROVE, and NORMAN APSLEY   *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 14 p (SEE N91-15154 07-06)   Sep. 1990
(AGARD-CP-482)   Copyright   Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The potential for the use of optical and electro optical techniques in information processing has been recognized for some time, but the field is only now reaching the stage of maturity when demonstration systems can be assembled. The potential is reviewed for electro optic modulators in III-V compound semiconductors to form the basic components within optical signal processing systems, particularly small fast electrically driven spatial light modulator arrays operating in the near infrared for optical interconnect applications. Emphasis is on the use of artificially layered Low Dimensional Structures; GaAs-Al(x)Ga(1-x)As, in which modulation in excess of 20 dB has been reported at 850 nm, and In(0.53)Ga(0.47)As-InP, in which devices which should produce similar modulation at the optical fiber wavelengths of 1.3 and 1.55 microns are proposed and the performance of a 5 x 5 spatial light modulator operating at 1.6 micron is described.   Author

N91-15158# Royal Signals and Radar Establishment, Malvern (England).
QUANTUM WELL INFRARED DETECTORS: AN INTRODUCTION
M. J. KANE, M. T. EMENY, NORMAN APSLEY, and C. R. WHITEHOUSE   *In* AGARD, Advances in Components for Active and Passive Airborne Sensors 5 p (SEE N91-15154 07-06)   Sep. 1990
(AGARD-CP-482)   Copyright   Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The bandstructure of gallium arsenide - aluminum gallium arsenide quantum wells can be made such that the spacing of the confined energy levels corresponds to the energy of photons in the mid infrared. This allows infrared electro-optic devices to be made from this versatile general purpose electronic materials

system which was not previously thought of as an infrared detector materials system. This potentially enables the whole of the well developed technology of gallium arsenide to be used in this region. The performance is described of quantum well infrared photoconductive detectors fabricated using molecular beam epitaxy. The link between the detector parameters such as operating wavelength, quantum efficiency, dark current, and noise and the structure parameters is discussed. Background limited performance is demonstrated and the dominant source of detector noise is shown to be shot noise.   Author

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SOCIAL SCIENCES (GENERAL)

Includes educational matters.

N92-12543# Acquired Intelligence, Inc., Victoria (British Columbia).
A KNOWLEDGE-BASED INTELLIGENT TUTORING SYSTEM: ACQUIRE (TM)-ITS
B. A. SCHAEFER, R. SIDE, R. WAGSTAFF, O. MAGUSIN, and I. R. MORRISON   *In* AGARD, Machine Intelligence for Aerospace Electronic Systems 6 p (SEE N92-12517 03-63)   Sep. 1991
(AGARD-CP-499)   Copyright   Avail: NTIS HC/MF A14; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
An automated knowledge acquisition system and expert system shell known as ACQUIRE was developed. A project was undertaken to extend the ACQUIRE system for uses as a domain independent, knowledge-based Intelligent Tutoring System (ITS). The purpose was to provide the tools that would enable corporate or governmental personnel to rapidly develop their own expert system knowledge bases and rapidly develop their own expert system knowledge bases and rapidly convert these knowledge bases for use in task/case oriented training. Emphasis was on providing tools that would enable computer users, rather than computer professionals, to develop the training packages. This extension to ACQUIRE has involved the development of two major modules: the curriculum author module; and the tutoring module. Using the curriculum author module experts or instructors are able to develop a curriculum composed of lessons in a case study approach. The tutoring module monitors a student's progress in solving cases and constructs a representation of the student's growing knowledge as a naive ACQUIRE knowledge base. The tutoring module gradually merges the student's naive knowledge base with the expert's by identifying incorrect rules, gaps in the knowledge, and, most importantly, poor structuring of the knowledge which indicates misconceptions about how knowledge should be used. ACQUIRE-ITS is written in the C programming language for execution on personal computers running MS-DOS or UNIX. The system has an x-window interface and incorporates hypermedia.
                                        Author

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ADMINISTRATION AND MANAGEMENT

Includes management planning and research.

N91-12583# British Aerospace Public Ltd. Co., Hatfield (England).
DETERMINING TECHNOLOGY OBJECTIVES
J. B. SCOTT-WILSON   *In* AGARD, Seminar on the Structure of Aeronautical R/D 4 p (SEE N91-12579 04-01)   May 1990
(AGARD-R-782)   Copyright   Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Scientific research continues to offer an ever increasing number of technological possibilities capable of exploitation. Governments and Industrial concerns alike have to make decisions on which technologies to support. When broad defense needs or market

objectives were determined the study method, developed by AGARD and its Aerospace Applications Studies Committee, provides an effective means of focusing technology objectives. The application of the study method to Project 2000, a broad technology forecast undertaken for the NATO Military Committee is described. Guidance is provided on how to set up similar studies. *Author*

N91-12584# Alabama Univ., Huntsville.
AERONAUTICAL COMPONENT RESEARCH
JAMES J. KRAMER *In* AGARD, Seminar on the Structure of Aeronautical R/D 5 p (SEE N91-12579 04-01) May 1990
(AGARD-R-782) Copyright Avail: NTIS HC/MF A06;
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The development of NACA to the present NASA is discussed. Details of the research planning process are reviewed. The planning and execution of a major research program, the Aircraft Energy Efficiency program, is reviewed and the various degrees of success are discussed. New areas of emphasis in component research include the use of computational analysis techniques on a broad range of topics and the continued emphasis on the environmental impact of aircraft operations. The historical role of NACA and NASA in aeronautics from the beginning in 1915 up to today has been and continues to be in component research. In aeronautics NASA does not apply technology to development or operation of its own systems as it does in space. Its only mission is to conduct research and develop technology for use by others. NACA/NASA aeronautical research is generally viewed as quite successful. Some reasons for its success were the favorable work environment created by management and the quality and flexibility of its research staff. *Author*

N91-12585# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PLANNING APPLIED RESEARCH IN FRANCE
A. AURIOL *In* AGARD, Seminar on the Structure of Aeronautical R/D 16 p (SEE N91-12579 04-01) May 1990
(AGARD-R-782) Copyright Avail: NTIS HC/MF A06;
Non-NATO Nationals requests available only from
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The development of a new weapon system is a very expensive operation. The development process consists of fundamental research, prototype design; and operational testing of the prototype. The organization of the Ministry of Defense; features of armament and aeronautical research; structure of aeronautical industry and research; and the orientation and programming of applied research are outlined in order to understand the development process. *B.G.*

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DOCUMENTATION AND INFORMATION SCIENCE

Includes information management; information storage and retrieval technology; technical writing; graphic arts; and micrography.

N89-23362# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
THE ORGANISATION AND FUNCTIONS OF DOCUMENTATION AND INFORMATION CENTRES IN DEFENCE AND AEROSPACE ENVIRONMENTS
Mar. 1989 114 p Meeting held in Athens, Greece, 19-20 Oct. 1988
(AGARD-CP-445; ISBN-92-835-0496-8; AD-A214323) Copyright Avail: NTIS HC A06/MF A01
Topics addressed include the information scene in the civil and defence sectors in Greece, ways to identify users and their needs, sources of information for a documentation center, ways of handling and managing information including the problems caused by security requirements, and ways of using multiple data bases in information retrieval. For individual titles, see N89-23363 through N89-23374.

N89-23363# National Hellenic Research Foundation, Athens (Greece).
THE OBJECTIVES AND ROLE OF THE GREEK NATIONAL DOCUMENTATION CENTRE
V. BOUBOUKAS, C. SKOURLAS, and E. POULAKAKI *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 4 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
A brief overview of the Greek information scene is presented. The objectives and the role of the National Documentation Centre are outlined together with some of its activities which proved to function within such an information environment as well as plans for continuity. *Author*

N89-23364# Hellenic National Defence General Staff, Athens (Greece). Communication and Informatics Directorate.
THE STATUS OF DEFENCE INFORMATION PROGRAMS IN GREECE
GEORGE N. TZOVLAS *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 7 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
The present situation, problems, needs, and benefits of a Documentation and Information Centre for the Hellenic National Defence are described. It also describes the efforts which started in 1985 by the Hellenic Airforce for the creation of a pilot information program which was developed to satisfy its own needs. The problems encountered in the realization of this effort which seem to be common with those of other countries and are caused by the variety of objectives, the multitude of user groups, the wide spectrum of information topics and the relatively limited number of users are presented. The problem of the language barrier is also mentioned in relation to the implementation of modern information systems. The results of a study for the Hellenic National Defence Documentation and Information Centre are described. The importance of a coordinated and efficiently managed effort for the development, organization, and operation of such a center is stressed. The impacts of state of the art high technology means and a gradual implementation strategy for a feasible solution is addressed. *Author*

N89-23365# Royal Aircraft Establishment, Farnborough (England).
USER NEEDS AND HOW TO DETERMINE THEM
RICHARD H. SEARLE *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 7 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
Without users libraries and information centers have no purpose. It is essential therefore that the customers and their needs are fully known and understood. Knowing and understanding the users must be essentially a process of two-way commmunication involving regular dialog. Libraries and information centers need to operate within clearly defined terms of reference which give authority to activities and form the basis for the user dialog. Once the customers know and understand this, why we exist and what is offered them, they are better equipped to express their needs. Some of the customers will have little or no requirement for the offered services and this fact must be known and appreciated. *Author*

N89-23366# Technisch Documentatie en Informatie Centrum voor de Krijgsmacht, The Hague (Netherlands).
SOURCES OF INFORMATION
B. H. A. ZIJLSTRA *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 14 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
The Scientific and Technical Documentation and Information Centre of the Armed Forces (TDCK) publishes monthly abstract bulletins concerning 15 subject areas, each bulletin containing 50 to 100 abstracts of maximum 200 words concerning scientific or technical reports and articles. Details are given about the information sources from which the reports and articles are selected and deals with external on-line or on-disc data bases that are

used. The TDCK also publishes the monthly acquisitions list of the Central Military Catalogue (CMC) and coordinates the production of the automated cumulative catalog of books. Details are given about the information sources (books, reference works, and encyclopedia) that are present in major Defense libraries. Attention is given to other information sources such as standards, manuals, loose leaf publications, videotapes, and to information guides and registries. Author

N89-23367# Defence Research Establishment Atlantic, Dartmouth (Nova Scotia). Information Services.
STANDARDIZED BIBLIOGRAPHIC PROCESSING
D. I. RICHARDSON *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 8 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
Because of an ever growing number of publications, and ever dwindling economic resources, those who work in the information community have always seen the need to share resources through standardization. Since the 1960s computer technologies have made the sharing and exchange of bibliographic records feasible. Throughout this period, standards for descriptive cataloging were refined so that the records being exchanged will be compatible. Based on these standard machine readable records, both libraries and the abstracting/indexing communities have developed various formal exchange formats. An overview is presented of the development of standardized bibliographic processing from the first cataloging rules through to computer exchange formats. The use of these standards by the defence and aerospace community is examined with particular emphasis on the treatment of technical reports. Author

N89-23368# Federal Armed Forces Documentation and Information Centre, Bonn (Germany, F.R.).
INDEXING AND ABSTRACTING
JAN MUELLER *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 8 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
The aim of content analysis of documents is to describe the intention of documents in condensed form as a document unit, to order and store it, and to retrieve the document by user request. To do this, formal systems of ordering (classifications), indexing terms of natural language-based or artificial documentation languages as well as abstracts formulated in a natural language are employed. Whereas classing establishes paradigmatic relations, indexing (keywords, subject headings, descriptors) provides the possibility to identify the content in a natural language and to establish syntagmatic relations; the processing of indexing, indexing principles, methods, and results will be described; the existence and basic principles of thesauri will also be discussed in this connection. In contrast, an abstract is a statement of contents formulated in a natural language with the purpose of setting forth not only the relevance but also the contents of a document concerning a specific subject; the different types of abstracts and abstracting procedures will be covered. It is emphasized that retrieval is the reversal of the intellectual processes classing, indexing and abstracting, which is indicative of the special importance of these processes for the efficacy of technical information systems. Author

N89-23369# Federal Armed Forces Documentation and Information Centre, Bonn (Germany, F.R.).
DATA SECURITY
HELMUT BRAUN *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 9 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
Maintaining adequate security standards for classified documents in military information systems is of eminent importance. Handling commercially sensitive information requires similar precautions. Basically, there are two approaches to solve these problems: to produce and operate a classified database, in which case national and NATO security regulations must be observed in handling documents and references to these documents; or to work with an unclassified databases which contains only

unclassified information, in which case the reference to classified documents have to be kept unclassified. Questions are discussed which are related to preparing unclassified references to classified documents, deals with release procedures, and with problems relating to housekeeping problems. Author

N89-23370# National Technical Information Service, Springfield, VA.
IDENTIFYING USERS AND HOW TO REACH THEM
JOSEPH F. CAPONIO, FREDERICK L. HAYNES, and A. RAHMAN KHAN *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 5 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
The importance of timely use of scientific and technical information is increasingly being recognized by the developing nations as well as the developed nations. It is recognized that it is not only important to develop a better mouse-trap but also it is equally important to ascertain that there is proper diffusion of such an innovation. Knowledge could lay dormant if it does not reach the end-users when they most need it. An attempt is made to address why this is important and focuses on some of the factors involved in identifying and reaching the end-users. Author

N89-23371# Horton (Forest W., Jr.), Washington, DC.
INFORMATION RESOURCES MANAGEMENT
FOREST W. HORTON, JR. *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 5 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
The transfer of scientific and technical information between and among nations poses increasing challenges because of: larger and larger volumes of data exchanged; the increasing variety of information interchange media; larger and larger numbers of intermediaries and end-users all along the information transfer chain; and increasing incompatibility of bibliographic and telecommunications formatting conventions. The emerging field of Information Resources Management (IRM) offers promise in helping to cope with these serious information exchanges. In particular, experiments in the U.S. Federal Government with a technique called information mapping, helps information managers identify, describe, inventory/survey, and control their total data, document, and literature flows and holdings, whether automated or manual, more completely. This approach of IRM, and the technique of information mapping, in several organizational contexts - one private (an Australian mineral and mining company), the other public (the U.S. Department of State) are introduced. Author

N89-23372# Telsystemes Questel, Paris (France).
TRANSDOC-ELECTRONIC DELIVERY PROGRAMME
J. SOULE *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 7 p (SEE N89-23362 16-82) Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01
The TRANSDOC test has yielded positive results and has made it possible to confirm the following: It is technically possible to perform archiving electronically and the organizations needed to implement these technologies do work. There is a good match between the services tested and the needs of the users; services can be created and current ones improved. Beyond purely technical tests, the significance of such testing which is oriented towards routine use and the evaluation of the needs of future customers is, by now, completely obvious. TRANSDOC has made it possible to confirm that the arrival of these technologies will considerably modify the information market in all its forms very quickly. Author

N89-23373# Bergen Univ. (Norway). Library.
DECENTRALIZATION OF DATABASES AND THE COMMUNICATION BETWEEN THEM
LEIF MAGNE IVERSLAND   *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 5 p (SEE N89-23362 16-82)   Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01

Database management systems (DBMS) were for many years used to develop centralized information systems, where the database and the application programs are stored at a central computer. The DBMS have also resulted in decentralized information systems in which data and programs are stored at several sites with none or very little communication between the sites. With the advent of distributed database management systems (DDBMS) possibilities for developing information systems have emerged. An ideal DDBMS supports an information system database stored at several sites in a computer network in such a way that users can access data at any site in the network as if they were stored at the local site. Some of the necessary properties of an ideal DDBMS including location, replication, and fragmentation transparencies are examined.   Author

N89-23374# Defense Applied Information Technology Center, Alexandria, VA.
FOSTERING INTERACTION OF GOVERNMENT, DEFENSE, AND AEROSPACE DATABASES
VIKTOR E. HAMPEL   *In* AGARD, The Organisation and Functions of Documentation and Information Centres in Defence and Aerospace Environments 20 p (SEE N89-23362 16-82)   Mar. 1989
(AGARD-CP-445) Copyright Avail: NTIS HC A06/MF A01

The Department of Defense (DOD) knowledge worker needs rapid access to select information contained in government, defense, and aerospace databases. In the United States, information of use to defense and aerospace specialists are contained in multiple government databases as well as in commercial databases. Policy and technology strategies are addressed, which are being developed by the Defense Technical Information Center (DTIC) to foster better interaction among government, defense, and aerospace databases. To improve interactions, considerable progress was made by evolving standards in communication protocols, operating systems of computers, database management systems, and command structures, but it is the Defense Gateway technology that permits interconnectivity and interoperability in the interim period. This makes it possible to make the growing number of heterogeneous databases available to the defense community in a progressively more unified and automated manner. The results of several projects that introduce a high degree of information robotics to Information Resource Management (IRM) with substantial increases in human productivity are described.   Author

N90-11402# Andrews Antennas, Adelaide (Australia).
ACCURATE MEASUREMENTS OF THE TOTAL ANGLE OF ARRIVAL OF HF SKYWAVES
Z. R. JEFFREY, P. T. MIDDLETON, and C. WINKLER   *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 10 p (SEE N90-11361 02-46) Apr. 1989
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03

The procedures adopted in the ANDREW Single Station Location (SSL) system, SKYLOC, to measure the azimuth and elevation angle of a skywave from an HF transmitter, with a view to determining the location of that transmitter by appropriate simulation of the ionosphere and the signals propagating through it are described. The procedures adopted are capable of providing very accurate measurements of the azimuth and elevation angle, well within the variability imposed by the ionosphere, and are able to process signals with very small signal-to-noise ratios.   Author

N90-22440# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
ELECTRONIC TRANSFER OF INFORMATION AND ITS IMPACT ON AEROSPACE AND DEFENCE RESEARCH AND DEVELOPMENT
Mar. 1990   190 p   Meeting held in Brussels, Belgium, 17-19 Oct. 1989
(AGARD-CP-466; ISBN-92-835-0550-6; AD-A221596) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Topics discussed include the present state and trends in the electronic transfer of information in Europe, North America, and Japan; operational and experimental systems for electronic storage and delivery of information; operational and experimental systems of electronic publishing and communication; and applications in the aerospace community. Included are papers on proposed telecommunications networks, Integrated Services Digital Network (ISDN) and satellite networks, plans for an integrated system for a large technical library, automation plans of the European Patent Office, optical disc systems, desk-top publishing, Standard Generalized Markup Language (SGML), electronic mail, computer conferencing and the U.S. Defense Department's Computer-aided Acquisition and Logistics Support (CALS) program. For individual titles, see N90-22441 through N90-22455.

N90-22441# Commission of the European Communities (Luxembourg). Directorate General Telecommunications.
TECHNOLOGIES FOR ELECTRONIC TRANSFER OF INFORMATION: THE PRESENT STATE AND TRENDS IN EUROPE
F. MASTRODDI   *In* AGARD, Electronic Transfer of Information and its Impact on Aerospace and Defence Research and Development 10 p (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The emergence of new data storage and transfer media is having a growing effect on the electronic information industry. Two decades ago, there were only a handful of bibliographic databases, operated over dedicated online networks. Today the mass storage possibilities of new technologies, potential cost/benefit ratios, integration with personal computers and telecommunications networks are typical perceived benefits. There are several hundred optical disc applications running in Europe, in business, in education, leisure and research. A Commission of the European Community (CEC)-sponsored survey has identified many of these, and has gathered the opinions of market leaders on present and future trends. The consensus of opinion points to a promising market potential for this sector, depending on overcoming a set of key barriers - technical, economic and organizational and on the introduction of new telecommunications facilities. The European Commission (EC), under its new telecommunications and information market programs, aims to encourage the rapid development of this sector and to help overcome the barriers to growth. A call for proposals for pilot/demonstration projects held in early 1989 is one example of EC action.   Author

N90-22442# National Federation of Abstracting and Indexing Services, Philadelphia, PA.
TECHNOLOGY FOR ELECTRONIC TRANSFER OF INFORMATION: THE PRESENT AND FUTURE IN NORTH AMERICA
BETTY UNRUH   *In* AGARD, Electronic Transfer of Information and Its Impact on Aerospace and Defence Research and Development 11 p (SEE N90-22440 15-82) Mar. 1990
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Developments in the electronic transfer of information are largely led by advances in technology. This has been true and continues to be so today. The technologies of today, how they have advanced, and what effect those advancements have had on the products being delivered as well as on the information industry and its member companies are addressed. The successful delivery of information, however, is not completely dependent on technology. Successful products (and the technologies they utilize)

are firmly rooted in the markets they serve. The importance of a product meeting a market need cannot be overlooked. How products, born of technology, have addressed market demands (when successful) or not addressed (when unsuccessful) will be included for both the past and present with an eye to what the lessons learned portend for the future.   Author

N90-22443# GMD Bureau Tokyo, Akasaka (Japan). Deutsches Kulturzentrum.
TECHNOLOGIES FOR ELECTRONIC TRANSFER OF INFORMATION: THE PRESENT STATE AND TRENDS IN JAPAN
U. WATTENBERG *In* AGARD, Electronic Transfer of Information and its Impact on Aerospace and Defence Research and Development 10 p (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A full picture of electronic transfer of information in Japan is given. The huge number (6000) of Kanji characters caused many difficulties for the information industry: a Japanese-Japanese dictionary is needed for inputting characters via the keyboard; the characters require high resolution screens, etc. Having solved these problems, Japan has turned such disadvantages into advantages: it is leading in the production of high resolution screens and fax machines. Together with China and Korea, Japan is establishing a 2-byte standard character set for up to 65000 characters. The Japan Information Center of Science and Technology (JICST) is one of the largest hosts and document supply centers in the world. The JICST file on science and technology e.g., grows by 700,000 documents per year and the number of documents copied per year 700,000 too. 100,000 documents per year are translated into machine English; machine translation systems are applied mainly for translations from English into Japanese. JICST hosts one of the STN nodes (Columbus, Karlsruhe, Tokyo) through which the JICST databases are worldwide accessible, those in English really, and those in Japanese in principle. Of high importance are also the activities of the Japan Patent Information Organization (JAPIO) which cooperates with the U.S. Patent and Trade Mark Office and the European Patent Office in establishing a worldwide image file of all patents since 1920. Instead of the traditional 16 mm microfilm and microfiche the JAPIO now distributes to its subscribers 12 cm CD-ROM including full text images and index data. There is a sophisticated retrieval system for trade marks. And patents can be applied now either online, or on floppy disk, or in printed form. Japanese newspaper companies now hold their journals in electronic form. There is a data base with 500,000 photos on CD-ROM. Each day 500 new photos enter the database.   Author

N90-22444# British Telecom, London (England).
INNOVATIONS IN TELECOMMUNICATIONS NETWORKS
CHRIS HOLMES *In* AGARD, Electronic Transfer of Information and its Impact on Aerospace and Defence Research and Development 12 p (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A public telecomms carrier has 6 main roles in the IT marketplace: a user; a vendor of telecommunications networks for voice, data and information services (both public and private); a vendor for components of IT systems, personal computers, UNIX machines, multiplexes, modems, etc.; a systems integrator offering complete customer solutions with adaptive engineering to meet specific customer needs; a conformance tester; and a standards maker. The major innovations in the first 3 of these roles in the field of electronic transfer of information are briefly examined. Inevitably it is biased towards the activities of the company but where appropriate the national and international linkages are explored.   Author

N90-22445# Ministere de l'Education Nationale, Paris (France).
MEGATENDANCES [MAGATENDANCES]
S. CHAMBAUD *In* AGARD, Electronic Transfer of Information and its Impact on Aerospace and Defence Research and Development 10 p (SEE N90-22440 15-82) Mar. 1990 In FRENCH
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Five megatrends from the area of electronic transfer of information are identified: Three are from a technological discipline, one raises socioeconomic aspects, and the last is dependent on the results of research. This analysis predicts the use of information systems in the future.   Transl. by E.R.

N90-22446#   Commission of the European Communities (Luxembourg). Directorate General Telecommunications.
DOCUMENT DELIVERY VIA ISDN OR SATELLITE NETWORKS
ANTHONY J. DUNNING *In* AGARD, Electronic Transfer of Information and its Impact on Aerospace and Defence Research and Development (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
As a preliminary to discussing telecommunications networks and services, the main characteristics of documents and document delivery systems are presented from a theoretical viewpoint. The physical and functional characteristics of archives and document receiving terminals are also presented. An outline review of voice and data communications networks in W. Europe is presented. The plans for the introduction of ISDN services, and the facilities offered by experimental and operational satellite services are discussed. Standards aspects of telecomms services are considered, in particular the layer 7 protocol elements. The emergence of open distributed processing in ECMA and ISO and the associated client/server model are mentioned in this context.
                              Author

N90-22447#   Air Force Weapons Lab., Kirtland AFB, NM. Technical Processing Section.
THE WEAPONS LABORATORY TECHNICAL LIBRARY: AUTOMATING WITH STILAS
BARBARA I. NEWTON and JANET M. JOURDAIN *In* AGARD, Electronic Transfer of Information and its Impact on Aerospace and Defence Research and Development (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
In 1983, the United States Air Force Weapons Laboratory Technical Library formally recognized the requirement to manage its large diversified collections by automating several functions. This awareness coincided with the initiation of a joint Library of Congress - Defense Technical Information Center (DTIC) procurement program for an automated library system to serve the sophisticated needs of Department of Defense scientific libraries. Prototypes of the DTIC-sponsored project were described in the literature as The Local Automation Model. The Weapons Laboratory agreed to install the first production version of the system that was renamed the Scientific and Technical Information Library Automated System (STILAS). STILAS incorporates the features of an integrated library system with gateway reference access to an assortment of remote data bases, allowing library staff members and end-users to access up to four data base systems simultaneously. In addition to this reference function, STILAS performs all of the traditional library management functions of circulation, serials control, acquisitions, and inventory control. STILAS access is provided to Kirtland Air Force Base and its tenant organizations.   Author

N90-22448# European Patent Office, Rijswijk (Netherlands).
Principal Directorate Classification Documentation.
**THE AUTOMATION PLAN OF THE GENERAL DIRECTORATE 1
(SEARCH) OF THE EUROPEAN PATENT OFFICE**
ROBERT BARE *In* AGARD, Electronic Transfer of Information
and its Impact on Aerospace and Defence Research and
Development 7 p (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The European Patent Office is actually realizing a huge
automation project corresponding to an investment of about 300
million DM. This project is undertaken to cope with the ever
increasing number of patent applications and volume of documents
to be searched. The automation effort will be conducted in three
directions: processing of textual information (Epoque); processing
of images (Bacon); and personal systems. Author

N90-22449# Electronic Publishing Digital Equipment Co. Ltd.,
Basing View (England).
DESK TOP PUBLISHING: WHAT YOU NEED TO KNOW
MALCOLM TAYLOR *In* AGARD, Electronic Transfer of Information
and its Impact on Aerospace and Defence Research and
Development 25 p (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    A comprehensive view on desk top publishing (DTP) is given.
DTP is the way many people can use some of the traditional
publishing skills. DTP can cope with different types of input (text,
images, etc.), is easier to read, more authoritative, more effective
in communicating, uses less paper, and facilitates multiple and
multimedia output. When the documentation of a device (e.g., an
aircraft) outweighs the device itself and when the documentation
needs frequent updating then DTP can save much money. The
minimum requirements for DTP are a PC, a screen to show input
or output, a printer (preferably a laser printer) to print the output,
a keyboard, a mouse and some DTP software. In addition to
creating pages the software should support document retrieval,
document management, revision control, revision tracking,
distribution, and distribution control. The system should accept
texts from other devices such as networks, should permit optical
as well as intelligent character reading, should accept images such
as line drawings and photographs, and should permit the creation
of graphics. Publishing standards and architectures such as the
Standard Generalized Markup Language (SGML) and the Office
Document Architecture (ODA) play an increasing role in DTP.
Author

N90-22450# MID Information Logistics Group G.m.b.H.,
Heidelberg (Germany, F.R.).
**ELECTRONIC PUBLISHING WITH STANDARD GENERALIZED
MARKUP LANGUAGE (SGML)**
MANFRED KRUEGER *In* AGARD, Electronic Transfer of
Information and its Impact on Aerospace and Defence Research
and Development 8 p (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    Electronic publishing of information made up of complex
structured text (including technical and scientific notations, graphics
and images) in large volumes with a long life cycle and suited for
multiple forms of output is examined. In such a scenario, Standard
Generalized Markup Language (SGML) serves as the basic tool
in order to achieve a new quality of organizational control and
managerial flexibility. The specific features of SGML will be
demonstrated describing applications developed within the
Association of American Publishers (AAP), the International
Organization for Standardization (ISO) and the CALS initiative
(Computer-aided Acquisition and Logistics Support) of the U.S.
Department of Defense. Author

N90-22451# Information Technology Applications S.A.
(Luxembourg).
ELECTRONIC MAIL SYSTEMS
BARRY MAHON *In* AGARD, Electronic Transfer of Information
and its Impact on Aerospace and Defence Research and
Development 3 p (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    Electronic mail, or the use of computers and
telecommunications networks for transferring messages, has been
available to users of computer systems for a number of years. It's
early availability was restricted to specialists and to those who
had ready access to telecommunications facilities. More recently
it has become widely available with a number of competing public
services, many originating in the USA. A new CCITT/ISO standard
known as X400 was agreed which is designed to facilitate the
interaction between previously incompatible electronic messaging
systems. It is expected that the availability of services supporting
the X400 standard will contribute to the wider use of electronic
messaging as a business and technical communication tool.
However, in the same time frame, the general availability of
equipment for productivity enhancement based on microprocessors,
generally classified as the Information Technologies, has left many
users or potential users of messaging systems with a bewildering
choice of facilities. The developments are briefly reviewed and
then the integration of message handling in the more advanced
systems is presented. In so doing the emphasis is on the different
functions which can be and should be covered by planners of
messaging services. Direct services such as telex, fax, and
interpersonal messaging are treated as well as the indirect facilities
of gateways to external databases, intelligent interfacing and
personal information management. A number of different scenarios
are presented which illustrate how existing equipment and
infrastructure can be more efficiently utilized to provide integrated
services. Author

N90-22452# Guelph Univ. (Ontario).
**COMPUTER CONFERENCING: MINDS MEETING ANYWHERE
ANYTIME**
JOHN B. BLACK and ELLEN PEARSON *In* AGARD, Electronic
Transfer of Information and its Impact on Aerospace and Defence
Research and Development 4 p (SEE N90-22440 15-82) Mar.
1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    Computer conferencing systems provide an effective means of
group communication without the limitations posed by real-time
interactions (e.g., audio and video tele-conferences) or physical
location (e.g., face-to-face traditional meetings). Using various
components of the myriad of telecommunications facilities available
today, they provide a means of sharing the collective memory of
a discussion among two, two hundred or two thousand participants
who may be scattered around the globe. A description of this
concept is provided, potential applications are discussed, and key
factors required to make computer conferencing successful are
indicated. Author

N90-22453# Defense Technical Information Center, Alexandria,
VA.
**APPLICATIONS TO THE AEROSPACE AND DEFENSE R AND
D COMMUNITY: THE DOD COMPUTER-AIDED ACQUISITION
AND LOGISTICS SUPPORT (CALS) INITIATIVE**
KURT N. MOLHOLM *In* AGARD, Electronic Transfer of Information
and its Impact on Aerospace and Defence Research and
Development 8 p (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
    The U.S. Department of Defense (DoD) Computer-aided
Acquisition and Logistics support (CALS) initiative is directed toward
improving the design, development, and support of weapons
systems through the use of current and emerging computer
technology. CALS emphasizes greater utilization of information
contained in DoD and contractor databases to provide optimum,
economic weapon system support using electronic transfer of
information to the maximum amount possible. Author

N90-22454# Aerospatiale, Suresnes (France). Centre dinformation Documentaire Commun.
ELECTRONIC TRANSFER OF INFORMATION APPLICATIONS IN THE SOCIETE AEROSPATIALE [TRANSFERT ELECTRONIQUE DE L'INFORMATION APPLICATIONS DANS LA SOCIETE AEROSPATIALE]
OLEG LAVROFF *In* AGARD, Electronic Transfer of Information and its Impact on Aerospace and Defence Research and Development 5 p (SEE N90-22440 15-82) Mar. 1990 In FRENCH
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The applications of electronic information transfer in Aerospatiale, a French company with 33,000 employees, a turnover of 28 billion French Francs, and involved in the production of the Concorde, Airbus and Ariane is described. A number of electronic information projects are being studied or implemented: a bibliographic database in the field of technics for internal (knowhow of company) and external (patents etc.) information which should obviate the intermediaries; a database on macroeconomics; a database on internal and external standards; a database on multilingual terminology, stored on CD-ROM, as an aid for translation; technical documentation, stored on optical media, for use by clients, in particular a maintenance information planning system; computer assisted aircraft trouble shooting; an aircraft document retrieval system (more than 200,000 pages text and images); an advanced project for European information exchange on technical documentation; and a system for automated online order processing, e.g., for ordering spare parts. With 70 percent of the production being exported, automatic translation of technical documentation is of utmost importance. Author

N90-22455# British Aerospace Public Ltd. Co., Preston (England). Project Management Systems.
INFORMATION TECHNOLOGY APPLICATIONS: A BRITISH AEROSPACE MILITARY AIRCRAFT LTD VIEW
K. HALL *In* AGARD, Electronic Transfer of Information and its Impact on Aerospace and Defence Research and Development 16 p (SEE N90-22440 15-82) Mar. 1990
(AGARD-CP-466) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A view of the use and impact of information technology in BAe Military Aircraft Ltd is presented. A precis of the current and expected business market place is included to give perspective to the importance of this indust..al sector. The current situation is described with reference to typical conflicting requirements and the dynamic, competitive background. An example of a high level integrated business architecture is included which comprises a basic element of information flow in a company. Many of the components of an IT system focus in the project management activity, and consequently a system used for the management of projects is described in more detail. This illustrates in more depth the nature and complexity of one of the main activities in aerospace, and gives in addition an indication of the investment and timescales involved in such large - scale projects. Some conclusions are presented for consideration as policy guidelines for adoption by the AGARD panel. Author

N91-13352# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
BENEFITS OF COMPUTER ASSISTED TRANSLATION TO INFORMATION MANAGERS AND END-USERS
Jun. 1990 148 p In ENGLISH and FRENCH Lecture series held in Washington, DC, 14-15 Jun. 1990; in Brussels, Belgium, 25-26 Jun. 1990; and in London, England, 28-29 Jun. 1990
(AGARD-LS-171; ISBN-92-835-0568-9; AD-A225965) Copyright Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The aim of this Lecture Series is to show how computer assisted translation (CAT) can be of benefit not only to information managers but also to end-users. Existing systems are described as well as the nature of the texts to be processed, the technical and human problems related to the use of such systems and the needs of end-users (quality level of translations, information acquisition in the mother tongue...). Examples of on-going applications and

systems under development are presented. These examples highlight the benefits documentation centers will derive from CAT and suggest solutions of interest to the end-user. For individual titles, see N91-13353 through N91-13361.

N91-13353# Commission of the European Communities (Luxembourg).
TYPOLOGY OF EXISTING SYSTEMS
IAN M. PIGOTT *In* AGARD, Benefits of Computer Assisted Translation to Information Managers and End-Users 5 p (SEE N91-13352 04-82) Jun. 1990
(AGARD-LS-171) Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Various attempts were made at defining a typology of Machine Translation (MT) systems, some based on generations of software and hardware developments, others on the nature of the translation process (e.g., direct, transfer, modular). Today, however, a classification based more generally on performance and user access would appear to be more appropriate. Differentiation is made between large software packages installed on mainframe computers for access by telecommunications and smaller PC packages functioning on MS-DOS equipment. Attention is also given to systems capable of dealing with limited vocabulary and syntax as well as to developments in Japan which are beginning to set new trends in MT technology. Finally, information will be presented on how systems are now being used in practice and how use is likely to evolve over the next decade. Author

N91-13354# Centre de Documentation de l'Armement, Paris (France).
THE TECHNICAL ENVIRONMENT OF COMPUTER ASSISTED TRANSLATION [L'ENVIRONNEMENT TECHNIQUE DE LA TRADUCTION ASSISTEE PAR ORDINATEUR]
ALBERT YANEZ *In* AGARD, Benefits of Computer Assisted Translation to Information Managers and End-Users 14 p (SEE N91-13352 04-82) Jun. 1990 In FRENCH
(AGARD-LS-171) Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Paradoxically, whereas enormous progress has been made in translation and interpretation, especially in the area of information technology, computer assisted translation seems to have set the pace, while at the same time in certain countries, it seems to be in regression. The main reason is that very often there are deplorable technical environments, especially in the areas of man-machine systems and human factors engineering. For clarity, the following outline is examined. The method in which a problem is posed: adjustment of the risk, different needs, and applications provided for different environments. The technical environment in the research and development phase, where a distinction is made between information and aspects which are related, on one hand, to linguistics, and on the other, to the stage leading to industrialization provided by a version of the product. The fragile and critical operational environment is clearly improvable. There is a need to integrate it in a particular application or a particular customer's case. That integration is possible if a certain number of conditions are met, especially in the case of translating. This can add to the system's operational life if human factors engineering, e.g., is used for sensible task reduction, so that energy is saved along with the responsibility of the final translation. The conclusion is in the form of a series of recommendations.
Transl. by E.R.

N91-13355# Department of the Secretary of State, Ottawa (Ontario).
TYPOLOGY TEST OF TEXT SOURCES IN THE FRAMEWORK OF COMPUTER AIDED TRANSLATION [ESSAI DE TYPOLOGIE DES TEXTES SOURCE, DANS LE CADRE DE LA TRADUCTION ASSISTEE PAR ORDINATEUR]
JEAN GORDON *In* AGARD, Benefits of Computer Assisted Translation to Information Managers and End-Users 8 p (SEE N91-13352 04-82) Jun. 1990 In FRENCH; ENGLISH summary
(AGARD-LS-171) Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
The question of whether or not to use computer-assisted translation requires serious thought. All factors must be taken into

consideration. A typology helps to identify the category into which texts fall and the extent to which they lend themselves to this approach. The typology is based on material considerations (medium used and compatibility), terminological considerations (variety, complexity and stability of vocabulary) and stylistic considerations (presence of certain linguistic characteristics that affect the quality of results). This examination of the profile of documents is a sort of pre-screening tool. A thorough analysis should also be conducted before any final decision is taken.

Author

N91-13356# Aerospatiale, Toulouse (France). Aircraft Div.
PROBLEMS ENCOUNTERED WITH THE USE OF COMPUTER ASSISTED TRANSLATION IN A TECHNICAL PUBLICATIONS PRODUCTION ENVIRONMENT
D. J. PINNA *In* AGARD, Benefits of Computer Assisted Translation to Information Managers and End-Users 9 p (SEE N91-13352 04-82) Jun. 1990
(AGARD-LS-171) Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
A brief overview is given of the problems evidenced during studies into the use of Computer Assisted Translation (CAT) in the Aerospatiale Aircraft Division technical publications production environment. The aim is not to review the capabilities of the various CAT systems available in a comparative study but rather to highlight the technical, economical and psychological problems that have to date precluded the integration of CAT in this very specific industrial context.

Author

N91-13357# Siemens A.G., Munich (Germany, F.R.).
END USERS' NEEDS
THOMAS SCHNEIDER *In* AGARD, Benefits of Computer Assisted Translation to Information Managers and End-Users 5 p (SEE N91-13352 04-82) Jun. 1990
(AGARD-LS-171) Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
To assure international communication the introduction of machine translation systems is unavoidable. To be of use in practical applications, however, a system must fulfill the criteria of operability defined by the end user. In this context, two different applications must be contrasted, namely automatic translation with the aim of gathering information for internal applications on one hand and automatic translation with the aim of producing publications for external recipients on the other hand. In the first case, throughput and coverage of the system lexicon are most important while preservation of layout and format information are secondary. In the latter case, a much higher translation quality is required to ensure user acceptance. To be effective in an office environment, additional aspects become relevant: user interface, integration with other office systems, efficient lexicon update and post editing tools. Necessary for all types of applications is an intensive end user training and continuing support from specialist consultants.

Author

N91-13358# Air Force Inst. of Tech., Wright-Patterson AFB, OH. Foreign Technology Div.
ASPECTS OF MACHINE TRANSLATION IN THE UNITED STATES AIR FORCE
DALE A. BOSTAD *In* AGARD, Benefits of Computer Assisted Translation to Information Managers and End-Users 5 p (SEE N91-13352 04-82) Jun. 1990
(AGARD-LS-171) Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Machine translation is used in the USAF to translate technical literature in a wide variety of disciplines to support studies that assess the capabilities and research of the Soviet Union and other countries. Two types of machine translation are used: partially edited machine translation with hard copy printing of the text; and raw machine translation for rapid information scanning of material at a terminal. A special software program is used for rapid post-editing of texts. Potential trouble spots and ambiguities are intercepted and corrections are made by post-editors. Raw machine translation for gisting large volumes of information has proven to be an effective tool for analysts and researchers. Statistics indicate

an ever-increasing use of machine translation for rapid information scanning.

Author

N91-13359# Siemens A.G., Munich (Germany, F.R.).
STATE OF THE ART IN WEST GERMANY
THOMAS SCHNEIDER *In* AGARD, Benefits of Computer Assisted Translation to Information Managers and End-Users 12 p (SEE N91-13352 04-82) Jun. 1990
(AGARD-LS-171) Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
In Europe, research and development in the field of machine translation has been boosted by the EEC's EUROTRA program. However, operative systems are usually based on older technologies, as in SYSTRAN or LOGOS. In recent years, the METAL system designed by Siemens has proved its applicability. As it exemplies the state of the art it is described in detail. METAL is a modular system with recursive grammars and non-sequential processing. It contains hierarchically structured lexicon modules to facilitate subject-specific translation. The end-user is provided with powerful tools to update his own lexicon. METAL is integrated into a chain of automated processes from the acquisition of the source text to the production of a camera-ready version of the target text. User experiences show a marked productivity gain and a reduction of turn-around time.

Author

N91-13360# Centre de Documentation de l'Armement, Paris (France).
SYNTHESIS OF SOLUTIONS PROPOSED FOR END-USERS [SYNTHESE DES SOLUTIONS PROPOSEES AUX UTILISATEURS]
ALBERT YANEZ *In* AGARD, Benefits of Computer Assisted Translation to Information Managers and End-Users 11 p (SEE N91-13352 04-82) Jun. 1990 In FRENCH
(AGARD-LS-171) Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Potential end-users of computer assisted translation (CAT), i.e., all in the profession, in order to reach and use the solution which adapts best to a particular case, must reduce the linguistic obstacles when meeting the level of communication beyond the proper language ghetto. In this synthesis, a list is found of solutions of some of the possible resources which go to a term bank dictionary until the logic of lexicographical management or of analysis of text or aid in translation, certain that in most cases agreement will be found. The results are usable, but if disappointing, assistance can be sought from a translator or human examiner. Meanwhile, the perfect system of the future, which has been researched for many years, does not exist because the bridge between the conceptualist and end-user has not been crossed. From their cooperation would come the solution. If solutions are not offered, they must be built. This is why products (tools and systems) available on the market, and CAT especially, emphasis must be placed on the socio-politico-economic aspects, if there are to be genuine solutions, i.e., a time when the introduction of these tools and CAT become factors of productivity, opportunity, and progress. Now some end-users have begun to use the method, in which others can also be involved, alone or unison.

Transl. by E.R.

N91-13361# Aerospatiale, Suresnes (France). Centre d'Information Documentaire Commun.
COMPARISON BETWEEN HUMAN AND AUTOMATIC TRANSLATIONS (QUALITY, COSTS, AND PROCESSING TIME)
OLEG LAVROFF *In* AGARD, Benefits of Computer Assisted Translation to Information Managers and End-Users 6 p (SEE N91-13352 04-82) Jun. 1990
(AGARD-LS-171) Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Rough machine translations or automatically translated texts and post-edited texts (resulting from a refined post edition) is presented together with the respective time a translator devotes to translation when using the SYSTRAN system. The times and costs of automatic translation are summarized, which thus highlights the increased productivity of CAT compared to an all-human translation. The results mentioned hereafter only apply to

translations for which the company's liability is not involved.

Author

N91-14076# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
LIST OF STANDARDS TO ACCOMPANY MANUAL OF DOCUMENTATION PRACTICES APPLICABLE TO DEFENCE-AEROSPACE SCIENTIFIC AND TECHNICAL INFORMATION. ADDENDUM
Oct. 1990   49 p
(AGARD-AG-235-ADD; ISBN-92-835-0583-2; AD-A229160)
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This addendum to the Manual of Documentation Practices Applicable to Defence-Aerospace Scientific and Technical Information, originally published in five volumes from 1978 to 1982, contains lists of standards applicable to information work, grouped by field of application and by nation.   Author

N91-22946# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
AGARD GUIDE TO AEROSPACE AND DEFENCE TECHNICAL REPORT SERIES IN NATO COUNTRIES
Mar. 1991   420 p   Revised
(AGARD-R-743-REV; ISBN-92-835-0606-5; AD-A236084)
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A guide is presented to technical reports series relating to aerospace and defense research and development currently published by governments, contractors, research laboratories or universities in NATO member countries. The guide lists reports series from Belgium, Canada, Denmark, Germany, France, Greece, the Netherlands, Norway, Portugal, Spain, United Kingdom, United States, and international organizations. Information given includes a technical report series code, a title (where available), name and address of the organization producing the series, availability (where known), type of organization, and other helpful information provided by the producers. Two indexes are provided: an overall one by number; and one by number within the country.   Author

N91-25902# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
BRIDGING THE COMMUNICATION GAP
Feb. 1991   122 p   In ENGLISH and FRENCH   Meeting held in Trondheim, Norway, 5-6 Sep. 1990
(AGARD-CP-487; ISBN-92-835-0604-9)   Copyright   Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The proceedings of the meeting are presented. Topics discussed include the following: optical media, computers assisted publishing, broader communication bands, natural language processing and machine translation, full text retrieval, intelligent on-line interfaces, full text indexing and retrieval, the problems faced by data base publishers, and the training of information specialists. The final paper suggests actions that might be taken by information center managers, and recommendations they might make to ministries and other official bodies. For individual titles, see N91-25903 through N91-25913.

N91-25903# Technical Univ. of Norway, Trondheim.
AN OVERVIEW OF OPTICAL MEDIA NOW AND IN THE FUTURE
R. STORLEER   In AGARD, Bridging the Communication Gap 8 p (SEE N91-25902 17-82)   Feb. 1991
(AGARD-CP-487)   Copyright   Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Optical Technology Family is examined, where the different members of the analog, hybrid and digital optical storage groups are presented. The different media have both advantages and disadvantages. Analog storage has up to the present been the only medium for storage and presentation of pictures and films with high quality. By digitalization of pictures, each picture needs

from 0.3 to 1.0 Mbyte depending on the quality. That means that a CD-ROM only can keep about 7 to 900 color pictures and only 25 to 35 seconds film presentation. A videodisk can keep more than 100,000 pictures which gives about one hour film presentation. Manufacturers are working hard to solve this problem by finding new comprimation algorithms. The presentation deals with the different types: LaserVision, RID, WORM, DRAW, CD-ROM, CD-ROM-XA, DVI, CD-I, Erasables, etc. What about storage capacity, which type of matter is useful to store on what media, existing standards, use and miscellaneous, future prospects etc. The main emphasis is on CD-ROM which is the most common used optical media in a library environment.   Author

N91-25904# Springer-Verlag G.m.b.H. and Co. K.G., Heidelberg (Germany, F.R.).
COMPUTER-ASSISTED PUBLISHING WITH ITS STANDARDS AND COMPATIBILITY PROBLEMS
HOLGER WENDT and CHRISTINE ZUERN   In AGARD, Bridging the Communication Gap 2 p (SEE N91-25902 17-82)   Feb. 1991
(AGARD-CP-487)   Copyright   Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The original task of a publishing house, that is, to publish information in printed form, has changed enormously during the past few years. The possibilities offered by electronic data processing have several effects: on the one hand, more and more authors are choosing to write their manuscripts on word processing systems and send them to the publishing house on data carriers or by electronic mail. On the other hand, the possibility of using one text for several purposes has increasingly led to information being published on new media. These options are briefly examined.   Author

N91-25907# Bell Communications Research, Inc., Morristown, NJ.
FULL TEXT RETRIEVAL WITH GRAPHICS
MICHAEL LESK   In AGARD, Bridging the Communication Gap 13 p (SEE N91-25902 17-82)   Feb. 1991
(AGARD-CP-487)   Copyright   Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Conventional full text retrieval systems often omit the pictures from the material they display. The existing machine-readable text of the American Chemical Society journals were scanned from microfilm and the images were extracted from the text by algorithms which analyze the digitized bitmaps. The combined pictoral and text material is used with full-text search to provide access to the complete file. The major experiments to be done are to: (1) measure the acceptability of the electronic systems; (2) compare full text search of titles, abstracts and/or indexing; and (3) compare presentation of full page images in bitmap format, presentation of text in ASCII with graphics on demand from images, and traditional paper copies of the journals. The major parts of the research are: (1) Software to partition digitize images of pages into textual, tabular and pictorial areas, (This is used to extract the graphics material, which is then matched with the commands referencing the pictures in the typesetting tapes, and prepared for display as bitmaps); (2) Search software which implements conventional searching capability (Boolean and coordinate index term search) on the full text of the journals, which is available from the typesetting and on-line operations of the American Chemical Society, (Experiments are also continuing with the use of singular value decomposition to group documents and concepts to aid searching); and (3) Browsing and reading software to help people read complex journal material on-line, by highlighting matches, formatting paragraphs, and providing interactive screen displays.   Author

N91-25908# Commission of the European Communities (Luxembourg). Computerized Language Processing Unit.
BEYOND MACHINE TRANSLATION
L. ROLLING   In AGARD, Bridging the Communication Gap 6 p (SEE N91-25902 17-82)   Feb. 1991
(AGARD-CP-487)   Copyright   Avail: NTIS HC/MF A06; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The essential aspects are described of computer translation: design, funding, development, experimental use, evaluation and implementation. The technical, economic, and psychological

obstacles to be overcome for efficient use of the new instrument are emphasized. Current applications will be supplemented by other, new applications in the Machine Translation (MT) market, which may well be centered on commercial communication and data base access. While the technical feasibility and the economic viability of MT depend on system design and implementation infrastructure, the quality of MT output ultimately depends on the representativity of available grammars and dictionaries vis-a-vis the real life use of human language. But MT is not the only application that requires a complete mastery of a number of languages by computer. Publishing, data base maintenance and interrogation, and many other natural language processing activities require all-encompassing text corpora, multi-purpose lexica, term banks and other linguistic and computational resources. The EC commission has a major role to play in the coordination of European efforts to standardize, develop and manage these resources, to be used also for speech-technology and knowledge based applications of the future. EC action includes a number of ESPRIT and IMPACT projects, but the coordinating and teaching tasks, now under the Commission's Multilingual Action Plan, may well be handled by a new agency to be created for this purpose.
<div align="right">Author</div>

N91-25910# American Inst. of Aeronautics and Astronautics, New York, NY.
DATABASE PUBLISHERS' CHALLENGES FOR THE FUTURE
BARBARA LAWRENCE *In* AGARD, Bridging the Communication Gap 10 p (SEE N91-25902 17-82) Feb. 1991
(AGARD-CP-487) Copyright Avail: NTIS HC/MF A06;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
The role of database publishers is analyzed. As an aid to achieving this focus, some recent words from Everett Brenner, long a gadfly of the database and secondary information service community is used as a theme: The success of information systems using computers, whether in research or business areas of the corporation, rarely ever depends on the technology. Success finally hinges on the information itself, its quality and ability for humans to communicate real needs which can be translated into a digestible and retrievable form. With the focus clearly on the role as information providers who are concerned with providing information content through various channels, the trends and the challenges are evaluated. Users, who are the reason for building databases, the very enticing visions of how databases can be used, and finally the more specific challenges that database producers must meet in order to remain effective in these future scenarios are all considered.
<div align="right">Author</div>

N91-25911# Profile Information, Sunbury-on-Thames (England).
THE ECONOMIC ASPECTS OF DEVELOPING AND MARKETING FULL TEXT DATABASES
MARK HEPWORTH *In* AGARD, Bridging the Communication Gap 3 p (SEE N91-25902 17-82) Feb. 1991
(AGARD-CP-487) Copyright Avail: NTIS HC/MF A06;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
A brief overview is given of PROFILE Information, the process involved in getting and delivering a full text source of information online and the primarily economic issues involved. The process is broken down into collecting the data, designing and developing the database, delivering and selling the database.
<div align="right">Author</div>

N91-25912# Sheffield Univ. (England). Dept. of Information Studies.
BRIDGING THE COMMUNICATION GAP: THE CASE OF THE PORTUGUESE INFORMATION SYSTEM FOR INDUSTRY
MARIA JOAQUINA BARRULAS and ZITA CORREIA (Laboratorio Nacional de Engenharia e Tecnologia Industrial, Lisbon, Portugal) *In* AGARD, Bridging the Communication Gap 15 p (SEE N91-25902 17-82) Feb. 1991
(AGARD-CP-487) Copyright Avail: NTIS HC/MF A06;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive
The recent Portuguese economic developments are described, as well as the main plans that shape the future developments in Portugal. A brief overview of the industrial structure is provided and the national information infrastructure is analyzed, with special reference to the National Library, the public libraries, the archives,

special libraries and information systems, telecommunications, the information industry and available training programs in Library and Information Science. The program for the Development of the Information System for Industry is described and special emphasis is given to the Course for Information Intermediaries, which is aimed at preparing qualified professionals to staff the information units of the System. In order to evaluate the impact of training provided through this Course on job engagement and performance of these information professionals, a survey was conducted and the results obtained are analyzed. The conclusion stressed that, considering the present state of development of the Portuguese information infrastructure, a major contribution to reduce the communication gap is still to invest further in education and training of information professionals.
<div align="right">Author</div>

N91-25913# Aerospatiale, Suresnes (France).
POSSIBLE RECOMMENDATIONS TO MINISTRIES AND OTHER AUTHORITIES BASED ON THE FOREGOING PAPERS
OLEG LAVROFF *In* AGARD, Bridging the Communication Gap 9 p (SEE N91-25902 17-82) Feb. 1991
(AGARD-CP-487) Copyright Avail: NTIS HC/MF A06;
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AGARD/Scientific Publications Executive
Many conclusions are drawn which arise from the other papers presented at the meeting and the tasks are identified which are ahead for information center managers, and recommendations are given that they could make to their superiors or to Government departments with responsibility for information policy, at least in those countries where there is a national information policy. Where there is no such policy, concerted action should be taken to persuade a ministry or other official body to define one, based on the recommendations arising from this meeting. It is of course a very ambitious project, but if all information center managers wish to be able to respond fully to the desires and needs of their end-users (who attach more and more importance to relevance of information and particularly to speedy delivery of it in their own language) the necessary means (logistic, personnel, financial and training), to enable them to exploit fully and effectively the new technologies which will soon be used in research and for information transfer.
<div align="right">Author</div>

N91-25959# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
A MANUAL ON THE EVALUATION OF INFORMATION CENTERS AND SERVICES
JOSE-MARIE GRIFFITHS and DONALD W. KING (King Research, Inc., Rockville, MD.) Apr. 1991 128 p
(AGARD-AG-310; ISBN-92-835-0614-6; AD-A237321) Copyright Avail: NTIS HC/MF A07; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
This manual is a follow-up to AGARD Lecture Series, The Evaluation of Information Centres and Services, LS 160, published in September 1988. It suggests an approach to evaluation which was refined over the last 20 years during involvement in nearly 300 projects involving the planning, evaluation and design of information centers and services. The manual emphasizes the use of evaluation measures, models and methods and includes data and results from actual studies. It also includes a comprehensive bibliography.
<div align="right">Author</div>

N92-18659# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
INTELLECTUAL PROPERTY RIGHTS
Oct. 1991 235 p In ENGLISH and FRENCH Lecture series held in London, England, 21-22 Oct. 1991, in Brussels, Belgium, 24-25 Oct. 1991, and in Arlington, VA, 6-7 Nov. 1991
(AGARD-LS-181; ISBN-92-835-0639-1) Copyright Avail: NTIS HC/MF A11; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive
Intellectual property has become one of the keys to the management of high technology sectors and communication systems. The concept is, however, used to describe a variety of different situations influenced by the combined effect of technical and economic change. From this results an intensive legal activity, not only in the passing of new legislation and the creation of jurisprudence, but also in the field of contractual and professional

practice, which is becoming more important. The aim of this Lecture Series is therefore to provide a few markers, to look at the prospects for these trends and to assess the stakes involved, so as to enable better evaluation and control of national and international legal practices. For individual titles, see N92-18660 through N92-18667.

N92-18660# Montpellier Univ. (France). Faculty of Law and Economic Science.
INTELLECTUAL PROPERTY AND INFORMATION: A COMPARATIVE INTERNATIONAL OVERVIEW
MICHEL VIVANT   *In* AGARD, Intellectual Property Rights 10 p
(SEE N92-18659 09-82)   Oct. 1991
(AGARD-LS-181)   Copyright   Avail: NTIS HC/MF A11;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

The methods that different national legal systems use to respond to the challenges of new information and communications technologies is examined. Additionally, the common features of what is at stake and the steps taken to cope with these identical challenges are highlighted. At the same time, the divergencies in philosophies and practices, which are sources of division between one country and another and thus run counter to the establishment of a sound and steady information products and services market, are pointed out.   Author

N92-18661# Defence Research Agency, London (England). Intellectual Property Dept.
SECTOR BASED LOGIC AND PRACTICE OF INTERNATIONAL COMPANIES IN THE FIELDS OF DATA MANAGEMENT AND TECHNOLOGY TRANSFER
ROBERT W. BECKHAM   *In* AGARD, Intellectual Property Rights 5 p (SEE N92-18659 09-82)   Oct. 1991
(AGARD-LS-181)   Copyright   Avail: NTIS HC/MF A11;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

In considering data management and technology transfer, it is found that different areas of industry and other organizations operating in technological fields have developed policies which best reflect the environment, both legal and national, in which they operate. Furthermore, attitudes of individual companies are colored by the attitudes of immediate competitors. In this talk, consideration will be given to the effectiveness of legal protection mechanisms in various parts of the world. It should be particularly noted that legal mechanisms specifically intended to promote technology transfers, particularly systems of compulsory licensing, often have the opposite effects, restricting both the availability of information and technology transfer.   Author

N92-18662# Copyright Licensing Agency, London (England).
REPRODUCTION: LEGAL LICENCE AND CONTRACTUAL PROCEDURES. PRINCIPLES AND PRACTICE
COLIN P. HADLEY   *In* AGARD, Intellectual Property Rights 18 p
(SEE N92-18659 09-82)   Oct. 1991
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Emphasis is on the practice and principles of licensing facsimile reproduction of copyright material. The principles of collective licensing, and the practice and the day-to-day running of a collecting society are examined. Electrocopying and the technologies being developed at the Copyright Licensing Agency to deal with this and other new advances in communication are also examined.
                                                                        Author

N92-18663# Database Development, Shorewood, WI.
ELECTRONIC INFORMATION SERVICES: PARTICULARITIES AND SELF-REGULATION (CONTRACTS AND CODES OF CONDUCT)
JOE BREMNER   *In* AGARD, Intellectual Property Rights 30 p
(SEE N92-18659 09-82)   Oct. 1991
(AGARD-LS-181)   Copyright   Avail: NTIS HC/MF A11;
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Traditionally, users of electronic information services have signed 'subscription agreements', which specify, not just what will be delivered, and the price, but state specific conditions on the use of the information. The basic intent of these agreements is to effect a license of the work - not a sale. While it may appear that the practices of database publishers and online hosts are awkward or unusual, they are based on sound business judgements. Publishers and hosts have had to contend with an international distribution environment that outstripped the state of international intellectual property laws; hence, they relied on contract law. The topics covered include: (1) industry background; (2) industry practices; (3) intellectual property issues; and (4) database distribution policies in the future.   Author

N92-18664# Gesellschaft fuer Mathematik und Datenverarbeitung, Cologne (Germany, F.R.).
PUBLIC SECTOR INFORMATION: TOWARDS A COMPREHENSIVE INFORMATION POLICY FOR RECONCILING DIVERGING INTERESTS
HERBERT BURKERT   *In* AGARD, Intellectual Property Rights 10 p (SEE N92-18659 09-82)   Oct. 1991
(AGARD-LS-181)   Copyright   Avail: NTIS HC/MF A11;
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There is an increasing need for public sector information expressed by individuals, organizations, and other public sector institutions, and within the framework of international cooperation. With the move towards electronic filing, public sector information resources are being rediscovered by the private sector intending to service these needs. Against the background of budgetary restraints, the public sector develops its own market interests in its information resources. These diverging interests call for comprehensive information policies. In trying to develop such policies, the public sector sees itself faced with a regulatory environment comprising copyright, secrecy regulations, privacy and access to government information regulations, as well as competition law. The interests are analyzed behind these regulations, their impact on the availability of public sector information and the problems they create with the change in public sector information handling from the traditional paper to the electronic filing environment. A balanced approach is pleaded for, which takes into account the specific functions of public sector information.   Author

N92-18665# Controle General des Armees, Paris (France).
TRANSFERS OF TECHNOLOGY: INTERNATIONAL NEGOTIATIONS AND WORK IN PROGRESS
PAUL FREIERMUTH   *In* AGARD, Intellectual Property Rights 8 p (SEE N92-18659 09-82)   Oct. 1991
(AGARD-LS-181)   Copyright   Avail: NTIS HC/MF A11;
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Areas of discussion which were presented at the COCOM meeting held in Paris on 23 and 24 May, 1991 are examined. The conferences were cognizant of the problems inherent in technology transfer. The meeting highlighted the government's problem of how to define a simple set of lines of conduct relating to technology for government (military) use. The three main topical areas of discussion are as follow: the end use of transfers of technology are many and varied, often falling into a political context of industrial strategy and appropriate legal instruments are used to implement them; how transfers of technology can take a variety of forms such as sale and as cooperation agreements; and how the obstacles have cultural, economic, technical, or political connotations.   E.R.

N92-18666# Commission of the European Communities, Brussels (Belgium).
THE NEW EUROPE
BRIDGET CZARNOTA   *In* AGARD, Intellectual Property Rights 9 p (SEE N92-18659 09-82)   Oct. 1991
(AGARD-LS-181)   Copyright   Avail: NTIS HC/MF A11;
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The characteristics and development of the information market in Europe are discussed. Topics covered include the actions taken by the European Community towards a European information market and the regulatory framework, including questions of patents, trademarks, and copyrights. Issues of standardization and the use of proprietary intellectual property rights are discussed, as well as research and development contracts. Relations among

countries and the role of the European Community in the international forum are discussed. Author

N92-18667# Information Industry Association, Washington, DC.
INFORMATION AND RESPONSIBILITY
STEVEN J. METALITZ *In* AGARD, Intellectual Property Rights 17 p (SEE N92-18659 09-82) Oct. 1991
(AGARD-LS-181) Copyright Avail: NTIS HC/MF A11;
Non-NATO Nationals requests available only from
AGARD/Scientific Publications Executive

A complex network of legal rights and responsibilities is part of the environment within which information products and services are developed and distributed. A brief survey of some aspects of this network or web of responsibility is provided from the perspective of the information content provider. Responsibilities to authors and other sources are governed by copyright principles, especially those recently discussed by the U.S. Supreme Court in the Feist case. Debate over responsibilities to data subjects has recently been dominated by discussion of the draft European Commission directive on data protection. Responsibilities to data consumers and customers are generally governed by expressed or implied contract terms, while responsibilities to end-users and ultimate beneficiaries of information products and services implicates questions of negligence and strict liability. Observations on the role of business and government in clarifying and defining legal responsibilities for information are given. Author

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LAW, POLITICAL SCIENCE AND SPACE POLICY

Includes NASA appropriation hearings; aviation law; space law and policy; international law; international cooperation; and patent policy.

N91-12586# Messerschmitt-Boelkow-Blohm G.m.b.H., Brussels (Belgium).
INTERNATIONAL COOPERATION IN AERONAUTICAL RESEARCH AND DEVELOPMENT CARRIED OUT BY INTERNATIONAL ORGANISATIONS
JUERGEN H. WILD *In* AGARD, Seminar on the Structure of Aeronautical R/D 27 p (SEE N91-12579 04-01) May 1990
(AGARD-R-782) Copyright Avail: NTIS HC/MF A06;
Non-NATO Nationals requests available only from
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The following subjects are addressed: objectives and structures of cooperative programs; review of cooperative schemes in research and development; description of programs and projects; funding systems schemes for research and technology cooperation; and the specific situation concerning research technology and development in Portugal, Greece, and Turkey. B.G.

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SOLAR PHYSICS

Includes solar activity, solar flares, solar radiation and sunspots.

N90-11362# Institut d'Aeronomie Spatiale de Belgique, Brussels.
SOLAR-TERRESTRIAL RELATIONS: FLARE AND SOLAR WIND EFFECTS
J. LEMAIRE *In* AGARD, Ionospheric Structure and Variability on a Global Scale and Interactions with Atmosphere and Magnetosphere 11 p (SEE N90-11361 02-46) Apr. 1989
Sponsored in part by Ministere de l'Education Nationale et de la Culture Francaise and Fonds National de la Recherche Scientifique
(AGARD-CP-441) Copyright Avail: NTIS HC A20/MF A03

The existence of solar terrestrial relations is clearly shown during solar flare events. During these catastrophic events the enhanced flux of XUV solar radiation as well as the sudden outburst of energetic solar cosmic ray particles induce a series of well identified effects in the Earth's magnetic field, in the terrestrial ionosphere and in the upper atmosphere. These geophysical effects and their solar origin are reviewed. Solar activity also perturbs the distribution of plasma and magnetic fields in the corona and in the interplanetary medium. Large-scale (low frequency) and small-scale (high frequency) inhomogeneities (perturbations) are produced in the expanding solar wind flow which then interacts with the Earth's magnetic field. The resulting variability of the impinging solar wind plasma triggers additional geophysical effects in the magnetosphere, in the terrestrial ionosphere, and in the upper atmosphere. Some of the geophysical consequences of this non-stationary interaction of the solar wind with the geomagnetic field, and, of impulsive penetration of small scale solar wind plasma irregularities into the magnetosphere are reviewed (e.g. polar cusp fields, currents, and related ionospheric irregularities). Author

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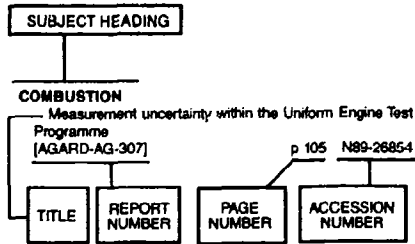
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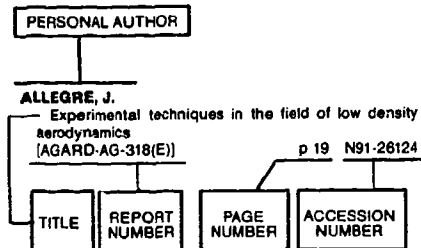
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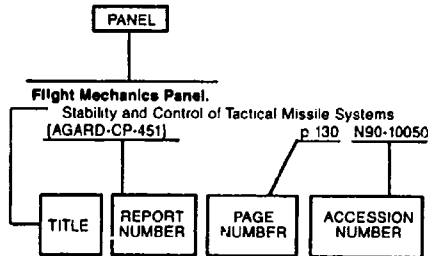
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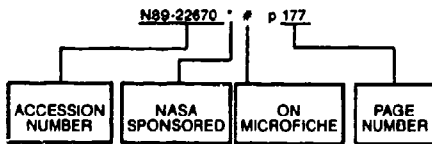
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