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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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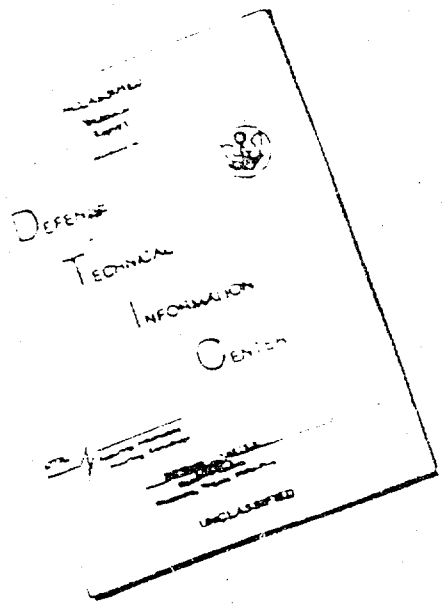

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NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

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- Exchanging of scientific and technical information;
- 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;
- Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;
- 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;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community.

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PREFACE

This volume provides abstracts and indexes for AGARD publications published during the period 1974 – 1976. By an arrangement with the US National Aeronautics and Space Administration in Washington, the NASA computerized data base 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 10 major subject divisions and 74 specific categories used by NASA in its abstract journals and bibliographies. The major subject divisions are listed in the Table of Contents, 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. N10,000 series (*STAR*) items appear before X70,000 series items. Examples of typical citations with abstracts are given following the Table of Contents.

There are five indexes: Subject, based on *NASA Thesaurus* nomenclature; Personal Author; Corporate Source; Report/Accession Number; and Accession/Report Number. Sample entries are shown on the first page of each index.

There are now five volumes in the current AGARD Index Series

– AGARD Index of Publications 1952–1970 Part I: Abstract Section		June 1972
– AGARD Index of Publications 1952–1970 Part II: Subject Index		October 1972
– AGARD Index of Publications 1952–1970 Part III: Author Index Part IV: Addendum to Part I	Bound together	September 1974
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Includes aeronautics (general); aerodynamics; air transportation and safety; aircraft communications and navigation; aircraft design, testing and performance; aircraft instrumentation; aircraft propulsion and power; aircraft stability and control; and research and support facilities (air).

For related information see also *Astronautics*.

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For related information see also *34 Fluid Mechanics and Heat Transfer*.

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08 AIRCRAFT STABILITY AND CONTROL 102
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ASTRONAUTICS

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14 GROUND SUPPORT SYSTEMS AND FACILITIES (SPACE) N.A.
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17 SPACECRAFT COMMUNICATIONS, COMMAND AND TRACKING N.A.
Includes telemetry; space communications networks; astronavigation; and radio blackout.
For related information see also *04 Aircraft Communications and Navigation* and *32 Communications*.

18 SPACECRAFT DESIGN, TESTING AND PERFORMANCE N.A.
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For life support systems see *54 Man/System Technology and Life Support*. For related information see also *05 Aircraft Design, Testing and Performance* and *39 Structural Mechanics*.

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Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

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ENGINEERING

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45 ENVIRONMENT POLLUTION 202
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Includes data sampling and smoothing; Monte Carlo method; and stochastic processes.

66 SYSTEMS ANALYSIS N.A.
Includes mathematical modeling; network analysis, and operations research.

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PHYSICS

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For related information see also *33 Electronics and Electrical Engineering* and *36 Lasers and Masers.*

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Includes quantum mechanics; and Bose and Fermi statistics.
For related information see also *25 Inorganic and Physical Chemistry* and *34 Fluid Mechanics and Heat Transfer.*

SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

80 SOCIAL SCIENCES (GENERAL) N.A.
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For related information see *03 Air Transportation and Safety, 16 Space Transportation,* and *44 Energy Production and Conversion.*

SPACE SCIENCES

Includes space sciences (general); astronomy; astrophysics; lunar and planetary exploration; solar physics; and space radiation.
For related information see also *Geosciences.*

88 SPACE SCIENCES (GENERAL) N.A.

89 ASTRONOMY N.A.
Includes radio and gamma-ray astronomy; celestial mechanics; and astrometry.

90 ASTROPHYSICS N.A.
Includes cosmology; and interstellar and interplanetary gases and dust.

91 LUNAR AND PLANETARY EXPLORATION N.A.
Includes planetology; and manned and unmanned flights.
For spacecraft design see *18 Spacecraft Design, Testing and Performance.* For space stations see *15 Launch Vehicles and Space Vehicles.*

92 SOLAR PHYSICS N.A.
Includes solar activity, solar flares, solar radiation and sunspots.

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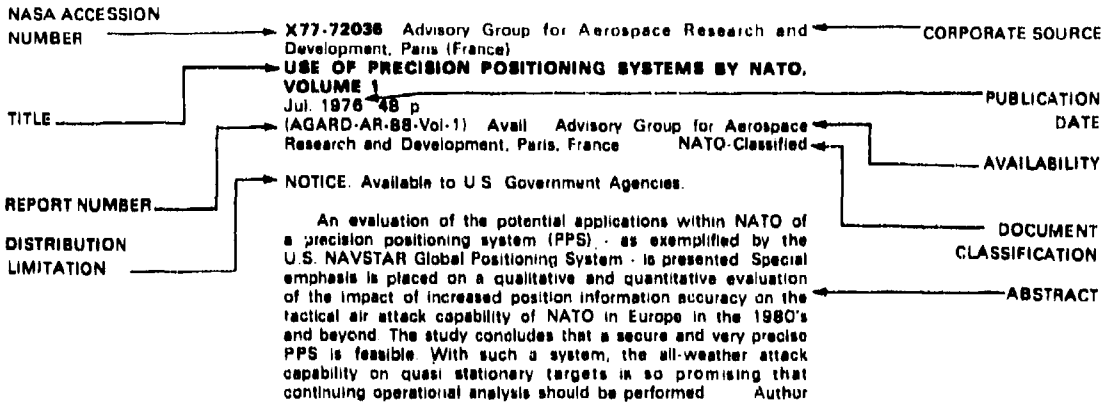

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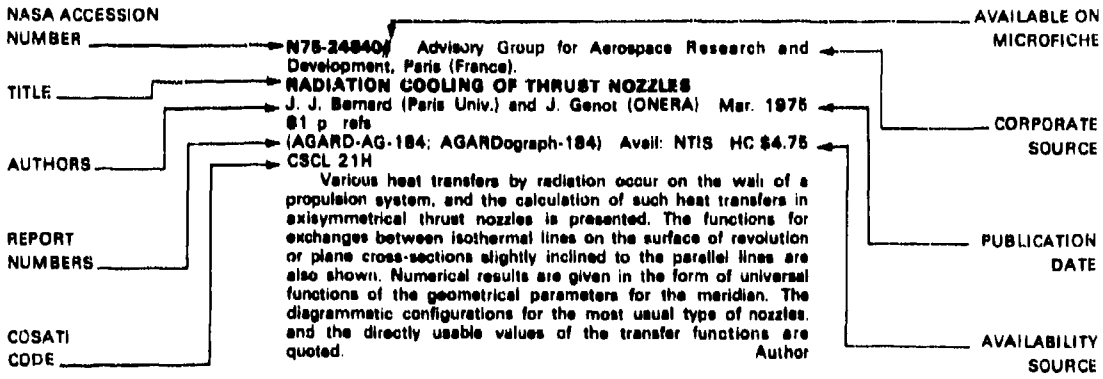

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01 AERONAUTICS (GENERAL)

N75-14710# Advisory Group for Aerospace Research and Development, Paris (France)
AGARD HIGHLIGHTS, MARCH 1974
Mar 1974 30 p
(AGARD-Highlights-74/1) Avail: NTIS HC $3.75

The activities and accomplishments of the Advisory Group for Aerospace Research and Development (AGARD) during the first quarter of 1974 are discussed. Some of the subjects considered are: (1) using science and technology to meet military requirements at reduced cost, (2) preliminary design applications for reducing development, production, and operational costs of aircraft systems, (3) atmosphere pollution by aircraft engines, and (4) design and development of large wind tunnels. Author

N75-14711# Advisory Group for Aerospace Research and Development, Paris (France)
THE PERKINS-GLASSER LECTURES, MARCH 1974
Sep 1974 27 p In ENGLISH, partly in FRENCH
(AGARD-Highlights-74/2) Avail: NTIS HC $3.75

An address to the Advisory Group for Aerospace Research and Development (AGARD) which was delivered in September, 1974 is presented. The subject of the address is the Impact of Research and Development on the United States Air Force. Some of the topics considered in the address are: (1) the National support of research, (2) basic and applied research in the Air Force, (3) development of inertial guidance systems, and (4) development of electronic digital computer. Areas of interest involved the methods for funding research and development activities and the process for making new technology available to industry. Author

N75-21219# Advisory Group for Aerospace Research and Development, Paris (France).
TAKE-OFF AND LANDING
Jan 1975 300 p refs Presented at 44th Meeting of the Flight Mech. Panel of AGARD, Edinburgh, 1-4 Apr. 1974
(AGARD-CP-160) Avail: NTIS HC $8.75

The proceedings of a conference on aircraft takeoff and landing are presented. The subjects discussed include the following: (1) aircraft design optimization, (2) energy management, (3) aircraft stability and control characteristics, (4) aircraft guidance using ground based and airborne equipment, and (5) operational aspects of approach control with short takeoff aircraft. For individual titles, see N75-21220 through N75-21241.

N75-21220* National Aeronautics and Space Administration Langley Research Center, Langley Station, Va.
HIGH-LIFT AERODYNAMICS: TRENDS, TRADES, AND OPTIONS
Richard J. Margason and Harry L. Morgan, Jr. *In* AGARD Take-off and Landing Jan. 1975 11 p refs (For availability see N75-21219 13-01)

The trend toward the utilization of higher maximum lift coefficient with increased aircraft size and cruise velocities is discussed. The impact of this trend on the need for tradeoffs between cruise performance and takeoff, climb, and landing performance is examined. Theoretical methods for the analysis of the two-dimensional characteristics of flap systems are described and compared with experimental data. Four powered-lift concepts are described to outline some of the options currently being developed. Two jet-flap theories are described which provide analytical methods for estimation of the three-dimensional aerodynamic high-lift performance characteristics of powered lift systems. Author

N75-21221* Messerschmitt-Boelkow Blohm G.m.b.H., Munich (West Germany)
COMPATIBILITY OF TAKE-OFF AND LANDING WITH MISSION AND MANOEUVRE PERFORMANCE REQUIREMENTS FOR FIGHTER AIRCRAFT
Dieter Reich and Josef Wimbauer. *In* AGARD Take-off and Landing Jan. 1975 7 p refs (For availability see N75-21219 13-01)

By means of an aircraft synthesis program, the effect of engine cycle, thrust to weight ratio, and wing parameter combination on field and flight performance has been investigated. For three different engine/intake configurations, thrust to weight ration and wing loading were varied. Each combination represents an aircraft designed to meet a specified mission radius. Using different lift systems and ground deceleration devices, the conditions are shown under which a matching of flight and field performance is economically feasible. Author

N75-21222 Aerospatiale Usines de Toulouse (France).
GENERAL CRITERIA FOR THE DEFINITION OF TAKE-OFF AND LANDING OF AN AIRCRAFT WITH NONLIMITED LIFT [CRITERES GENERAUX POUR LA DEFINITION AU DECOLLAGE ET A L'ATTERRISSAGE D'UN AVION NON LIMITE EN PORTANCE]
C. Pelagatti and T. Markham (British Aircraft Corp., Bristol, England) *In* AGARD Take-off and Landing Jan. 1975 11 p In FRENCH (For availability see N75-21219 13-01)

The performance of a slender wing aircraft configuration with unlimited lift was studied. A description is given of the approach process, aerodynamic characteristics, and certification regulations. The optimization of characteristics based on speed was developed after considering examples from the Concorde. Transl. by E.I.W.

N75-21223* Boeing Commercial Airplane Co., Seattle, Wash.
TERMINAL AREA CONSIDERATIONS FOR AN ADVANCED CTOL TRANSPORT AIRCRAFT
Mark B. Sussman. *In* AGARD Take-off and Landing Jan. 1975 14 p refs (For availability see N75-21219 13-01)
(Contract NAS1-12018)

Projected future conditions at large urban airports were used to identify design objectives for a long-haul, advanced transport airplane introduced for operation in the mid-1980s. Operating constraints associated with airport congestion and aircraft noise and emissions were of central interest. In addition, some of the interaction of these constraints with aircraft fuel usage were identified. The study allowed for advanced aircraft design features consistent with the future operating period. A baseline 200 passenger airplane design was modified to comply with design requirements imposed by terminal area constraints. Specific design changes included: (1) modification of engine arrangement, wing planform; (2) drag and spoiler surfaces; (3) secondary power systems; (4) brake and landing gear characteristics; and (5) the aircraft avionics. These changes, based on exploratory design estimates and allowing for technology advance, were judged to enable the airplane to: reduce wake turbulence, handle steeper descent paths with fewer limitation due to engine characteristics; reduce runway occupancy times, improve community noise contours; and reduce the total engine emittants deposited in the terminal area. The penalties to airplane performance and operating cost associated with improving the terminal area characteristics of the airplane were assessed. Finally, key research

problems requiring solution in order to validate the assumed advanced airplane technology were identified Author

N75-21224 Service Technique de l'Aeronautique, Paris (France)
BRAKING PERFORMANCES
Georges Leblanc *In* AGARD Take-off and Landing Jan 1975 17 p In FRENCH. ENGLISH summary (For availability see N75-21219 13-01)

During Landing or aborted take-off, the braking distances are depending on the speed allowed by high lift devices and on the Kinetic energy which must be absorbed by the braking systems according to the available friction coefficient of tire runway Studies on this last point have not yet been so extensive as aerodynamic studies Beside obvious interest for performances, it is necessary to know how to determine the safety margins which have to be taken on braking distances according to actual conditions of the runway For the prediction of braking distance a comprehensive scheme of friction phenomena on wet runway according the three zone's GROUCH model is proposed. The test results obtained with CARAVELLE Aircraft confirm that the proposed model is correct and that it can give a satisfactory prediction of the braking distance. Author

N75-21225 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
TRADEOFF PARAMETERS OF ALTERNATIVE TAKEOFF AND LANDING AIDS
Kennerly H. Digges *In* AGARD Take-off and Landing Jan 1975 18 p refs (For availability see N75-21219 13-01)

The various aids for reducing takeoff and landing distance are discussed The launch aids include rocket assist, catapults and powered lift The landing aids include reversed turbojet thrust, parachutes and wheel brakes. New technology aimed at reducing the weight or increasing the performance of landing aids is indicated The ways in which stopping distance is affected by varitions in parameters such as lift coefficient, drag coefficient, reversed thrust, landing velocity and runway friction coefficient are shown. Author

N75-21226 Royal Aircraft Establishment, Bedford (England)
A TECHNIQUE FOR ANALYSING THE LANDING MANOEUVRE
R. F. A Keating *In* AGARD Take-off and Landing Jan 1975 12 p refs (For availability see N75-21219 13-01)

Studies of steep gradient aviation have highlighted the need to find the underlying piloting strategy of landings. A graphic presentation of landing records is put forward which, it is hoped, will assist in the solution to this problem. By expressing the pilot's longitudinal control activity as equivalent speed and climb rate demands, it is possible to plot simultaneously the aircraft motion and the control strategy against the performance chart as a reference grid. By suitable choice of axis scaling, the aircraft's response to simple control input traces out simple geometric patterns such as circular arcs. Examples are given of flight data, principally of the HS 125 in normal, steep and two segment approaches. Power margins and target speeds are discussed for these examples Author

N75-21227* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
STABILITY AND CONTROL HARMONY IN APPROACH AND LANDING
Seth B Anderson *In* AGARD Take-off and Landing Jan 1975 8 p refs (For availability see N75-21219 13-01)

A review of the factors which affect stability and control harmony in approach and landing is made to obtain a clearer understanding of the proper relationship, the trade-offs involved, and to show how limits in stability and control harmony are established for advanced aircraft Factors which influence stability and control harmony include the longitudinal short period response of the aircraft and the level of several pitch control characteristics including control power, control sensitivity, and control feel. At low stability levels for advanced aircraft, less conventional control techniques such as DLC are needed to improve harmony and some form of stability augmentation must be provided to improve precession of flight path control and reduce pilot work load Author

N75-21228 National Aeronautical Establishment, Ottawa (Ontario)
THE INFLUENCE OF STOL LONGITUDINAL HANDLING QUALITIES OF PILOTS' OPINIONS
K-H Doetsch, Jr. *In* AGARD Take-off and Landing Jan 1975 17 p refs (For availability see N75-21219 13-01) (Contract F33615-71-C-1722)

Consideration is given to some of the factors which distinguish the longitudinal handling qualities of STOL aircraft from those of the CTOL class and to the influence of these differences on pilot's opinions The effects of wind, wind-shear, trim speed, thrust vector inclination, speed coupling, pitch characteristics and of using different control technique options on flight-path control are discussed briefly In flight evaluations of variations in some of these parameters provided a basis for assessing their relative importance to the pilot when he was faced with a demanding instrument approach task Control of pitch proved to be central to the overall flight path control task and the more easily and precisely the pilot could modulate pitch, the more adverse the speed coupling effects he was prepared to tolerate. For the typical unaugmented stability characteristics of the STOL class of aircraft exhibiting small modal separation, the handling qualities were governed by the overall responses to control and disturbance inputs rather than by the location of individual roots of the characteristic equation. Author

N75-21229 Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost.
LOW-SPEED STABILITY AND CONTROL CHARACTERISTICS OF TRANSPORT AIRCRAFT WITH PARTICULAR REFERENCE TO TAILPLANE DESIGN
E Obert *In* AGARD Take-off and Landing Jan 1975 16 p (For availability see N75-21219 13-01)

For modern transport aircraft generally emphasis is put on operational flexibility. This means among other things that the ability is required to operate at low take-off and landing speeds under a wide range of loading conditions Consequently the operational envelope of the aircraft covers a large range of lift coefficients and C.G positions. The ensuing requirements for the design of horizontal tail surfaces and elevators are difficult to fulfil Some of the low-speed tailplane and elevator problems are considered Particular reference is made to the possibility of tailplane stall. Some related experience obtained in the design and flight testing of the Fokker-VFW F-27 and F-28 is discussed Author

N75-21230 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany).
SOME LOW SPEED ASPECTS OF THE TWIN-ENGINE SHORT HAUL AIRCRAFT VFW 614
Hartmut Grlem, Juergen Barche, Hans J. Beisenherz, and Guenther Krenz *In* AGARD Take-off and Landing Jan. 1975 19 p refs (For availability see N75-21219 13-01)

The flight characteristics of the VFW 614, short haul aircraft, are discussed. The low speed aspects of the aircraft are analyzed with respect to: (1) wing stall aerodynamics, (2) tail stall aerodynamics, (3) longitudinal control, and (4) lateral/directional control. The aircraft design criteria are identified. The dimensions and configurations of the aircraft controls are tabulated Flight test results are summarized. Author

N75-21231 British Aircraft Corp., Weybridge (England) Commercial Aircraft Div.
DIRECT LIFT CONTROL APPLICATIONS TO TRANSPORT AIRCRAFT: A UK VIEWPOINT
M. R. Smith *In* AGARD Take-off and Landing Jan. 1975 10 p refs (For availability see N75-21219 13-01)

The longitudinal controllability of large conventional transport aircraft during the approach and landing flight phases, and of conventional high lift 'STOL' aircraft during short landings, is discussed. The advantage of a direct lift control system (DLC) is indicated, and a practical design, using wing spoilers, is described, with its disadvantages. Theoretical and flight simulator investigations on the VC.10 aircraft, and the BAC 1-11 aircraft are described, together with investigations of similar systems for improving the automatic landing of current British jet aircraft. Some recent investigations on a DLC application to a STOL aircraft are noted It is concluded that DLC applications can improve controllability and performance for most transport aircraft. A more detailed study is required for each application before its true value can be assessed, even for large transport aircraft Application of DLC to conventional lift STOL aircraft looks attractive for achieving satisfactory flare performance Author

N75-21232 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
INVESTIGATIONS ON DIRECT FORCE CONTROL FOR CCV AIRCRAFT DURING APPROACH AND LANDING

Wolfgang J Kubbat *In* AGARD Take-off and Landing Jan 1975 11 p (For availability see N75-21219 13-01)

The aerodynamic characteristics of control configured vehicles (CCV) with direct force controls (DFC) are discussed The following aspects are considered: (1) the influence of the controls on the natural stability, (2) the influence of DFC on the controllability of the aircraft, (3) the integration of the DFC with the control system in CCV designs, (4) the behavior of CCV aircraft with DFC during approach and landing, and (5) the relationship of the results presented in the basic CCV concept Author

N75-21233 Yingling (George L.), Dayton, Ohio
GUIDANCE PHILOSOPHY FOR MILITARY INSTRUMENT LANDING
George L. Yingling *In* AGARD Take-off and Landing Jan. 1975 13 p refs (For availability see N75-21219 13-01)

Instrument landing guidance philosophy for military aircraft is affected by the type of operation, the nature of the environment, the kind of aircraft involved and system dynamics considerations. Guidance philosophy and requirements are inseparable from control dynamics and tradeoffs exist between the two in arriving at an optimum solution for particular cases. In some countries, compatibility and interoperability with the civil system is considered important if not essential. The National Microwave Landing System program in the U.S.A. is of great interest internationally, and the U.S.A. Department of Defense is supporting, at present, the goal of a common civil/military system. Representative unclassified operational requirements are reviewed as a lead to discussing the various factors having an impact on choice of guidance philosophy. The single most important consideration is the choice of technique to overcome landing guidance system multipath effects. The choice of technique must satisfy the many system dynamic considerations and present field test programs must provide clear and valid engineering data upon which to base a decision. A system solution to a hypothetical but representative military situation is presented for discussion purposes. In addition a requirement for an all-airborne, self-contained landing system is discussed. Author

N75-21234 Royal Aircraft Establishment, Bedford (England).
THE IMPROVEMENT OF VISUAL AIDS FOR APPROACH AND LANDING
A. J. Smith and D. Johnson *In* AGARD Take-off and Landing Jan. 1975 16 p refs (For availability see N75-21219 13-01)

The effect of fog on the operational capability of runway lights is discussed. A study on the variations of fog gradients with altitude is reported. Improvements in approach and runway lighting to overcome the attenuation caused by fog are described. The characteristics of a precision approach path indicator for steep gradient and two-segment approaches are analyzed. The author states that landings made using the improved equipment have been achieved with a touchdown scatter that is much smaller than is normally achieved. Author

N75-21235 National Aerospace Lab., Amsterdam (Netherlands).
FLIGHT TESTS WITH A SIMPLE HEAD-UP DISPLAY USED AS A VISUAL APPROACH AID
G. L. Lamers *In* AGARD Take-off and Landing Jan. 1975 11 p refs (For availability see N75-21219 13-01)

A simple head-up display (HUD), giving only glide path information with a depressed horizon bar, has been tested as an approach aid in visual flight conditions. An important improvement was observed in the accuracy of the glide path performance when approaches with the use of a HUD are compared with visual approaches without an approach aid. Using the HUD decreased the standard deviations of height by a factor of 2 to 4 depending on distance from the runway. From this limited series of tests no significant differences in other flight parameters could be demonstrated. The subject pilots indicated a preference for use of the HUD during visual approaches, especially in night conditions. Author

N75-21236 Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France)
ALL-WEATHER LANDING SYSTEM FOR MERCURY [LE SYSTEME D'ATTERRISSAGE TOUS TEMPS DU MERCURE]
Armand Pile *In* AGARD Take-off and Landing Jan 1975 11 p In FRENCH (For availability see N75-21219 13-01)

Principle characteristics of the AIR-INTER version of an all-weather landing system with collimators for Mercury are outlined Transl. by E.H.W.

N75-21237 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
REQUIRED PILOT CUES AND DISPLAYS FOR TAKEOFF AND LANDING
Jean-Claude Wanner *In* AGARD Take-off and Landing Jan 1975 14 p In FRENCH; ENGLISH summary (For availability see N75-21219 13-01)

A model of pilot behavior during the takeoff and landing phases of flight was constructed. The model was used to determine the necessary cues and in turn the parameters which have to be displayed in order to minimize the pilot work load and improve flight safety. A future cockpit display was designed, based on the display parameters. The main part of the system is a head-up display presenting the ground track of the air velocity vector and the total climb angle With these two parameters the pilot can directly control the airpath, knowing exactly the necessary rating of the engines and observing a correct safety margin for the angle of attack. Author

N75-21238 Ministry of Transport, Ottawa (Ontario).
SOME DHC-6 TWIN OTTER APPROACH AND LANDING EXPERIENCE IN A STOL SYSTEM
Richard P. Bentham *In* AGARD Take-off and Landing Jan. 1975 11 p (For availability see N75-21219 13-01)

The Canadian Government's decision to introduce a STOL demonstration service revealed a need for practical data and flight experience to assist in aircraft approval and development of safe operational procedures. From 1971 to 1973, a series of flight tests concerned with the steep approach and landing task were carried out, initially in a DHC-6-100 Twin Otter and later in a DHC-6-300S. Approach angles of 6 deg, 7 deg, and 8 deg were assessed in terms of pilot work load and aircraft touchdown and landing distances. Other relevant factors peculiar to the steep approach and landing task were investigated including transition from en-route guidance to approach guidance, crew co-ordination, night operation, missed approach and engine out missed approach, and approach turbulence and wind shear. Community noise sensitivity was closely monitored. The flight test program resulted in some modifications to the production aircraft, the development of approach and landing operating procedures and the definition of some potential problem areas. Author

N75-21239 Air Force Flight Test Center, Edwards AFB, Calif.
LO'V POWER APPROACH
B. Lyle Schofield *In* AGARD Take-off and Landing Jan. 1975 11 p refs (For availability see N75-21219 13-01)

Discussions are presented on current final approach-to-landing procedures along with the relationship of conventional approach speeds to the lift to drag (L/D) relationships of aircraft. The characteristics of L/D relationships are discussed in view the landing approach maneuver, identifying the potential advantages of operating on the front side of the L/D curve. Flight experience of low L/D, idle power approaches using the front side of the L/D curve are reviewed in light of the piloting task. The velocity convergence relationship for operating on the front side of the L/D curve are presented and the convergent characteristics for both transport and fighter aircraft are explored. Front side approach and landing performance for the KC-135A and T-38A aircraft are presented. Convair 990 touchdown dispersions from low L/D, idle approaches are presented. Other significant advantages of the low power, front side L/D landing approach are enumerated. Author

N75-21240 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
STEEP APPROACH FLIGHT TEST RESULTS OF A BUSINESS-TYPE AIRCRAFT WITH DIRECT LIFT CONTROL

P G Hamel, K K Wilhelm, D H Hanke, and H H Lange *In* AGARD Take-off and Landing Jan. 1975 19 p refs (For availability see N75-21219 13-01)

The trends in aircraft approach and landing procedures are such that increasingly noise abatement constraints impact on vehicle flying (handling) qualities. A ground-based flight simulator program and concurrently a flight test program were conducted using a MBB HFB-320 Hansa Jet airplane which was retrofitted with an analogue fly-by-wire flap and thrust control system. The direct lift control system was used for alleviating handling qualities problems during steep noise-abatement landing approaches. A variable direct lift control system was made feasible for optimization purposes by changing the gearing ratio of the electric flap-elevator interconnect. Facilitation in pilot's workload and improvements in flight path control were analyzed by statistical methods. Experiences gained by flight test results and noise measurements show that routine 2-segment noise-abatement approach paths can be introduced successfully when adequate path guidance, quick-response flight path corrections and minimum throttle activity are possible. Author

N75-21241 Centre d'Essais en Vol, Bretigny-sur-Orge (France).
MODERN MEANS OF TRAJECTOGRAPHY [MOYENS MODERNES DE TRAJECTOGRAPHIE]
Alain Tart *In* AGARD Take-off and Landing Jan. 1975 15 p In FRENCH (For availability see N75-21219 13-01)

Various equipment and systems developed and utilized for take-off and landing trajectography of modern aircraft are examined. The STRADA, LIDAR, and inertial navigation systems are covered; systems are designed to measure trajectories accurately and rapidly without error. Transl. by E.H.W.

N75-29997# Advisory Group for Aerospace Research and Development, Paris (France).
METHODS FOR AIRCRAFT STATE AND PARAMETER IDENTIFICATION
May 1975 440 p refs Meeting held at Hampton, Va., 6-8 Nov 1974
(AGARD-CR-172) Avail: NTIS HC $11.25

Papers which discuss and compare results obtained with different parameter identification techniques applied to specific fighter aircraft at high angles of attack, subsonic, and supersonic transports, VTOL and STOL aircraft, and helicopters are presented. Special problems areas such as systems modelling with high internally generated fluctuations, aircraft state estimation in non-steady flight, and parameter identification for nonlinear aerodynamic regimes are covered. For individual titles, see N75-29998 through N75-30026.

N75-29998 Royal Aircraft Establishment, Bedford (England).
MODELLING OF SYSTEMS WITH A HIGH LEVEL OF INTERNAL FLUCTUATIONS
J. G. Jones *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 18 p refs (For availability see N75-29997 21-01)

The problem of modelling the structure of systems with a high level of internally generated fluctuations is discussed and problems in parameter identification are reviewed. The systems considered typically have two types of behavior, determined by the magnitude of a controlling parameter which influences stability. For a finite range of parameter values the system is stable and its structure may be described by a deterministic set of differential equations. If not subjected to external disturbances the system will achieve a state of equilibrium. At some 'critical' value of the parameter, however, the system becomes unstable and beyond this boundary the system no longer achieves a state of equilibrium but may exist (as a result of nonlinearities) in a steady state typified by continuous fluctuations. This state may either be described as a regular limit-cycle type of oscillation or may be essentially random in nature. Practical examples include aircraft buffeting and wing-rocking, forms of fluctuating motion which occur respectively in structural and rigid-body modes. In these examples aircraft incidence may be regarded as the controlling parameter and the fluctuating motion is associated with the existence of extensive areas of separated flow at high incidence. A structure which falls into the type considered, is the standard human-pilot model in which the internal fluctuations are represented by a 'remnant'. An example is discussed which illustrates problems that can arise in the identification of this type of system when operating as part of a closed loop. Author

N75-29999 Calspan Corp., Buffalo, N.Y.
IDENTIFICATION OF NONLINEAR AERODYNAMIC STABILITY AND CONTROL PARAMETERS AT HIGH ANGLE OF ATTACK
B. J. Eulrich and E. G. Rynaski *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 15 p refs (For availability see N75-29997 21-01)
(Contract F33615-72-C-1248)

A procedure is described for the estimation of the nonlinear aerodynamic stability and control coefficients at high aircraft angles of attack. It is based on a nonlinear, iterated Kalman filter/fixed-point smoother identification algorithm and a least squares equation error method. Key ingredients for successful identification are the mathematical model, instrumentation system, control inputs, and the identification algorithm. The major emphasis is placed on the use of the identification procedure in analyzing high angle of attack flight data. Specifically, model form and initial estimates are established from wind tunnel data using series expansions to represent the nondimensional force and moment coefficients for selected ranges of angle of attack. This high dimensional representation is reduced by: (1) preprocessing the flight data using the instrumentation system model and the six-degree-of-freedom aircraft kinematic equations to perform optimal state estimation and hence decrease the effects of instrumentation errors; and (2) separating the six equations of motion into two separate four-degree-of-freedom systems; one for extracting the longitudinal coefficients and the other for the lateral-directional coefficients. Specific problems associated with the identification procedure at high angles of attack and parameter identifiability problems caused by poorly conditioned flight data are reviewed. Selection of the coordinate system for the aircraft model, the determination of the initial covariance estimates, and the measurement and process noise statistics required to use the iterated Kalman technique are discussed. Author

N75-30000 Societe Nationale Industrielle Aerospatiale, Toulouse (France).
METHODS USED FOR OPTIMIZING THE SIMULATION OF CONCORDE SST USING FLIGHT TEST RESULTS
Jacques Tardy *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 10 p (For availability see N75-29997 21-01)

The elaborate calculation means provided by a simulator were used in the design of CONCORDE. Different simulators of more and more sophisticated design, were installed from a fixed base analog simulator to the present simulator which is described. This simulator is used for various design purposes: development studies for the aircraft and its systems, handling qualities, flying controls, various piloting aids, failure research; flight test preparation and crew training, crew work load studies; studies for introducing CONCORDE into air traffic in liaison with EUROCONTROL, and preparation for aircraft certification, examination of requirements and participation in certification for the most critical conditions to be tested in flight, testing very low probability failures or investigations in the extreme regulatory atmospheric conditions. Author

N75-30001* National Aeronautics and Space Administration Langley Research Center, Langley Station, Va.
APPLICATION OF A NEW CRITERION FOR MODELING SYSTEMS

Lawrence W. Taylor, Jr. *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 9 p refs (For availability see N75-29997 21-01)
CSCL 12B

A new criterion is proposed for modeling systems which promises to be useful in deciding how complex a model should be. The criterion is based on the expected model response error instead of the error in fitting the data used for estimating the model parameters. The new criterion also does not require withholding data to be used exclusively for testing. There remains, however, the difficulty of testing a large number of candidate models that correspond to the combinations of terms used in the dynamic equations. A computational approach is suggested which greatly reduces the computations required in searching for the best model. In the suggested approach the gradient of the response with respect to the model coefficients is held fixed and numerous combinations of terms are assessed. After determining the most promising candidate model, the gradient is updated and the process is repeated. This procedure gives greater assurance that the best model is selected and does not rely on the analyst's judgement. Author

N75-30002* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
A MONTE CARLO ANALYSIS OF THE EFFECTS OF INSTRUMENTATION ERRORS ON AIRCRAFT PARAMETER IDENTIFICATION
Wayne H. Bryant and Ward F. Hodge *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 19 p refs (For availability see N75-29997 21-01)
CSCL 01C

An output error estimation algorithm was used to evaluate the effects of both static and dynamic instrumentation errors on the estimation of aircraft stability and control parameters. A Monte Carlo analysis, using simulated cruise flight data, was performed for a high performance military aircraft, a large commercial transport, and a small general-aviation aircraft. The effects of variations in the information content of the flight data, resulting from two different choices of control input maneuvers, were also determined. The results indicate that unmodeled instrumentation errors can cause inaccuracies in the estimated parameters which are comparable to their nominal values. Control input errors and angular accelerometer lags were found to be most significant of the instrumentation errors evaluated, and the perturbations they produce are much larger than those arising from the combined effects of static errors and white noise in the output response measurements. Author

N75-30003 Technische Hogeschool, Delft (Netherlands)
ADVANCED FLIGHT TEST INSTRUMENTATION: DESIGN AND CALIBRATION
R. J. A. W. Hosman *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 17 p refs (For availability see N75-29997 21-01)

A series of flight tests with a Hawker Hunter Mk.7 aircraft was performed to determine the performance as well as stability and control characteristics. The instrumentation system used in these tests is described. Major topics discussed include: the choice of the specifications for the transducers as related to the desired accuracy of the characteristics of the aircraft to be determined; the methods applied to meet these specifications, especially for the pressure transducers; the calibration program to determine the characteristics of the transducers in the statistical format, and to apply modern system theory to the analysis of the flight measurements. Author

N75-30004* National Aeronautics and Space Administration Langley Research Center, Langley Station, Va.
A COMPLEMENTARY FILTERING TECHNIQUE FOR DERIVING AIRCRAFT VELOCITY AND POSITION INFORMATION
Frank R. Niessen *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 16 p refs (For availability see N75-29997 21-01)
CSCL 01C

An onboard navigation system which employed complementary filtering was developed to provide velocity and position information. The inputs to the mix filter included both acceleration inputs, which provided high-frequency position and velocity information, and radar position inputs, which provided the low-frequency position and velocity information. Onboard aircraft instrumentation, including attitude reference gyros and body-mounted accelerometers, was used to provide the acceleration information. An in-flight comparison of signal quality and accuracy showed good agreement between the complementary filtering system and an aided inertial navigation system. Furthermore, the complementary filtering system was proven to be satisfactory in control and display system applications for both automatic and pilot-in-the-loop instrument approaches and landings. Author

N75-30005 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany)
SENSORS AND FILTERING TECHNIQUES FOR FLIGHT TESTING THE VAK 191 AND VFW 614 AIRCRAFT
Werner E. Seibold *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 14 p (For availability see N75-29997 21-01)

The flow of the flight test data of the VFW 614 (VAK 191B) Aircraft from the sensor through the data acquisition, selection, and preprocessing process is described. An overview of the sensors included in the VFW 614 is given. Two important sensors for takeoff and landing performance are described. The data smoothing and filtering techniques are discussed. Special emphasis is given to a powerful digital filter, the SI or Riedel filter. Author

N75-30006 National Aerospace Lab., Amsterdam (Netherlands)
DESIGN AND EVALUATION OF A SYMMETRIC FLIGHT-TEST MANOEUVRE FOR THE ESTIMATION OF LONGITUDINAL PERFORMANCE AND STABILITY AND CONTROL CHARACTERISTICS
H. W. Kleingeld *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 6 p refs (For availability see N75-29997 21-01)

Longitudinal performance and stability and control data are derived from measurements in one flight test maneuver. The maneuver is comprised of quasi-steady accelerating parts and nonsteady oscillating parts. A moving base simulator is used to determine the problems which accompany the manual application of the required elevator control input and to teach the pilot to generate the signal without feedback. Results of this evaluation program are given and compared with corresponding results of the actual flight tests. Author

N75-30007 Dornier-Werke G.m.b.H., Friedrichshafen (West Germany)
DETERMINATION OF STABILITY DERIVATIVES FROM FLIGHT TEST RESULTS COMPARISON OF FIVE ANALYTICAL TECHNIQUES
Horst Wuennenberg, Heinz Friedrich, Ulrich VonMeier, and Hans-Joachim Munser *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 12 p refs (For availability see N75-29997 21-01)

Analytical techniques in stability derivatives estimation are compared. The test aircraft, a G 91-T3, was equipped with a sophisticated instrumentation and data acquisition system. The analytical techniques, manual evaluation of special flight maneuvers, time vector method, forced oscillation method, analog matching, and regression analysis are compared in relation to the amount of time and equipment for the flight testing, complication of the data reduction, and the quality of the results. The accuracy of the data acquisition is the most important problem. Therefore an accurate check of all test data has to be performed before sophisticated evaluation programs are used. It is summarized that several measuring and evaluation techniques should be used in parallel. Author

N75-30008 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
FIVE IDENTIFICATION METHODS APPLIED TO FLIGHT TEST DATA
Jean-Pierre Chequin *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 8 p refs (For availability see N75-29997 21-01)

The parameter of linear multivariable systems using input and output measurements is determined. It is assumed that the physical system, which is to be investigated, can be described by a set of linear differential equations with constant coefficients. These estimations are to be applied to the derivation of active control parameters. Tests of well known methods, such as least squares, modulating functions, conjugate gradients and analog matching, are developed. Some results are proposed to be used as support for the comparison of the comparison of the different methods. Author

N75-30009* Harvard Univ., Cambridge, Mass.
STATUS OF INPUT DESIGN FOR AIRCRAFT PARAMETER IDENTIFICATION
R. K. Mehra and N. K. Eupta (Systems Control, Inc.) *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 21 p refs (For availability see N75-29997 21-01)
(Contracts NAS4-2068; N00014-67-A-0298-0006)
CSCL 01C

Results are presented on the design of aircraft inputs (i.e. elevator, rudder and aeleron deflection time histories) to identify aircraft stability and control derivatives from flight test data. The problem is first reduced to an optimization problem with differential and integral constraints. The criteria used are either expressed in terms of the Cramer-Rao lower bound on the covariance matrix of the parameter estimates or in terms of the maximum prediction error variance. Both time-domain longitudinal and lateral dynamics of C-8 and Jet Star aircrafts and comparison with doublet type inputs are made Author

N75-30010 Calspan Corp., Buffalo, N.Y. Flight Research Dept.
INPUT DESIGN FOR AIRCRAFT PARAMETER IDENTIFICATION: USING TIME-OPTIMAL CONTROL FORMULATION

Robert T. N. Chen *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 15 p refs (For availability see N75-29997 21-01)
(Contract N00019-73-C-0504)

A new formulation and a practical and useful solution to the input design for identification of aircraft stability and control parameters is presented. Necessary conditions and the structure of the optimal control input are discussed. By using Walsh functions and calculating the Cramer-Rao lower bounds recursively, a practical and useful design procedure is then presented. Application of the new approach are then made to the design of flight test inputs for identification of stability and control parameters of several types of aircraft Author

N75-30011 Royal Aircraft Establishment, Farnborough (England)
DETERMINATION OF AERODYNAMIC DERIVATIVES FROM TRANSIENT RESPONSES IN MANOEUVRING FLIGHT

A. Jean Ross *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 10 p refs (For availability see N75-29997 21-01)

Computer programs using optimization techniques to obtain aerodynamic derivatives from flight records are briefly described. Results pertaining to aircraft flying at high angles of attack are presented. J.M.S

N75-30012 Naval Air Test Center, Patuxent River, Md. Flight Test Div.
ADVANCEMENT IN PARAMENTER IDENTIFICATION AND AIRCRAFT FLIGHT TESTING
Roger A. Burton *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 16 p refs (For availability see N75-29997 21-01)

Results are presented from a program to develop parameter identification technology with specific emphasis placed on studies conducted in parameter identifiability and (optimal) control inputs for parameter estimation. Navy applications for parameter identification technology are discussed with specific areas in aircraft stability and control testing outlined. Specific criteria required for defining optimal control inputs and establishing parameter identifiability are discussed. Parameter identification results from the analysis of flight test data are presented which establish the need for considering input design in planning tests for extracting aerodynamic coefficients from flight test data. Parameter identifiability results for specific control inputs used are presented. In cases where identifiability problems are shown to exist the use of a rank deficient solution to improve parameter identifiability is demonstrated. Author

N75-30013* National Aeronautics and Space Administration. Flight Research Center, Edwards, Calif.
PRACTICAL ASPECTS OF USING A MAXIMUM LIKELIHOOD ESTIMATOR
Kenneth W. Iliff and Richard E. Maine *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 15 p refs (For availability see N75-29997 21-01)
CSCL 01C

The application of a maximum likelihood estimator to flight data is discussed and procedures to facilitate routine analysis of a large amount of flight data are proposed. Flight data were used to demonstrate the proposed procedures. Modeling considerations are discussed for the system to be identified, including linear aerodynamics, instrumentation, and data time shifts, and aerodynamic biases for the specific types of maneuvers to be analyzed. Data editing to eliminate common data acquisition problems, and a method of identifying other problems are considered. The need for careful selection of the maneuver or portions of the maneuver to be analyzed is pointed out. Uncertainty levels (analogous to Cramer-Rao bounds) are discussed as a way of recognizing significant new information. Author

N75-30014 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugmechanik.
DETERMINATION OF AIRCRAFT DERIVATIVES BY AUTOMATIC PARAMETER ADJUSTMENT AND FREQUENCY RESPONSE METHODS
M. Marchand and R. Koehler *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 18 p refs (For availability see N75-29997 21-01)

Experiences are reviewed in the estimation of aircraft parameters by means of three identification methods: frequency response, maximum-likelihood, and model with automatic parameter adjustment. Results using flight test data from the Do-27 and HFB-320 aircraft are presented. The effects of including nonlinear terms and turbulence in the model are also discussed. The model with the automatic parameter adjustment method was used for studying the problems of derivative identification for rotorcraft type vehicles. Preliminary results obtained when evaluating simulated Sikorsky S-61 flight data with various input signals are given. Some aspects of designing input signals for flight tests are discussed, system parameters and are easily flown by the pilot Author

N75-30015 Air Force Flight Test Center, Edwards AFB, Calif.
A COMPARISON AND EVALUATION OF TWO METHODS OF EXTRACTING STABILITY DERIVATIVES FROM FLIGHT TEST DATA
Paul W. Kurten *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 26 p refs (For availability see N75-29997 21-01)

Two methods for extracting stability derivatives from flight data are compared. A modified Newton-Raphson minimization technique and a digital-analog (hybrid) matching technique were used to analyze the same data maneuvers obtained from two aircraft. About 55 maneuvers of an F-111E aircraft were analyzed over a Mach 0.3 to 2.0 and an angle of attack range of 3 to 19 degrees. About 15 maneuvers were analyzed for the X-24A lifting body at Mach numbers of 0.8 and 0.9 and an angle of attack range of 4 to 13 degrees. Stability derivatives were extracted from these maneuvers, and the results from the two techniques along with wind tunnel results were compared. The hybrid matching mathematical model contained complete five-degree-of-freedom equations (no velocity derivatives) with variable dynamic pressure, whereas the Newton-Raphson model used uncoupled, three-degree-of-freedom equations with constant dynamic pressure. Both techniques were found to be capable of giving accurate results, but required a fairly extensive knowledge of the method being used. The Newton-Raphson technique tends to be less time consuming, and is suited for processing large quantities of data maneuvers. Hybrid matching is well suited for programs in which a limited amount of data is processed for each flight. Author

N75-30016 Technische Hogeschool, Delft (Netherlands).
ESTIMATION OF THE AIRCRAFT STATE IN NON-STEADY FLIGHT
J. A. Mulder *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 21 p refs (For availability see N75-29997 21-01)

Kalman filtering and smoothing and maximum likelihood estimation techniques were applied to the problem of estimating the aircraft state in nonsteady flight from onboard noisy inertial and barometric measurements. Applied to actual flight test data, the estimation schemes yielded similar results. Author

N75-30017 Dornier-Werke G m b H., Friedrichshafen (West Germany).
DETERMINATION OF STABILITY DERIVATIVES FROM FLIGHT TEST RESULTS BY MEANS OF THE REGRESSION ANALYSIS
Heniz Friedrich *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 8 p refs (For availability see N75-29997 21-01)

Some fundamental remarks about regression analysis are made, the method is described, and some test results with simulated data are given. The experiences with regression analysis gained from flight tests with the aircrafts Dornier Do 31 and Fiat G91-T3 are discussed in detail. The possibilities of the method were studied, and improvements by using a Kalman filter are considered. For each equation of motion, an example is represented. Author

N75-30018 Systems Control, Inc., Palo Alto, Calif.
MODEL STRUCTURE DETERMINATION AND PARAMETER IDENTIFICATION FOR NONLINEAR AERODYNAMIC FLIGHT REGIMES
W. Earl Hall, Jr., Narendra K. Gupta, and James S. Tyler, Jr. *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 21 p refs (For availability see N75-29997 21-01) (Contract N00014-72-C-0328)

The identification of nonlinear stall/spin regime air dynamic forces and moments is discussed, along with applications to simulated and flight test response data. For this development, a two-step method is presented. The first step is the application of an algorithm which determines the order and coefficients of polynomial expansions which determines the order and coefficients of polynomial expansions which determines the order and coefficients of polynomial expansions of the nonlinear aerodynamic forces and moments which characterize the stall/post-stall flight regime. The second step is the use of a nonlinear six degree-of freedom maximum likelihood algorithm which accurately estimates the values of the polynomial coefficients. This method was applied to simulated and flight test data for a twin engine swept wing fighter aircraft. Suggested approaches to general nonlinear flight regime identification are given. Author

N75-30019* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
IMPORTANCE OF HELICOPTER DYNAMICS TO THE MATHEMATICAL MODEL OF THE HELICOPTER
William F. White, Jr. *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 12 p refs Prepared by Army Air Mobility Res. and Develop. Lab., Hampton, Va. (For availability see N75-29997 21-01)
CSCL 01C

A mathematical model of the helicopter requires appropriate representation of the constituent elements of rotor dynamics. General-purpose programs that model a variety of configurations for a broad range of operating conditions result in varying and incompatible levels of sophistication. Analysis of specific dynamic problems facilitates the identification of configuration parameters which determine system behavior. For the present analysis, the nonlinear equations of a torsionally rigid hingeless rotor are linearized about an equilibrium condition to determine flap-lag stability characteristics in hover. A collocation method was used to obtain the coupled natural frequencies and modes. These modes allow exact treatment of the effect of elastic coupling which more than compensates for the destabilizing inertial coupling. The sensitivity of damping to the number of modes was found to be small, and reasonable accuracy was obtained the first flapwise and edgewise coupled modes. The range of destabilizing precone was found to be small. Author

N75-30020 National Aeronautical Establishment, Ottawa (Ontario). Flight Research Lab.
ESTIMATES OF THE STABILITY DERIVATIVES OF A HELICOPTER AND A V/STOL AIRCRAFT FROM FLIGHT DATA
D. G. Gould and W. S. Hindson *In* AGARD Methods for Aircraft State and Parameter Identification Jul. 1957 9 p refs (For availability see N75-29997 21-01)

Stability derivatives for the Bell 205 helicopter were derived from flight data using a least squares quasi-linearization technique. The aircraft model, which included a first order representation of rotor response characteristics, was based on fundamental parameters descriptive of the particular design. A conglomerate analysis procedure estimates based on data from several similar maneuvers was used to increase the confidence in the results observed. Data from CL-84 V/STOL aircraft were also analyzed, indicating the validity of certain a priori longitudinal stability derivatives for the aircraft, and yielding estimates of others. The results indicate the need to use a more elaborate modeling technique, (such as was used for the Bell 205) which takes into account the particular complexities of the aircraft. Author

N75-30021* United Aircraft Corp., Stratford, Conn. Sikorsky Aircraft Div.
ROTORCRAFT DERIVATIVE IDENTIFICATION FROM ANALYTICAL MODELS AND FLIGHT TEST DATA
John A. Molusis *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 31 p refs Sponsored in part by NASA and USAAMRDL (For availability see N75-29997 21-01)
CSCL 01C

A general procedure is presented for systematic development of rotorcraft models for use in systems identification, which includes fuselage and rotor degrees of freedom (DOF). Formulations for rigid blade flap and lag as well as the normal mode representation of an elastic blade are developed for hingeless and articulated rotor systems. The method of multiblade coordinates is used to obtain linear constant coefficient state variable models of various levels of approximation. Two of the approximate models, a 6 DOF, are identified from a nonlinear articulated helicopter computer simulation. The results demonstrate the accuracy attainable for each model. Advanced results outline the status of rotorcraft modeling and systems identification and indicate areas that require further investigation. Author

N75-30022* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
ROTOR SYSTEMS RESEARCH AIRCRAFT (RSRA) REQUIREMENTS FOR, AND CONTRIBUTIONS TO, ROTORCRAFT STATE ESTIMATION AND PARAMETER IDENYIFICATION
Gregory W. Condon *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 18 p refs Prepared by Army Air Mobility Res. and Develop. Lab., Hampton, Va. (For availability see N75-29997 21-01)
CSCL 01C

Rotor System Research Aircraft (RSRA) is designed to provide the capabilities necessary for the effective and efficient in-flight test and verification of promising rotor concepts and supporting technology developments. The RSRA requirements for, and possible contributions to, rotorcraft state estimation and parameter identification technology are discussed. Author

N75-30023 Bell Helicopter Co., Fort Worth, Tex.
COMMENTS ON COMPUTATION OF AIRCRAFT FLIGHT CHARACTERISTICS
C. L. Livingston *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 8 p (For availability see N75-29997 21-01)

A digital computer program (C81) used to compute performance, dynamics, and loads of a wide variety of aircraft is described. Some of the configurations which have been simulated on C81 are depicted. Author

N75-30024 Calspan Corp., Buffalo, N.Y. Flight Research Dept.
THE EFFICIENT APPLICATION OF DIGITAL IDENTIFICATION TECHNIQUES TO FLIGHT DATA FROM A VARIABLE STABILITY V/STOL AIRCRAFT
J. Victor Lebacqz *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 13 p refs (For availability see N75-29997 21-01)
(Contracts N00019-69-C-0534, N00019-72-C-0044, N00019-72-C-0417, N00019-73-C-0504)

A prerequisite in the use of response-feedback variable stability aircraft to obtain flying qualities data is an accurate method for estimating stability and control parameters from flight data. It is necessary, however, that such methods be efficient and cost effective to minimize the effort and expense spent performing the estimation. The application of a digital identification technique X-22A V/STOL research aircraft is discussed. Emphasis is placed on practical aspects of identifying efficiently data covering a wide range of dynamic characteristics, particular attention is paid to the elimination of adjustments in the technique for each data run and the use of particular pilot control inputs to maximize identifiability. Results are presented for a variety of simulated dynamics. Author

N75-30025* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

PARAMETER ESTIMATION OF POWERED-LIFT STOL AIRCRAFT CHARACTERISTICS INCLUDING TURBULENCE AND GROUND EFFECTS

Rodney C. Wingrove *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 10 p refs (For availability see N75-29997 21-01)

CSCL 01C

Longitudinal aerodynamic coefficients are estimated from data recorded during flight tests of a powered-lift STOL aircraft. A comparison is made between the coefficient values determined by the regression and quasilinearization identification techniques from records taken during elevator pulse maneuvers. The results show that for these tests the regression method provides less scatter in coefficient estimates and provides better correlation with the predicted values. Special techniques are developed which allow identification of the coefficients from records taken during landing maneuvers in which the aircraft encounters turbulence while flying in ground effect. Flight test results are presented to illustrate the effects of air turbulence and ground proximity on the estimated coefficient values. Author

N75-30026 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.

ESTIMATION OF ELASTIC AIRCRAFT AERODYNAMIC PARAMETERS

Robert C. Schwanz and William R. Wells *In* AGARD Methods for Aircraft State and Parameter Identification May 1975 10 p refs (For availability see N75-29997 21-01)

The importance of including aeroelasticity in aircraft parameter estimation is discussed using the B52E and C-5A aircraft as examples. A parameter estimation method, employing the modal truncation dynamics math model and the maximum likelihood estimation algorithm, is selected to illustrate the computational difficulties that must be solved. A combined in-house and contractual research program is then outlined that addresses these anticipated problem areas. The aircraft selected for the initial application of the methods is the B52E that was flown in the Control Configured Vehicle (CCV) research program of the AF Flight Dynamics Laboratory. Author

N75-30027# Advisory Group for Aeronautical Research and Development, Paris (France).

IMPACT OF ACTIVE CONTROL TECHNOLOGY ON AIRPLANE DESIGN

Jun 1975 318 p refs In ENGLISH and partly in FRENCH Presented at a Joint Symp of the Flight Mech Panel and Guidance and Control Panel of AGARD, Paris, 14-17 Oct 1974 (AGARD-CP-157) Avail: NTIS HC $9.25

The papers are reported which were presented at sessions on active control technology in advanced airplane design, analysis and simulation programs, flight test programs, advanced flight control systems, and current operational systems. They cover a wide range of activities, from advanced research to systems in operation on the C-5A and Boeing 747 aircraft. For individual titles, see N75-30028 through N75-30051.

N75-30028 Societe Nationale Industrielle Aerospatiale, Toulouse (France).

CCV PHILOSOPHY: SEMANTICS AND UNCERTAINITY. THE CONCEPT OF AIRCRAFT REVOLUTION BY PROGRESS IN THE FLIGHT CONTROL SYSTEM [CCV PHILOSOPHIE: SEMANTIQUE ET INCERTITUDES LA CONCEPTION DES AVIONS VA-T-ELLE ETRE BOULEVERSEE PAR LES PROGRES DANS LES SYSTEMES DE COMMANDES DE VOL]

P. Lecomte and M. Bossard *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 14 p refs In FRENCH; ENGLISH summary (For availability see N75-30027 21-01)

The possible definitions are examined of the term control configured vehicle (CCV) and some other associated notions such a autostabilization, flight by wire, etc. The characteristics common to all the so called CCV systems are examined simultaneously, together with the most noteworthy differences encountered. The present possibilities of these systems are reviewed, considering, for each case, the safety objectives, and performance objectives for transport and combat aircraft. Finally, long term prospects are considered. Author

N75-30029 Royal Aircraft Establishment, Bedford (England)

ACTIVE CONTROL AS AN INTEGRAL TOOL IN ADVANCED AIRCRAFT DESIGN

W. J. G. Pinsker *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 12 p refs (For availability see N75-30027 21-01)

The scope of active control in the design and operation of aircraft is broadly reviewed, and the automatic control, stability and control augmentation, artificial static stability, gust alleviation, stall and spin protection and various methods for reducing airframe loads are studied. It is argued that active control should not be treated as a piece-meal solution to isolated design problems but rather refinements will the true potential of these powerful techniques be realized. In particular it is shown that many CCV applications require commensurate improvement in the aerodynamic performance of the control surface. Author

N75-30030* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.

POTENTIAL BENEFITS TO SHORT-HAUL TRANSPORTS THROUGH USE OF ACTIVE CONTROLS

D. William Conner and Glenn O. Thompson (Boeing Co., Wichita, Kans.) *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 10 p refs (For availability see N75-30027 21-01)

The potential applications of active controls are examined for improving the characteristics of transport type aircraft used in short-haul service (1,000-kilometer range capability). The types of aircraft to meet future needs (quiet operation, congestion alleviation, fuel conservation, operating economy, and traveler acceptance) are identified as helicopters for shorter stage lengths and fixed wing aircraft of reduced field-length capability for longer stage lengths. Likely uses for active controls for these aircraft are examined regarding payoffs which can be expected and problems and constraints which must be dealt with. Uses showing significant benefits include augmented stability and control, gust-load alleviation, and ride smoothing. Gust load alleviation is particularly effective for low-wing-loading aircraft employing conventional lift. Ride-smoothing systems are indicated to be the furthest advanced and ready for production commitment for those applications where they can be shown to have payoff. Author

N75-30031 Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany)

TRANSPORT AIRCRAFT WITH RELAXED/NEGATIVE LONGITUDINAL STABILITY: RESULTS OF A DESIGN STUDY

Heinz G. Klug *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 15 p (For availability see N75-30027 21-01)

Application of active longitudinal control on transport aircraft with relaxed/negative longitudinal stability was studied. Using two aircraft of different configuration as baseline designs, versions incorporating active longitudinal control were derived. Configuration changes were studied with varying tail size, and center of gravity position. Based upon the requirement for handling qualities equivalent to the baseline designs, optimum control laws were derived. Controllability and stability were checked by simulating various gust cases. Limits for tail size and cg-position were derived. Wing size was changed where required to hold performance unchanged. Structural and fuel weight changes were calculated and the configuration, within the geometrical and controllability limits, giving the highest payload increase, was selected. Sensitivity of payload benefit to performance specification was checked by parametric variations. It was found that payload benefit depends upon configuration to a high degree. Best payload benefit will be achieved for high wing, T-tail STOL aircraft using large trailing edge flaps. Payload increase may be up to 15% for such aircraft. Author

N75-30032 British Aircraft Corp., Weybridge (England). Commercial Aircraft Div.
IMPACT OF ACTIVE CONTROL TECHNOLOGY ON AIRCRAFT DESIGN
P. R. G. Williams and B. S. Campion. *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 6 p (For availability see N75-30027 21-01)

Use of active control technology on civil transport aircraft is considered, both as regards improvement of a conventional aircraft and as regards development of new configurations to exploit such technology. Significant gains in weight and operating cost may be made by using artificial stability augmentation and load alleviation on a conventional design, though the precise gains depend on the way in which weight savings are exploited. Unconventional means are suggested whereby active control technology might best be exploited on short and long range subsonic aircraft, and also on supersonic aircraft. It appears that the largest gains are likely to be made when new techniques are used in combination rather than singly. Author

N75-30033 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
HORIZONTAL CANARDS FOR TWO-AXIS CCV FIGHTER CONTROL
S. C. Stumpfl and R. A. Whitmoyer. *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 8 p refs (For availability see N75-30027 21-01)

The potential use is described of active horizontal canards in the design of fighter aircraft to provide flight path control along both the longitudinal and directional axes. The results are based on wind tunnel tests conducted on two CCV fighter configurations under the Fighter CCV Program of the USAF Flight Dynamics laboratory. A method for generating direct sideforce using differentially deflected horizontal canards is discussed. The direct lift control capabilities of horizontal canards are also presented. In addition, the use of horizontal canards in implementing the concepts of relaxed static stability and maneuver polar enhancement is described. Finally, the USAF Fighter CCV Program is outlined as it relates to demonstrating the performance improvements achievable through application of advanced control system technology. Author

N75-30034 Hawker Siddeley Aviation Ltd., Brough (England).
ACTIVE CONTROL TECHNOLOGY: A MILITARY AIRCRAFT DESIGNER'S VIEWPOINT
R. Melling. *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 16 p (For availability see N75-30027 21-01)

The most likely gains to be obtained by the application of active control technology to small combat aircraft are considered. There are seen to be considerable attractions, although the most significant benefits may turn out to be orientated towards the improved control and design freedom offered by ACT rather than towards revolutionary shapes or greatly increased efficiency or reduced weight. In the design of the ACS itself, it is considered essential that a mechanical back up is avoided in order to produce a more flexible, efficient and safe system, and to this end a suitably progressive system design philosophy must be developed. Despite some doubts as to the more ambitious claims for ACT, its ultimate adoption is expected for all but the simplest of aircraft. Author

N75-30035 National Aerospace Lab., Amsterdam (Netherlands).
HANDLING QUALITY CRITERIA DEVELOPMENT FOR TRANSPORT AIRCRAFT WITH FLY-BY-WIRE PRIMARY FLIGHT CONTROL SYSTEMS
H. A. Mooij. *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 14 p refs (For availability see N75-30027 21-01)

The introduction of fly-by-wire primary flight control systems in future transport aircraft, in some cases including direct-lift-control, makes it highly desirable to initiate further studies into handling quality criteria for future guidance in system design. The handling quality criteria for such aircraft must be based on parameters which describe the combination of the aircraft and its closed loop flight control system. Approach flight simulation and compensatory tracking, performed on a three degrees of freedom flight simulator as applied to a conceptual jet transport developed around the relaxed static stability concept, is described. The stiffness of the pitch attitude system and the effectiveness of the direct-lift-control-system were varied. The following topics are discussed: required direct-lift-control-effectiveness for an aircraft with a very low value of the normal acceleration sensitivity, required bandwidth of the pitch attitude control system for an aircraft with a value of the normal acceleration sensitivity typical for the present-day jumbo aircraft, pilot opinion on the absence of a stable stick force/(deflection) versus airspeed gradient for pitch-stabilized aircraft, results of compensatory tracking experiments, and evaluation of the applicability of the criterion for the configurations tested. Author

N75-30036 Messerschmitt-Boelkow-Blohm G m b H., Munich (West Germany)
CONTROL OF AN ELASTIC AIRCRAFT USING OPTIMAL CONTROL LAWS
Werner Dressler. *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 11 p (For availability see N75-30027 21-01)

The design of a multivariable control system for gust alleviation is demonstrated. The use of computers for control design, summarized under the name computer aided design is described. The gust control system for gust alleviation is integrated into an overall flight guidance control system. Two control designs, using optimal control laws, are achieved, one with complete and the second with incomplete state measurement. In the model description the elastic behavior of the wing is included as well as the nonsteady aerodynamic lift generation and the dynamic behavior of the actuators. For a STOL-transport aircraft the efficiency of gust alleviation are shown in a flight through turbulent air. The increase of wing lifetime and the corresponding decrease in structure weight by use of a gust alleviation system is calculated. Author

N75-30037 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
CLOSED FORM EXPRESSION OF THE OPTIMAL CONTROL OF A RIGID AIRPLANE TO TURBULENCE
Gabriel Coupry. *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 10 p refs In FRENCH; ENGLISH summary (For availability see N75-30027 21-01)

The flight of military aircraft at high speed, low altitude makes it necessary to use ride control systems to improve comfort, handling qualities and combat ability. The open loop system that is described senses turbulence which is used, after filtering, to act on the controls. Such a system does not change at all the handling qualities of the aircraft. Wiener's theory is used to to derive in closed form the transfer function of the filter used for control. It is shown that this transfer function can be expressed in autoadaptative form, the poles being proportional to the velocity of the aircraft. The influence of parameters like mass, scale of turbulence, is discussed. Author

N75-30038 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. fuer Dynamik der Flugsysteme
APPLICATION OF ADVANCED MODEL-FOLLOWING TECHNIQUES TO THE DESIGN OF FLIGHT CONTROL SYSTEMS FOR CONTROL CONFIGURED VEHICLES
Gerd Hirzinger. *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 15 p refs (For availability see N75-30027 21-01)

After a review of optimal control, the model-following concept is applied for approaching a desired tracking behavior, especially concerning the airplane's response to a flight path angle command, in a systematic way. However, it turns out that the disturbance behavior of the controlled system, represented by the airplane's response to an initial deviation in the flight path angle, is unsatisfactory. Therefore a new concept combining model following and partial state vector feedback is applied for designing disturbance behavior and tracking behavior separately, in each of both cases achieving a good compromise between the desired system trajectory and limited control action. It appears that the control system thus designed is very insensitive to variations in the most critical parameter, that is the location of the center of gravity. Author

N75-30039 McDonnell Aircraft Co., St. Louis, Mo.
SURVIVABLE FLIGHT CONTROL SYSTEM: ACTIVE CONTROL DEVELOPMENT, FLIGHT TEST, AND APPLICATION
F. M. Krachmalnick, R. L. Berger (AFFDL), J. E. Hunter, J. W. Morris (AFFDL), and J. K. Ramage (AFFDL). *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 24 p (For availability see N75-30027 21-01)

The major portion of the Survivable Flight Control System (SFCS) Program initiated by the United States Air Force in July 1969 was performed to establish the practicality of active control concepts for use in future military aircraft. The SFCS quadruplex (four channel redundancy) primary flight control system is described. Incorporation of this type of control system in a tactical vehicle is expected to provide benefits in enhanced survivability, reliability, maintainability, cost of ownership, aircraft design freedom, and aircraft maneuvering performance. The simulations and ground-based system compatibility testing performed to verify equipment performance and establish high level of pilot confidence prior to flight, are discussed. A summary of the flight test results obtained during 84 successful flights is presented. Flight test results indicate that the F-4 with the SFCS installed exhibits greatly improved handling qualities over those characteristic of the production F-4. This aircraft incorporating control configured vehicle and maneuver load control conceptual features was successfully test-flown and evaluated. Results obtained from the pilot-in-the-loop simulations and actual flight tests are discussed. Flight test results verify that significant performance improvements in combat maneuvering envelope, buffet levels, and specific excess power are achievable in the F-4 with judicious application of control configured vehicle concepts. Author

N75-30040 Air Force Armament Lab., Eglin AFB, Fla.
WEAPON DELIVERY IMPACT ON ACTIVE CONTROL TECHNOLOGY
H. Smith and Dave Carleton (AFFDL) *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1971 14 p refs (For availability see N75-30027 21-01)

The need for cooperative efforts among the laboratories/test-organizations and users is emphasized to improve and properly match aircraft pointing and armament component accuracies to achieve the maximum effectiveness with conventional weapons. The Data Measurement Programs of the Armament Development and Test Center/Air Force Armament Laboratory are discussed, including the results and plans for the Instrumented Rack/Bomb and Gunnery Pipper/Fireline Trace and Impact Pattern Model Programs. The Active Control Technology Programs of the Air Force Flight Dynamics Laboratory including objectives, designs, and results of the Tactical Weapon Delivery (TWesD) Program are discussed. The objectives of the Multimode Control and the Control Configured Vehicle/Advanced Fighter Technology Integrator Programs are delineated. It is concluded that incorporation of active control technology and matched armament component accuracies in future weapon systems shows promise for considerable improvement in the effectiveness of unguided weapons. Author

N75-30041 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
CONTROL CONFIGURED VEHICLES B-52 PROGRAM RESULTS
Bruce T. Kujawski *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 8 p refs (For availability see N75-30027 21-01)

The concepts considered for the CCV B-52 program, and the expected benefits are discussed. The system design criteria are described along with the maneuver load control system. An off design condition is evaluated. F.O.S.

N75-30042 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany)
A QUADRUREDUNDANT DIGITAL FLIGHT CONTROL SYSTEM FOR CCV APPLICATION
Wolfgang J. Kubbat *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 9 p (For availability see N75-30027 21-01)

A parallel redundant digital fly-by-wire system is described. It will be tested in the near future on a CCV-test aircraft (modified F-104 G). Starting from a fail-op, the reasons for the choice of a digital system are outlined. The system works with freely programmable identical airborne computers which run identical software. The computers perform the control laws and act also as central voters and monitors. Basic of the design is the principle of majority decision with elimination of a failed component. Finally the Quadruplex system represents a functional integration of autopilot, stabilization, air data computation and built-in-test-equipment. Author

N75-30043 Naval Air Development Center, Warminster, Pa.
THE ASSET (ADVANCED SKEWED SENSORY ELECTRONIC TRIAD) PROGRAM
C. R. Abrams and W. D. Weinstein (Grumman Aerospace Corp.) *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 12 p refs (For availability see N75-30027 21-01)

A redundant arrangement of angular rate sensors with skewed input axes, dispersed on an aircraft bulkhead, was designed for fly-by-wire control applications. Compared to other redundant configurations, it best satisfied system reliability, survivability, and maintenance requirements. By also utilizing a high reliability solid-state angular rate sensor, expected maintenance costs will be decreased. The data management system designed for the ASSET configuration featured a parallel path failure detection and isolation algorithm. A unique method of selecting failure thresholds was developed to insure that false alarm probability and system errors were minimized. The results of this effort will contribute to the practical implementation of a digital fly-by-wire system, since a successful attempt was made to match proposed operational requirements. The ASSET concept will therefore provide a fail-operational and combat-survivable set of rate sensors designed to interface with all active control systems, regardless of redundancy requirements. Author

N75-30044 Marconi-Elliott Avionic Systems Ltd., Rochester (England). Flight Control Div.
THE RELEVANCE OF EXISTING AUTOMATIC FLIGHT CONTROL SYSTEMS TO THE FUTURE DEVELOPMENT OF ACTIVE CONTROL
R. Ruggles, D. Sweeting, and I. A. Watson *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 15 p refs (For availability see N75-30027 21-01)

Some relevant examples of failure-survival automatic flight control systems are examined to show how the results of their design, implementation and operational usage can contribute to the successful introduction into full-time use of active control technology (ACT). Ground rules which were evolved some years ago for such redundant systems are re-examined in the interest of full-time ACT. The important parameters affecting the successful design of a full-time ACT system are discussed. Some of the problem areas are mentioned and the use of some existing techniques for successful certification are suggested. The step from current fail-operative systems relying on some reversionary system to full-time ACT is examined. The design requirements for the hardware and software for digital computations are detailed and some special problems of digital systems are highlighted and solutions are suggested. Some of the problems of system components such as sensors, computers and actuators are discussed. Author

N75-30045 Sperry Rand Corp., Phoenix, Ariz. Sperry Flight Systems.
PRODUCTION DESIGN REQUIREMENTS FOR FLY BY WIRE SYSTEMS
J. Flannigan and J. Emfinger *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 11 p refs (For availability see N75-30027 21-01)

The problems of specifying design requirements for production Fly-By-Wire (FBW) flight control systems are addressed based on current state-of-the-art trends. The design goals and requirements of two development FBW programs are reviewed. Emphasis is placed on the impact of specific requirements on hardware mechanization complexity. Of particular interest is the sensitivity of FBW system design to safety, survivability and mission reliability requirements, and to related subsystem and interface concepts. Experience to date is used to provide recommendations and insight into specifying practical design requirements for production FBW systems. Author

N75-30046 British Aircraft Corp. (Operating) Ltd., Bristol (England). Avionics Engineering Dept.
EXPERIENCE WITH THE CONCORDE FLYING CONTROL SYSTEM
Neville Brenchley and Ronald Grant *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 14 p (For availability see N75-30027 21-01)

The Concorde Flight Control System is discussed along with its performance, reliability, and behavior in flight. Possible future developments are considered. Author

N75-30047 Societe Nationale Industrielle Aerospatiale, Toulouse (France)
DESIGN OF AN ENTIRELY ELECTRICAL FLYING CONTROL SYSTEM
G Brohanne, R Deque, and M. Bossard *In* AGARD Impact of Active Control Technol. on Airplane Design Jun 1975 13 p (For availability see N75-30027 21-01)

After reviewing the reasons for using entirely electrical flying controls, that is controls without mechanical standby systems, and defining the control modes available for a transport aircraft, the general architecture of the system is described. It is shown that if safety requirements impose minimum redundancy, several precautions must be taken for the theoretical reliability achieved by this redundancy to be real. The equipment required is described briefly. From a maintenance point of view, the complexity of the system is compared with that of the flying controls on existing aircraft. Author

N75-30048 Royal Aircraft Establishment, Farnborough (England) Flight Systems Dept.
THE HUNTER FLY-BY-WIRE EXPERIMENT: RECENT EXPERIENCE AND FUTURE IMPLICATIONS
F. R Gill and P. W. J. Fullham *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1975 12 p refs (For availability see N75-30027 21-01)

The impact of active control technology on the design of future aircraft depends on the development of full-time and full authority control systems which have an integrity similar to that of the basic airframe. One of the major items of the R and D Programme in the UK which is aimed at providing this flight experience with this system is described. The implications of the future application of active control technology are discussed in terms of the airworthiness problem, and the manner of designing systems so as to ease the certification of high integrity, full-time and full authority control. Author

N75-30049* National Aeronautics and Space Administration. Flight Research Center, Edwards, Calif.
F-8 DIGITAL FLY-BY-WIRE FLIGHT TEST RESULTS VIEWED FROM AN ACTIVE CONTROLS PERSPECTIVE
Kenneth J. Zalai and Dwain A Deets *In* AGARD Impact of Active Control Technol. on Airplane Design Jun 1975 14 p refs (For availability see N75-30027 21-01)

The results of the NASA F-8 digital fly-by-wire flight test program are presented, along with the implications for active controls applications. The closed loop performance of the digital control system agreed well with the sampled-data system design predictions. The digital fly-by-wire mechanization also met pilot flying qualities requirements. The advantages of mechanizing the control laws in software became apparent during the flight program and were realized without sacrificing overall system reliability. This required strict software management. The F-8 flight test results are shown to be encouraging in light of the requirements that must be met by control systems for flight-critical active controls applications. Author

N75-30050 Boeing Commercial Airplane Co., Seattle, Wash.
USE OF ACTIVE CONTROL TECHNOLOGY TO IMPROVE RIDE QUALITIES OF LARGE TRANSPORT AIRCRAFT
Gerald C. Cohen and Richard L. Schoenman *In* AGARD Impact of Active Control Technol. on Airplane Design Jun 1975 16 p refs (For availability see N75-30027 21-01)

The analyses, construction, and flight testing of two systems, Beta-vane, and modal suppression augmentation system (MSAS), which were developed to suppress gust induced lateral accelerations of large aircraft are described. The Boeing 747 transport was used as the test vehicle. The purpose of the Beta-vane system is to reduce acceleration levels at the dutch roll frequency whereas the function of the MSAS system is to reduce accelerations due to flexible body motions caused by turbulence. Data from flight test, with both systems engaged, shows a 50-70 percent reduction in lateral aft body acceleration levels. It is suggested that present day techniques used for developing dynamic equations of motion in the flexible mode region are limited. These techniques produce results which are satisfactory for analyzing dynamic loads and stability problems, but may be insufficient for development of active control systems operating in the same frequency region. Author

N75-30051 Lockheed-Georgia Co., Marietta.
THE C-5A ACTIVE LIFT DISTRIBUTION CONTROL SYSTEM
William F. Grosser, Wayne W. Hollenbeck, and Don C. Eckholdt *In* AGARD Impact of Active Control Technol. on Airplane Design Jun. 1971 18 p refs (For availability see N75-30027 21-01)

The technical details are presented of the development of the Active Lift Distribution Control System (ALDCS) for the C-5A aircraft. A structural loads, and flutter-control system interaction are developed in such a way that the unique aspects of the analysis, aeroelastic wind tunnel test, and flight test portion are bound together to indicate the system design characteristics performance. The purpose of the ALDCS is to reduce gust and maneuver incremental wing root bending moments while minimizing the effects of the control system on torsion, flutter, and flying qualities. These criteria are based on axial load reduction as a means of improving wing fatigue endurance without significantly affecting existing flutter margins or handling qualities. Even though this is a retrofit system which was required to use as much existing hardware as possible, throughout the flight test all design goals were met. The system is currently planned to be manufactured and installed on the fleet during the next several years. Author

N75-30052# Advisory Group for Aerospace Research and Development, Paris (France).
THE GUIDANCE AND CONTROL OF V/STOL AIRCRAFT AND HELICOPTERS AT NIGHT AND IN POOR VISIBILITY
May 1975 281 p refs In ENGLISH and partly in FRENCH Presented at the 18th meeting of the Guidance and Control Panel of AGARD, Stuttgart, 14-16 May 1974
(AGARD-CP-148) Avail: NTIS HC $8.75

Reports are presented concerning (1) requirements, tasks, and environments; (2) performance and design of low light, infrared, and other sensors; (3) man/machine interface; (4) navigation and guidance; and (5) implications on flight control, and autopilot design. For individual titles, see N75-30053 through N75-30081.

N75-30053 Ministry of Defence, Bonn (West Germany).
THE USE OF HELICOPTER CAPABILITIES IN BAD WEATHER NEEDS AND REQUIREMENTS FOR FUTURE EQUIPMENT
K. W. Ernst *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 8 p (For availability see N75-30052 21-01)

The operational requirements and problems for improving the use of helicopters in bad weather conditions are discussed. The characteristics for the wide spectrum of applications are given along with flight profiles for bad weather. F.O.S.

N75-30054 Army Operational Test and Evaluation Agency, Fort Belvoir, Va.
TRADEOFFS BETWEEN CREW TRAINING AND EXOTIC EQUIPMENT FOR NIGHT AND FOUL WEATHER FLYING
Elmer R. Ochs *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 2 p (For availability see N75-30052 21-01)

The requirement for an all-weather, night flying capability is discussed. The solution to achieving this capability is some combination of man-machine capability. A combination which must be reasonably attainable and which represents the best balance between the benefits and burdens associated with both the man and the machine. If the focus is weighted toward the man portion of the equation in order to reduce the machine cost and maintenance burdens, the risk is faced of creating an unacceptable training burden. If the focus shifts too far toward the machine solution, the converse overburden may result. A first step in attacking the problem is to determine the boundaries. The outer boundary is represented by the state of the art while the inner boundary is a full appreciation of what can be accomplished with current assets. A clear understanding of this inner boundary or base line is necessary to objectively assess the additional man-machine requirements which will provide a viable night, foul weather flying capability. Author

N75-30055 Army Combat Developments Experimentation Command, Fort Ord, Calif.
EFFECT ON NAP-OF-THE-EARTH REQUIREMENTS ON AIRCREW PERFORMANCE DURING NIGHT ATTACK HELICOPTER OPERATIONS

In AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 10 p refs (For availability see N75-30052 21-01)

Night nap-of-the-earth (NOE) flight is described as it relates to three major areas: man, machine, and operational use. The findings and operational experience reported were encountered in exploratory efforts for a major field experiment. Activities discussed include aviator selection and training, psychological and physiological effects, mission planning, map reading and terrain interpretation, aircraft handling, emergency procedures, and man-machine operations. Behavioral research requirements and other needs established for night NOE training and operations by current scout and attack helicopters are presented, and a training program for night NOE training is offered as a general guideline. Author

N75-30056 United Aircraft Corp., Stratford, Conn. Sikorsky Aircraft Div.

H-53 NIGHT OPERATIONS

Richard L. Mills *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 6 p refs (For availability see N75-30052 21-01)

The H-53 Night Operation System (NOS) includes night vision equipment and an approach and hover coupler. The automatic approach and hover coupler subsystem permits the pilot to transition automatically over all types of terrain, including mountains, from search altitude and cruise speed to a hover and automatically maintain the hover. The night vision equipment extends this capability to night flights. The basic system was declared operational by the United States Air Force following a ninety-day combat evaluation in Southeast Asia. It is also used by foreign military. Extensive flight testing and operational use have led to additional development tests to further the capabilities of NOS. Flight test results of a prototype symbology generator and prototype electronic localizer under hover coupler are discussed along with the night vision equipment and the approach and hover coupler. Author

N75-30057 Human Engineering Labs., Aberdeen Proving Ground, Md.

US ARMY EXPERIENCE IN LOW-LEVEL NIGHT FLIGHT

Robert W. Bauer *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 6 p refs (For availability see N75-30052 21-01)

During the period of U.S. conflict in Southeast Asia there were a number of air operations conducted under adverse visibility conditions or at night. There were even a few night operations involving large numbers of aircraft, but most were made up of one or two aircraft, engaged in an insertion, extraction, long-range patrol or supply movement. Some lessons learned from these experiences are reviewed. Current developments and testing have demonstrated an improved capability in night flight, using either selected specialists without night vision systems or a wider group of aviators aided by the night vision goggles. The electroluminescent formation flight lights and rotor-tip lights have greatly increased safety in formation flights at night. But each approach has been hampered by design limitations in display panels, poor lighting quality and poor lighting control in the aircrew stations. Landing in dark unimproved areas, navigation over unfamiliar terrain and target acquisition also present special problems which have not yet been completely overcome. Author

N75-30058 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).

REQUIREMENTS FOR OPERATION OF LIGHT HELICOPTERS AT NIGHT AND IN POOR VISIBILITY

M. Rade *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 12 p refs (For availability see N75-30052 21-01)

Normally the VTOL-ability of helicopters is not used under Instrument Flight Rules. For helicopter missions at night and in poor visibility special devices are necessary, but there are only some experimental systems partly derived from devices for fixed wing aircraft. Basic requirements for normal missions will be defined. They include handling qualities, navigation equipment and landing aids. The use of sensors giving high definition pictures of the terrain in nonvisual conditions are considered. Secondary requirements are generated by some problems resulting from the full use of the all weather capability. They consist of the concept of automatic flight-control-systems and display-arrangements for the pilot. These additional requirements depend on the planned missions and on the possibilities, which are given by the type of helicopter. As important conditions for special missions deicing, noise reduction, infrared and radar camouflage will be discussed. Author

N75-30059 Royal Aircraft Establishment, Farnborough (England).

HELICOPTER AVIONICS: UK RESEARCH PROGRAMME

H. B. Johnson *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 7 p refs (For availability see N75-30052 21-01)

A limited review of the status of UK avionic systems for helicopters is given and the current needs of military helicopters discussed. The rapidity with which the use of helicopters has grown is such that it is no longer possible to meet these needs by simple modification of off the shelf equipment. A program of research and development work specifically directed towards the needs of helicopters is outlined. This program is centered around the use of a Sea King Mk I helicopter and is aimed at equipping this vehicle with a number of new equipments in the areas of flight control, electronic displays and computer aided navigation. Particular emphasis is placed on the development of night vision systems for use in helicopters and an experimental pilot's TV system is described. This will be used to explore fundamental aspects of imaging systems prior to the use of an LLTV camera for typical night flying tasks. Author

N75-30060 Naval Weapons Center, China Lake, Calif.

MICROWAVE RADIOMETRIC ALL-WEATHER IMAGING AND PILOTING TECHNIQUES

Robert P. Moore *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 10 p (For availability see N75-30052 21-01)

The Naval Weapons Center (NWC), China Lake, Calif., U.S.A. has developed a millimeter-wave radiometer capable of producing high-quality images. Automatic terrain correlation aircraft navigation was demonstrated using real-time in-flight digital processing. For V/STOL aircraft and helicopter applications during hover and descent, a system capable of rapid two-dimensional scanning will be the most useful. It is indicated that automatic navigation can be carried out with a very economical nonscanning device. Author

N75-30061 Royal Aircraft Establishment, Farnborough (England). Instrumentation and Ranges Dept.

APPLICATIONS OF LOW LIGHT TELEVISION TO HELICOPTER OPERATIONS

R. J. Corps *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 2 p (For availability see N75-30052 21-01)

The status of LLTV systems in the UK is reviewed. With the aid of cine film, practical results which have been obtained with several systems from helicopters during recent years are presented. Author

N75-30062 Army Electronics Command, Fort Monmouth, N.J. Avionics Lab.

AN OPTICAL RADAR SYSTEM FOR OBSTACLE AVOIDANCE AND TERRAIN FOLLOWING

C. M. Kellington *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 8 p refs (For availability see N75-30052 21-01)

The operational requirements are discussed for obstacle avoidance and terrain following systems, the nature of obstacles, the tradeoff considerations involved in the selection of a laser for a system and finally a unique state of the art carbon dioxide (CO_2 - 10.6 micron) laser radar system presently under development. Atmospheric penetration properties of the 10 micron radiation which permit moderate weather operation are deduced. The main thrust centers around a technical description of the CO_2 system which is called the Laser Obstacle/Terrain Avoidance Warning System (LOTAWS). System parameters e.g., 30 KHz pulse rate, 10 watts average power, 1/3 milliradian beamwidth, 300 nanosecond pulse width, 20 deg x 20 deg field of view, etc., and the methods by which they are achieved are discussed. Other system characteristics including the local oscillator, IF bandwidth, AFC loops, scanner and scan patterns, signal processing, and display to the pilot are discussed. Finally, plans for integration of the LOTAWS with other airborne equipment, including forward looking IR sensors and flight tests beginning in 1974 are outlined. Author

N75-30063 Royal Radar Establishment, Malvern (England) Airborne Radar Group.
IR THERMAL IMAGING SENSORS FOR HELICOPTERS

F. A. Holmes *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 4 p (For availability see N75-30052 21-01)

The general requirements are considered for night vision sensors which can assist the helicopter crew in their flying and tactical tasks during night operations. It is shown that two classes of sensors are needed, one for the pilot to fly the helicopter and the other for surveillance and target acquisition. The performance parameters required for each class of sensor are analyzed and some of the constraints and compromises on the sensor design are considered. The parameters thus derived show that a common sensor is not compatible for both the flying and target acquisition functions. Some of the vehicle integration and systems interface aspects are discussed to indicate that the final cost-effective choice is most likely to be determined from the overall system considerations rather than that of the IR sensor. Display requirements for both functions are shown to lead to larger units than are currently considered possible for cockpit installation, and matching of the sensor display and operator performances are likely to be the main problem in future systems. Author

N75-30064 Army Night Vision Lab., Fort Belvoir, Va.
NIGHT VISION IMAGING SYSTEM DEVELOPMENT FOR LOW LEVEL HELICOPTER PILOTAGE
Karl Stich *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 5 p (For availability see N75-30052 21-01)

Flight test data of low level night operations in UH-1 helicopters using electro-optical image forming sensors as a pilot flight aid are presented, along with details of the systems used in the investigations. Significant findings and major problem areas driving future work are given along with some present night vision pilot aids. Finally, long range night vision developments for helicopter pilotage are examined. Author

N75-30065 Army Electronics Command, Fort Monmouth, N.J. Avionics Lab.
LOW LEVEL NIGHT OPERATIONS OF TACTICAL HELICOPTERS
William J. Kennealy *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 14 p refs (For availability see N75-30052 21-01)

Initial results are presented of the U.S. Army's Low Level Night Operations Program, an on-going research program to define Avionic equipment parameters for low level night and adverse weather conditions. Results of the program include quantitative data on the performance of pilots flying at low level with varying levels of avionic equipment augmentation (e.g. none, Night Vision Goggles, FLIR, LLLTV and Radar); simulation and experimental flight test data on conceptual systems (e.g. symbolically augmented visual imaging systems) as well as experimental measurements of various candidate hardware for obstacle detection. The results are utilized to develop preliminary conceptual avionic systems for low level night operations as well as to identify areas in which additional research is required. Future research efforts directed to identified barrier problems are also presented. Author

N75-30066 Royal Radar Establishment, Malvern (England).
TERRAIN AVOIDANCE RADAR USING OFF-BORESIGHT TECHNIQUES
W. M. Nixon *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 6 p refs (For availability see N75-30052 21-01)

The two dimensional techniques (height, range) used in Terrain-Following systems were extended to three-dimensions (height, range, distance off-track) by the use of off-boresight processing. Such techniques enable the high data rate volumetric cover required in Terrain-Avoidance (TA) systems to be achieved. Various methods of off-boresight processing are mentioned and the amplitude/phase conversion method used in an experimental UK, monopulse radar is described in some detail. Signal validation techniques which reject signals of small amplitude or which appear from outside the calibrated angular range of the system are described and a possible method of presenting the TA information to a pilot is shown. A simple approach was made to the comparison of amplitude monopulse and interferometer systems. It is concluded that there is little difference in the sensitivities of the two systems in general but that operational constraints will govern the choice between them. Author

N75-30067 Princeton Univ., N.J. Dept. of Aerospace and Mechanical Sciences.
DISPLAY FOR APPROACH AND HOVER WITH AND WITHOUT GROUND REFERENCE
Theodor A. Dukes *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 9 p refs (For availability see N75-30052 21-01) (Contracts DAABO7-72-C-0161, DAABO7-74-C-0051)

The various elements of flight variable information available from an image display are discussed from the point of view of image enhancement by means of superimposed symbology. The significance of a heading reference for accurate positioning is emphasized. Two particular symbology formats are described. For approach and hover unaided by ground based instrumentation, the position information obtainable from an image display is improved by superposition of an electronically stabilized 'terrain marker'. If a radiating point source is available on the ground, quantitative error information can be derived from suitable instrumentation, and the deviation from a nominal point can be displayed superimposed on the image. Additional flight variable information (horizon, airspeed, climb rate, etc.) is also incorporated. Author

N75-30068 Royal Aircraft Establishment, Farnborough (England) Avionics Dept.
THE FLIGHT DEVELOPMENT OF ELECTRONIC DISPLAYS FOR V/STOL APPROACH GUIDANCE
J. N. Barrett and R. G. White *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 16 p refs (For availability see N75-30052 21-01)

Two series of flight trials are described which were aimed at the development of electronic displays for the approach guidance of V/STOL aircraft in visual and IFR conditions. The first series of trials was flown in the Canadair CL84 and was aimed at extending the approach capability of current operational V/STOL aircraft. The second, flown in the Shorts SC1, investigated the terminal guidance of inter-city VTOL transport aircraft. Performances achieved in the two trials are discussed, and display and flight control system changes are recommended. Author

N75-30069 Royal Aircraft Establishment, Farnborough (England). Experimental Flying Dept.
PILOTING ASPECTS OF V/STOL APPROACH GUIDANCE

C. C. Rustin *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 9 p refs (For availability see N75-30052 21-01)

A pilot's viewpoint is presented of the results of the handling, display, and operational aspects encountered during the flight trials of the CL-84 and SC-1 aircraft. Author

N75-30070 Bell Helicopter Co., Fort Worth, Tex.
RESEARCH ON DISPLAYS FOR V/STOL LOW-LEVEL AND IMC OPERATIONS
Dora Dougherty Strother and Hubert W. Upton *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 11 p refs (For availability see N75-30052 21-01)

The results of several research studies covering cockpit displays and their effect on the performance of helicopter pilots. These studies evaluated displays used for the guidance and control of helicopters at night and in restricted visibility, especially for operations at extremely low altitudes. Author

N75-30071 Human Engineering Labs., Aberdeen Proving Ground, Md.
FLIGHT SYMBOLOGY AUGMENTATION OF SENSOR DISPLAYS
William B. DeBellis and Clarence A. Fry *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 8 p refs (For availability see N75-30052 21-01)

A study is described in which scales were designed to provide altitude, airspeed, and heading information, and were combined into six candidate flight display formats. Both moving and fixed scales are considered. A repeated measure factorial experiment was designed to use response time and control error as dependent

variables, and display format and scale indication as independent variables. Twelve Army aviators flew each format under static base simulation condition by providing a cyclic control stick response to various scale value changes. It was hypothesized that display formats with markedly differing scale types would strongly affect the pilot's response times and errors, but multivariate and univariate analysis of variances did not verify this hypothesis. There were pronounced differences, but only between individual scale indications. Significant differences in pilot performance between display formats arose from differences in scale factor rather than from the types of scales. Author

N75-30072 Standard Elektrik Lorenz A.G., Stuttgart (West Germany)

NEW RADIO NAVIGATION AIDS BASED ON TACAN PRINCIPLES

M. Boehm and E. Coors *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 22 p (For availability see N75-30052 21-01)

The German TACAN family concept with MITAC as an advanced micro-TACAN airborne equipment, FOTAC as a station keeping system, ORTAC-M as a new enroute navigation aid, and SETAC as a landing aid, meets tactical requirements for cargo as well as attack helicopters with reasonable cost of procurement and ownership. Small radio aids for special purposes can be derived from this equipment family (for example, short range omnidirectional beacon (SROB)). The TACAN-mini-beacon SROB works with a 15 Hz-modulation-signal only, and gives omnidirectional azimuth and distance information to an aircraft within 30 NM of the station. The antenna system works without movable parts and generates a rotating cardioid-pattern by feeding RF-energy from an electronic goniometer to fixed radiating elements. Precautions were taken to achieve highly precise horizontal patterns independent of the operating frequency, thus keeping the inherent error of the system F less than or equal to 3 deg over the entire TACAN-band. Experiments under field conditions, using a normal TACAN-airborne-equipment, show the desired operational properties of the system. Author

N75-30073 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

A GUIDANCE SYSTEM FOR FIXED OR ROTARY WING AIRCRAFT IN APPROACH AND LANDING ZONES

Jean Besson *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 8 p refs In FRENCH; ENGLISH summary (For availability see N75-30052 21-01)

The proposed system for guiding fixed or rotary wing aircraft in approach and landing zones makes use of the time-frequency principle. It ensures all weather guidance over a few kilometers or, in a more sophisticated form, the ground control of aircraft in approach. It is based on the measurements of the distance separating the moving vehicle from a number of ground stations. Its main advantages are: the use of independent measurements, time multiplexing avoiding frequency cluttering, and the possibility of entering into a multifunction integrated system. Author

N75-30074 VDO-Luftfahrtgerate Werk Adolf Schindling G.m.b.H., Frankfurt (West Germany).

THE NUCLEAR LANDING AID FOR HELICOPTERS DURING THE FINAL APPROACH PHASE

Karl H. Busch *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 13 p (For availability see N75-30052 21-01)

A method and procedure are described for landing a helicopter in poor visibility on a beam generated by two gamma-ray sources. The one source gives the pilot the distance on the flightpath to go and to land safely in front of the source, the other gives pitch- and bank-commands indicated with a cross-pointer-instrument. The aim was to get a light weight, unsophisticated device with simple ground equipment for which batteries and power generators can be omitted. The prototype-equipment on board the helicopter consists of three gamma-ray detectors and one electronic box to drive the instruments, while the ground equipment consists of one shielding case with both the sources and collimators inside. The center line of the beams can be adjusted to different pitch angles by turning the case around the horizontal axis. Author

N75-30075 MEL Equipment Co. Ltd., Crawley (England)

DEVELOPMENTS IN THE MADGE LANDING AID

D. Atter *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 7 p refs (For availability see N75-30052 21-01)

Microwave aircraft digital guidance equipment (MADGE) is a portable approach and landing aid suited to tactical operations involving helicopters, V/STOL, or fixed-wing aircraft operating into secondary airfields and confined landing sites. The equipment is capable of providing the equivalent of civil category-II performance when deployed at runway threshold or on a helicopter pad. Rapid deployment is possible by two men, and the equipment can be operational within 15 minutes of arrival at the landing site. Up-dated information is provided on the development status of the equipment; some aspects are described of exploitation of the system's flexibility afforded by the integral two-way selectively addressed data link in conjunction with the wide-angle coverage and availability of aircraft coordinates both in the air and on the ground. Author

N75-30076 Air Force Avionics Lab., Wright-Patterson AFB, Ohio.

DEVELOPMENTAL MICRON LABORATORY TEST RESULTS

Robert R. Warzynski and George C. Radic *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 3 p (For availability see N75-30052 21-01)

A moderately accurate, low cost of ownership inertial navigator system, called micro-navigator (MICRON) was developed which will satisfy a wide range of applications including V/STOL aircraft and helicopters. The gyroscope for MICRON is an electrostatic gyro (ESG) operated in a strapdown mechanization. The gyro's performance in a developmental MICRON system, designated the N57A-1, was verified. The N57A-1 was subjected to heading sensitivity, repeatability, scoreby, shock, vibration, angular rates, cold soak, and mobile tests; over 70 navigation runs were conducted. The N57A-1 demonstrated performance better than the goals of 1 nm/hr and 5 ft/sec for all tests. Author

N75-30077 Boeing Vertol Co., Philadelphia, Pa.

HEAVY-LIFT HELICOPTER FLIGHT CONTROL SYSTEM DESIGN

E. D. Diamond and J. M. Davis *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 10 p (For availability see N75-30052 21-01)

The Army heavy-lift helicopter (HLH) is designed to operate under instrument flying conditions. Dynamic performance, reliability, and survivability considerations, led to selection of a fly-by-wire flight control system with no mechanical backup. Present helicopter handling qualities are generally not acceptable to fly with heavy external loads (up to 35 tons in the HLH case) into unprepared areas under instrument conditions. This mission required development of new helicopter handling qualities including automatic precision hover hold, linear velocity control responses, load stabilization, and automatic approach to hover. Efficient hover and low-speed operations necessitated incorporation of a rear-facing station for a load controlling crewman, who has separate aircraft controls optimized for the precise maneuvering and trim-hold functions required for cargo transfer. Development of the HLH primary and automatic flight control systems is discussed. Pertinent flight simulation and hardware ground- and flight-test results are reported. Author

N75-30078 Royal Aircraft Establishment, Farnborough (England).

HELICOPTER AUTOMATIC FLIGHT CONTROL SYSTEMS FOR POOR VISIBILITY OPERATIONS

P. Robinson, J. L. Hollington (Smiths Industries Ltd.), and J. Meadows (Smiths Industries Ltd.) *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 13 p refs (For availability see N75-30052 21-01)

Operations are described which helicopters may be required to carry out at night and in poor visibility. Because of the very high pilot work load likely to arise in these situations, it is shown that the helicopter should be equipped with an autostabilization system having a defect-survival capability. One system which meets this requirement was developed for installation and trails in a Sea King helicopter. This system is triplex, with digital computation and has the development potential to include autopilot facilities, sophisticated control techniques, and extended system redundancy. The redundancy philosophy together with salient design and engineering details of the system are described. Author

N75-30079 Sperry Rand Corp., Phoenix, Ariz
AN AUTOMATIC FLIGHT CONTROL SYSTEM FOR A HELICOPTER NIGHT LANDING SYSTEM
R. J. Miller and E. R. Tribken *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 9 p refs (For availability see N75-30052 21-01)

An automatic flight control system (AFCS) is described which provides the vehicle with handling qualities sufficient for the pilot to perform IFR approach and landings manually, using cockpit displays. It provides absolute maximum operational simplicity so as not to contribute to cockpit workload already increased by the requirement to operate display controls. The AFCS provides stability and command augmentation in pitch, roll and yaw, and the pilot relief functions of pitch, roll, heading hold, and both barometric and radar altitude hold. To provide the improved handling qualities required for the night landing problem, feedback gains and shaping were chosen to attenuate basic aircraft response, and to provide model following of the closed-loop system. The rationale behind the specific aircraft response provided by the system for this mission, the establishment of the operational characteristics and procedures, and the implementation of the system are described in detail. Author

N75-30080 Societe de Fabrication d' Instruments de Mesure SFIM, Massy (France).
LOW VISIBILITY APPROACH OF HELICOPTERS AND ADAC AIRCRAFT [L'APPROCHE SANS VISIBILITIE DES HELICOPTERES ET DES AVIONS ADAC. CONSIDERATIONS SUR LE DEVELOPPEMENT ET RESULTATS OPERATIONNELS]
J. C. Grisard *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 22 p In FRENCH (For availability see N75-30052 21-01)

The development of prolonged helicopter flight capability without visibility was examined. Automatic pilots and stabilization equipment were studied as possible methods of developing such flight. The SFIM principle was used to develop a family of automatic pilots for utilization in SA 330, SA 321, and the Alouette 3 VSV series helicopters. Operational results covering flight approach, control, and direction are given.
Transl. by E.H.W.

N75-30081 Naval Air Test Center, Patuxent River, Md. Flight Test Div.
US NAVY VTOL AUTOMATIC LANDING SYSTEM DEVELOPMENT PROGRAM
Robert S. Buffum, Richard W. Huff, and Gerald L. Keyser *In* AGARD The Guidance and Control of V/STOL Aircraft and Helicopters at Night and in Poor Visibility May 1975 8 p (For availability see N75-30052 21-01)

The role of fixed and rotary wing VTOL in military missions was expanded with the advent of the light airborne multipurpose system and the sea control ship concepts. A project is described to coordinate the various technologies which impact on the capability of the pilot, the aircraft system and the landing environment, with a goal of an approach, hover, and landing under instrument meteorological conditions. A number of display and automatic control system development programs which will be of significance in the VTOL hover and landing are discussed. Hovering vehicle versatile automatic control is a research and development automatic flight control system which was utilized to develop the requirements for VTOL automatic approach, hover, and landing. The test program to date includes system definition of the vehicle dynamics via a sine wave forcing function method. Curved and straight path approaches were controlled by the airborne digital computer in a simulated microwave landing system environment. Author

N75-32001# Advisory Group for Aerospace Research and Development, Paris (France).
TWO-DIMENSIONAL SHOCK WAVE-BOUNDARY LAYER INTERACTIONS IN HIGH SPEED FLOWS
J. J. Ginoux, ed. (Von Karman Inst. for Fluid Dyn.) and R. H. Korkegi, ed (ARL) Jun. 1975 117 p refs
(AGARD-AG-203; AGARDograph-203) Avail: NTIS HC $5.25

Two dimensional supersonic interactions are reviewed, including separation for laminar and turbulent flows. Theoretical developments in interacting flows are discussed, along with numerical techniques for calculating these flows, using finite difference and integral methods. Experimental studies are also presented which were directed toward understanding the fluid mechanics of attached and separated regions of shock wave-boundary layer interaction in the supersonic and hypersonic flow. For individual titles, see N75-32002 through N75-32007.

N75-32002 Aerospace Research Labs., Wright-Patterson AFB, Ohio.
THEORETICAL MODEL FOR VISCOUS INTERACTIONS
Wilbur L. Hankey, Jr. *In* AGARD Two-Dimensional Shock Wave-Boundary Layer Interactions in High Speed Flow Jun. 1975 p 2-13 (For availability see N75-32001 23-01)

Theoretical development employing the boundary layer equations for interacting flows is discussed. Although differences in details exist between the various approaches, a general recipe has evolved for solving this class of flows, and a procedure was developed which nearly guarantees success. The following is a list of the necessary ingredients: (1) boundary layer program; (2) simple inviscid equation; (3) couple the boundary layer with the inviscid flow and solve simultaneously; (4) initiate the program with arbitrary initial conditions and iterate on these until the desired downstream boundary condition is satisfied, and (5) computing the reversed flow region. Author

N75-32003 Aerospace Research Labs., Wright-Patterson AFB, Ohio.
SPECIAL TOPICS
Wilbur L. Hankey, Jr. *In* AGARD Two-Dimensional Shock Wave-Boundary Layer Interactions in High Speed Flows Jun. 1975 p 13-40 refs (For availability see N75-32001 23-01)

Two integrodifferential equations for the shear stress and heat transfer at the wall are included in place of the set of partial differential equations. The integral form is most useful when employing approximate techniques in that an integration tends to compensate for errors whereas a differentiation magnifies inaccuracies. Author

N75-32004 Calspan Corp., Buffalo, N.Y.
THE DEVELOPMENT OF MODELS OF SHOCK WAVE BOUNDARY LAYER INTERACTION
Michael S. Holden *In* AGARD Two-Dimensional Shock Wave-Boundary Layer Interactions in High Speed Flow Jun. 1975 p 42-44 (For availability see N75-32001 23-01)

Theoretical study of shock wave-turbulent boundary layer interaction in supersonic and hypersonic flows is presented. The Crocco-Lees method in a modified form was used successfully to describe complete regions of shock wave-laminar boundary layer interaction in supersonic flow, if the mixing rate parameters were deduced from experiment. The analyses, to describe laminar and turbulent boundary layer separation, contain most of the features which are now used in analysis of viscous interaction regions. J.A.M.

N75-32005 Calspan Corp., Buffalo, N.Y.
EXPERIMENTAL FACILITIES AND MEASUREMENT TECHNIQUES
Michael S. Holden *In* AGARD Two-Dimensional Shock Wave-Boundary Layer Interactions in High Speed Flows Jun. 1975 p 44-48 (For availability see N75-32001 23-01)

Most early experimental studies of laminar and turbulent separated regions were conducted in conventional continuous or blowdown tunnels; there is an increasing use of facilities such as shock tunnels, gun tunnels, and Ludwieg tubes to achieve high Reynolds and Mach numbers. These latter facilities are discussed. Heat transfer instrumentation is studied, along with surface and flow field pressure measurements. Total temperature and hot-wire anemometer measurements are considered; finite span effects are also examined. J.A.M.

N75-32006 Calspan Corp., Buffalo, N.Y.
SHOCK WAVE-LAMINAR BOUNDARY LAYER INTERACTIONS
Michael S. Holden *In* AGARD Two-Dimensional Shock Wave-Boundary Layer Interactions in High Speed Flows Jun. 1975 p 48-58 (For availability see N75-32001 23-01)

Qualitative features, strong interaction regime, leading edge bluntness, and surface curvature effects of shock wave-laminar boundary layer interactions were studied. Solutions in the weak regime interaction regime, strong interaction regime, and normal pressure gradient were compared to experimental measurements of the integral forms of the boundary layer equations. J.A.M.

N76-32007 Calspan Corp., Buffalo, N.Y.
SHOCK WAVE-TURBULENT BOUNDARY LAYER INTERACTIONS
Michael S. Holden *In* AGARD Two-Dimensional Shock Wave-Boundary Layer Interactions in High Speed Flows Jun 1975 p 58-110 refs (For availability see N76-32001 23-01)

Boundary layer transition was studied at high speeds. Heat and skin friction measurements were compared with turbulent theories. Incipient separation, separated turbulent interaction regions, and unsteady characteristics of turbulent separated interaction regions were also investigated. J.A.M.

N76-14018# Advisory Group for Aerospace Research and Development, Paris (France)
THE EFFECTS OF BUFFETING AND OTHER TRANSONIC PHENOMENA ON MANEUVERING COMBAT AIRCRAFT
Jul. 1975 276 p refs
(AGARD-AR-82) Avail: NTIS HC $9.25

A number of papers were presented dealing with various aspects of buffeting, its causes, and its effects on maneuvering combat aircraft. Some of the subjects discussed include: operational problems at transonic speeds, human factors engineering, flow distribution at transonic speeds, dynamic response under buffeting conditions, stability and control, flight tests and wind tunnel techniques, and effects of configuration factors. For individual titles, see N76-14019 through N76-14031.

N76-14019 Royal Aircraft Establishment, Bedford (England).
THE OPERATIONAL PROBLEMS ENCOUNTERED DURING PRECISE MANEUVERING AND TRACKING c05
B. I. L. Hamilton *In* AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul. 1975 p 1-8 (For availability see N76-14018 05-01)

A summary of the main events that occur in air combat and affect its maneuvers and handling limitations was provided. The basic phases and conduct of air combat were first reviewed. The following phenomena that may affect precise maneuvering were defined and described: buffeting, wing rock, wing drop or 'roll off', nose slice or 'yaw off', nose wander or 'snaking', pitch up, and departure. All these phenomena can occur in transonic flight and some of them may be found at the lower Mach numbers, where air combat is usually conducted after a protracted engagement. Other factors influencing air combat maneuvering are: control forces, harmonization, and pilot induced oscillations, displays, and workload. The use of the following systems in tracking was described: automatic flight controls and stability augmentation, direct lift control and direct side force control, reaction controls. Y.J.A.

N76-14020 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
AIRCREW CAPABILITIES AND LIMITATIONS
R. N. Sierve *In* AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul 1975 p 9-14 (For availability see N76-14018 05-01)

The pilot factors that can influence aircraft tracking precision during maneuvering flight and the effects of sustained and vibratory accelerations on human performance were reviewed. The effects of various values of buffeting accelerations on vision were presented. It was pointed out that the effect of sustained acceleration on tracking is of far more importance than that of vibration in the current operational environment. Degradation effects of the following factors on pilot performance were discussed: noise, temperature, fatigue, psychological motivation, personal equipment, man-machine interface/control dynamics and configuration. It appears that the best vibration alleviation techniques primarily involve adequate pilot restraints and seating design to minimize excessive relative cockpit-pilot motion.
Author

N76-14021 Office National d'Etudes et de Recherches Aerospatiales, Paris (France)
FLOW FIELD ASPECT OF TRANSONIC PHENOMENA
B. Monnerie *In* AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul 1975 p 15-20 (For availability see N76-14018 05-01)

The aerodynamics aspects of flow field over a wing in transonic maneuvering flight were reviewed in order to investigate the problem of buffeting. The case of a two-dimensional airfoil was first presented, followed by a discussion of three-dimensional flows. It was shown that most transonic troubles, and particularly buffeting, are due to the presence of more or less extended regions of separated flow. These are directly or indirectly related to the shock waves which form on the aircraft in the transonic speed regime. Prediction of what will occur in flight must be based on wind tunnel tests in view of the difficulty to theoretically predict flows with separated regions in the general case. Taking into account the continuous increase in flight Reynolds numbers due to increasing aircraft size, there is a need for higher Reynolds numbers wind tunnels.
Author

N76-14022* Advisory Group for Aerospace Research and Development, Paris (France)
DYNAMIC RESPONSE OF AIRCRAFT STRUCTURE
In AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul 1975 p 21-44 (For availability see N76-14018 05-01)
(Contract NAS2-6475)

The physical and mathematical problems associated with the response of elastic structures to random excitations such as occurs during buffeting and other transonic phenomena were discussed. The following subjects were covered: (1) general dynamic system consisting of the aircraft structure, the aerodynamic driving forces due to separated flow, and the aerodynamic forces due to aircraft structural motion, (2) structural and aerodynamic quantities of the dynamic system with special emphasis given to the description of the aerodynamic forces, and including a treatment of similarity laws, scaling effects, and wind tunnel testing, and (3) methods for data processing of fluctuating pressure recordings and techniques for response analysis for random excitation. A general buffeting flutter model, which takes into account the interactions between the separated and motion induced flows was presented. Relaxations of this model leading to the forced vibration model were explained.
Author

N76-14023 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
STABILITY AND CONTROL STATUS FOR CURRENT FIGHTERS
W. G. Williams and J. L. Lockenour *In* AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul 1975 p 45-53 (For availability see N76-14018 05-01)

The current state-of-the-art of stability and control technology for maneuvering and precision tracking was discussed, including basic aerodynamics and aerodynamic stability and control, flight control system concepts, and methods of prediction and analysis. It was shown that the maximum useable maneuvering capability of present fighter aircraft is often limited to 'g' levels below the maximum aerodynamic lift capability by stability, control and handling qualities degradations. In addition, handling qualities degradations often prohibit precision tracking although gross maneuvering may still be possible. Automatic flight control systems (stability augmentation and command augmentation) are being employed to correct many of the bare airframe deficiencies and additional capability is being provided by advancements in the fire control systems.
Author

N76-14024 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
STABILITY AND CONTROL POTENTIAL FOR FUTURE FIGHTERS
J. L. Lockenour and W. G. Williams *In* AGARD The Effect of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft 1975 p 54-62 (For availability see N76-14018 05-01)

Advanced stability and control concepts aimed at further improving maneuvering and precision tracking were presented. The proposed new modes of control, methods of generating the required forces and moments necessary to produce the motions, flight control system concepts to implement the maneuvering modes, and the additional impact of pilot factors were discussed. Methods of prediction and analysis were also presented, and recommendations were made regarding the concepts and areas of analysis which are considered to be most important. Author

N76-14025 Advisory Group for Aerospace Research and Development, Paris (France)
BUFFET DEFINITION AND CRITERIA
In its The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul 1975 p 63-83 (For availability see N76-14018 05-01)

Two areas related to aircraft buffeting were discussed: wing and tail buffet, and bomb bay buffeting. In the first area, basic definitions were given, followed by buffeting criteria for fighter and transport aircraft, classification of wing flow and buffeting for various types of wings, buffet onset and the severity of buffeting, and tail buffeting. It was concluded that (1) for bubble flows, the largest excitation is found just upstream of the reattachment point, (2) for slender wings with sharp leading edges the buffeting is light but just measurable, (3) for swept wings buffeting measurements must be made on rigid models. Bomb bay buffeting was defined as the specific dynamic behavior of an aircraft when excited by forces of random and harmonic nature due to flow separation in open bays or cavities. A remarkable large change in mean pressures occurs for bays with a length/depth ratio of about six, for which drag raises abruptly. YJA

N76-14026 Aeronautical Systems Div., Wright-Patterson AFB, Ohio.

BUFFET ANALYSIS

P. J. Butkewicz *In* AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul. 1975 p 84-90 (For availability see N76-14018 05-01)

The methods available for transonic buffet analysis were reviewed. The analysis methods were divided into two groups, experimental model testing including associated empirical prediction methods, and semi-empirical or theoretical procedures which require some flow field calculations. Due to the complexity of the transonic flow about wings experiencing unsteady separation, wind tunnel testing is the primary tool for obtaining detailed information about the buffet intensity. A serious problem however exists in applying the results to full scale due to improper boundary layer modelling at the relatively low test Reynolds numbers. A buffet onset prediction method suitable for theoretical analysis was outlined and is primarily applicable to thick, aft loaded airfoils which display a significant pressure rise from the shock and trailing edge and which therefore have a tendency for rear separation. Author

N76-14027 Aeronautical Systems Div., Wright-Patterson AFB, Ohio.

BUFFET FLIGHT TEST TECHNIQUES

P. J. Butkewicz *In* AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul. 1975 p 91-98 (For availability see N76-14018 05-01)

Buffet instrumentation and flight test techniques were discussed. Details of the instrumentation installed for buffet tests of a F-106A aircraft were given. In general, flight instrumentation for buffet tests should include: static pressure taps, total pressure and boundary layer rakes, accelerometers, strain gauges, aircraft attitude sensors, high speed camera and wing tufts. Particular attention must be paid to the application of wing tufts for flow visualization and for the mounting of the camera. The schedule used in buffet flight testing should incorporate that sequence of aircraft configurations and Mach-altitude conditions which will provide the most rapid collection of data based on (1) the time required to attain the desired aircraft configuration and test condition, and (2) the aircraft modification time required for the subsequent configurations. Author

N76-14028 Royal Aircraft Establishment, Bedford (England).

LIMITATIONS IN THE CORRELATION OF FLIGHT/TUNNEL BUFFETING TESTS

D. G. Mabey *In* AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul. 1975 p 99-104 (For availability see N76-14018 05-01)

Some possible sources of discrepancies between flight and wind tunnel buffeting measurements were discussed. The single, most serious causes of discrepancies is probably the failure to represent on the model the development of flow separations on the actual aircraft. The best way to improve future predictions is to test as large a model as possible, including the representation of gaps, surface roughness, etc., at as high a Reynolds number as possible, and then to insist on an extensive flight program. Other sources of discrepancies include: flight test measurement errors, visualization of areas of separated flows, influence of tunnel characteristics on model buffeting, measurement of buffeting. Author

N76-14029 Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).

INFLUENCE OF CONFIGURATION FACTORS ON BUFFETING

H. Max *In* AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul. 1975 p 104-107 (For availability see N76-14018 05-01)

Data concerning the effects of the geometrical configuration parameters, Reynolds number, external stores and supercritical wing layout of an aircraft on its buffet boundaries and the buffet intensities was presented. The following geometrical parameters were considered: wing aspect ratio, taper ratio, sweep angle, relative maximum thickness of the wing root section, and relative maximum camber of the wing section. The effects of these parameters on buffeting were shown graphically. An equation was given from which the light buffet lift coefficient may be estimated for a given wing at specific transonic Mach numbers and Reynolds numbers. Author

N76-14030 Aeritalia, Turin (Italy).

IMPROVEMENT OF AIRCRAFT BUFFET CHARACTERISTICS

G. Bucciantini *In* AGARD The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul. 1975 p 108-110 (For availability see N76-14018 05-01)

A series of provisions which can be taken to improve the buffet characteristics of an aircraft were described. These include maneuver slats and flaps, strakes, aerodynamic fixing (notch, sawtooth, fence, etc.), and vortex generators. The effects of these devices were shown graphically. A separate discussion on the possibility of tailplane buffet and suitable remedial actions was also given. Author

N76-14031 Advisory Group for Aerospace Research and Development, Paris (France).

CONCLUSIONS AND RECOMMENDATIONS

In its The Effects of Buffeting and other Transonic Phenomena on Maneuvering Combat Aircraft Jul. 1975 p 111-112 (For availability see N76-14018 05-01)

General conclusions and specific recommendations on aircraft buffeting problems were presented. These include the need for (1) a total system analysis to determine the effects of buffeting during maneuvering flight, (2) improved methods of viscous flow field and separation prediction, (3) comparing results from existing buffet onset prediction with wind tunnel and flight test data to determine their range of applicability, (4) better understanding of wind tunnel perturbation effects, (5) understanding of high speed stall progression, (6) identification of the interaction between the random aerodynamic driving forces and the structural response forces, (7) understanding the basic and interacting phenomena on existing and emerging fighters, and (8) isolating the effects of the various parameters more clearly, broadening the spectrum of the various parameters, and giving a better understanding of the physical process of buffeting. Author

N76-14032# Advisory Group for Aerospace Research and Development, Paris (France).

APPROACH AND LANDING SIMULATION

Oct. 1975 68 p refs

(AGARD-R-632) Avail. NTIS HC $4.50

Realism, validation, and standardization of flight simulators are discussed. External disturbances and visual and motion cues are evaluated as to their effect on pilot performance. Filter design for the von Karman spectrum and pitching moment coefficient model for Boeing 747 aircraft are appended. A bibliography with 58 references is included. For individual titles, see N76-14033 through N76-14039.

N76-14033 Advisory Group for Aerospace Research and Development, Paris (France).

APPROACH AND LANDING SIMULATION, INTRODUCTION

In its Approach and Landing Simulation Oct. 1975 p 1-3 refs (For availability see N76-14032 05-01)

Historical notes on flight simulation are presented, progressing from simplified and rudimentary displays to today's sophisticated simulators. Primarily nonhardware aspects of simulation are discussed. J.A.M.

N76-14034 Advisory Group for Aerospace Research and Development, Paris (France).

ELEMENTS OF APPROACH AND LANDING SIMULATION

In its Approach and Landing Simulation Oct. 1975 p 3-4 (For availability see N76-14032 05-01)

In simulations of the approach and landing flight regime, aircraft models are simplified by the absence of significant aerodynamic effects of varying Mach number, and only in the case of the very large, very flexible airplane are aeroelastic effects rigorously considered. In STOL and VTOL aircraft, widely varying interactions between aerodynamics and propulsion are encountered in the range of speeds appropriate to approach and landing. The importance of mathematical representation of atmospheric perturbations and the aircraft's response to them is discussed. Simulator hardware elements are reviewed, including all the mechanisms that provide the pilot with means to input control commands to the computer system model of the aircraft, and to assess the aircraft's response to either his inputs or other excitations. J.A.M.

N76-14035 Advisory Group for Aerospace Research and Development, Paris (France)
EXTERNAL DISTURBANCES
In its Approach and Landing Simulation Oct. 1975 p 4-14
(For availability see N76-14032 05-01)

External disturbance models are used to test the pilots' reactions to given situations and to test the controllability of particular aircraft. Wind profiles, wind shear, and atmospheric turbulence are used in the simulation. The power spectra due to von Karman and to Dryden are discussed for turbulence simulation. A cross power spectra is also considered, relating the turbulence velocities in different directions as zero. Various causes of errors in ILS guidance systems are included, along with irregularities in runway conditions. J.A.M.

N76-14036 Advisory Group for Aerospace Research and Development, Paris (France).
AIRCRAFT CHARACTERISTICS
In its Approach and Landing Simulation Oct. 1975 p 14-15
(For availability see N76-14032 05-01)

The types of data and the degree of detail used in modern simulations are discussed for large subsonic jet transports and powered lift STOL transports. It is shown how aircraft characteristic models will differ depending on the significant aerodynamic, structural, and propulsion effects of the particular aircraft. J.A.M.

N76-14037 Advisory Group for Aerospace Research and Development, Paris (France).
VISUAL AND MOTION CUES
In its Approach and Landing Simulation Oct. 1975 p 15-19
(For availability see N76-14032 05-01)

Limitations of both day and night landing scenes used in a flight simulator are discussed. These limitations include field of view, resolution, depth of focus, display, terrain model, and dynamic performance. Motion cue constraints are examined for both rotational and linear motion. J.A.M.

N76-14038 Advisory Group for Aerospace Research and Development, Paris (France).
SIMULATION DEVELOPMENT, VALIDATION AND PILOT LEARNING
In its Approach and Landing Simulation Oct. 1975 p 19-28
(For availability see N76-14032 05-01)

Views and experiences are presented, regarding the processes and procedures used to develop confidence in a simulation; overall interactions of the various elements in approach and landing simulation are discussed. Achieving confidence in a simulation through the demonstration of its acceptability by simulating an existing known aircraft is emphasized. The significance of the pilots' learning process is demonstrated, as well as their experience level with a specific simulation in the development of their confidence in that particular simulation. J.A.M.

N76-14039 Advisory Group for Aerospace Research and Development, Paris (France)
CONCLUDING REMARKS
In its Approach and Landing Simulation Oct. 1975 p 28-61 refs
(For availability see N76-14032 05-01)

The attempts at realism during flight simulation are discussed. Validation and ample training of pilots are stressed. Little standardization is noted among simulator testing and evaluation. The main weak elements of flight simulation, motion and visual cues, are also considered. A bibliography with 58 references is included. J.A.M.

N76-20067# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD HIGHLIGHTS, MARCH 1976
1 Mar. 1976 33 p
(AGARD-Highlights-76/1) Avail: NTIS HC $4.00

Reports of AGARD activities are presented. The articles presented concern hurricane Eloise, Von Karman medals for 1975, air traffic control, aircraft fire safety, and personnel changes. F.O.S.

N76-31179# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD HIGHLIGHTS, SEPTEMBER, 1976
Sep. 1976 21 p
(AGARD-Highlights-76/2) Avail: NTIS HC $3.50

Highlights of the 1976 AGARD meeting held in Paris, France are presented. Topics discussed were the following: the control configured vehicle concept; anti-flutter systems and anti-turbulence systems; direct force control surfaces; load reduction during maneuvers; aircraft safety; systems reliability; and stall/spin problems of military aircraft. B.B.

N76-33130# Advisory Group for Aerospace Research and Development, Paris (France)
AGARD BULLETIN: TECHNICAL PROGRAM, 1977
Jul. 1976 37 p
(AGARD-Bull-76-2) Avail: NTIS HC $4.00

The AGARD technical program for 1977 approved by the national delegates board was presented. The following information is given: chronological listing of meetings tentatively scheduled to take place, detailed description of the individual panel programs, consultant and exchange program, and military committee studies program, total budget required, and publications summary. Author

N77-11969# Advisory Group for Aerospace Research and Development, Paris (France)
NUMERICAL METHODS AND WINDTUNNEL TESTING
Oct. 1976 206 p refs Partly in ENGLISH and FRENCH; ENGLISH summaries. Papers presented at the Fluid Dyn. Panel Specialists Meeting, Von Karman Inst. for Fluid Dyn., Rhode-St-Genese, Belgium, 23-24 Jun. 1976
(AGARD-CP-210, ISBN-92-835-0178-0) Avail: NTIS HC A10/MF A01

Wind tunnel stability tests for various aerodynamic configurations are presented, emphasizing low speed and transonic wind tunnels. Some data processing was performed with minicomputers, some of which processed in real time. For individual titles, see N77-11970 through N77-11986.

N77-11970# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
DIGITAL COMPUTER ASPECTS OF THE INSTRUMENTATION AND CONTROL OF THE NEW RAE 5 METRE LOW SPEED TUNNEL
R. J. North, R. W. Jeffery, J. A. Dolman, and A. N. Tuck *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 10 p refs (For primary document see N77-11969 03-01)
Avail: NTIS HC A10/MF A01

account is given of the applications of online and offline minicomputers in its instrumentation and control systems. Some of the hardware and software design considerations are discussed; various options for future development are outlined. The connections with the control computers and other ancillary systems are mentioned. Author

N77-11971# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Centre de Modan Avrieux.
OPERATIONAL USE OF COMPUTERS ASSOCIATED WITH THE MODANE WIND TUNNELS
Gerard Gronat *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 9 p refs In FRENCH, ENGLISH summary (For primary document see N77-11969 03-01)
Avail: NTIS HC A10/MF A01

Measuring units for wind tunnels of the Modane-Avrieux Centre were gradually equipped with minicomputers for insuring the following functions: measurement acquisition management, test control and monitoring, and automatic operations. Multitask type software offers a great flexibility for dialogue with the experimenter and allows an exchange of informations with the outside, at a rate close to that of a stand alone computer. The

whole system is operational since April 1976. Three applications are described: two dimensional profile tests, convertible rotor tests with real time simulation of rotor tilting, and device for weighing missiles close to the aircraft with a view to calculate step by step the missile relative trajectory (captive trajectory method). These examples outline the functions entrusted to the computers associated to measuring units, the loads they can withstand, and the limits of their possibilities. Author

N77-11972*# National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
APPLICATIONS OF THE REAL-TIME DATA ANALYSIS SYSTEM IN THE AMES 40- BY 80-FOOT WIND TUNNEL

Mark W. Kelly, Stanley O. Dickinson, and Everett E. Maynard *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 10 p refs (For primary document see N77-11969 03-01)
Avail: NTIS HC A10/MF A01 CSCL 14B

The first major overhaul and refurbishment of the Ames 40- by 80-foot wind tunnel since it was put into operation in 1944 was recently completed. A substantial part of this refurbishment was devoted to providing this wind tunnel with a modern real time data acquisition and analysis system to increase the safety, efficiency, and accuracy of experimental investigations in this facility. Background leading to the requirements for the new system, major elements of the system, and some of the applications of the system are summarized. The potential of computerized data acquisition systems for wind tunnels in terms of long term trends in hardware and software costs, and the constraints which must be dealt with to achieve the full potential of computerized data acquisition systems are discussed. Author

N77-11973# Boeing Vertol Co., Philadelphia, Pa.
THE USE OF COMPUTERS IN ROTARY WING TESTING

William G. S. Hardy and Edward J. Pyne *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 12 p refs (For primary document see N77-11969 03-01)
Avail: NTIS HC A10/MF A01

Computer requirements for testing rotary wing aircraft models are discussed, and a general purpose processing system is described. Some considerations for data acquisition and presentation are presented. The types of analyses required for rotary wing models are covered. Both real time and off-line analysis methods are reviewed. Author

N77-11974# Arizona Univ., Tucson.
SOME EXPERIENCES WITH THE EXPLOITATION OF MEASUREMENTS OF THE PERTURBATION FIELD IN A WIND TUNNEL TO IMPROVE SIMULATION

W. R. Sears *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 4 p Prepared in cooperation with Calspan Corp. (For primary document see N77-11969 03-01)
Avail: NTIS HC A10/MF A01

The essential feature is that both the flow within the tunnel and the computed exterior field are iteratively adjusted to achieve the matching. The tunnel flow is adjusted by mechanical changes of tunnel wall geometry, for example, by varying the pressures in subdivided plenum chambers surrounding the working section and communicating with the tunnel through porous walls or slots. The exterior flow field is adjusted by altering the boundary values prescribed at S, on the basis of measurements of flow perturbation distributions at or near S. Author

N77-11975# Southampton Univ. (England). Dept. of Aeronautics and Astronautics.
APPLICATION OF THE COMPUTER FOR ON-SITE DEFINITION AND CONTROL OF WIND TUNNEL SHAPE FOR MINIMUM BOUNDARY INTERFERENCE

M. Judd, M. J. Goodyer, and S. W. D. Wolf *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 14 p refs (For primary document see N77-11969 03-01)
Avail: NTIS HC A10/MF A01

The use is described, of flexible top and bottom walls, as a means of eliminating or minimizing wall interference effects on two dimensional wind tunnel models. Strategies for producing streamline contours and their extension to three dimensions are discussed. Errors due to theoretical assumptions and practical implementation are explored so that computational resolution can be made consistent. The need for efficient and rapidly convergent algorithms for wall adjustment is stressed and discussed. These must be developed in order to reduce the current data acquisition times and make feasible the present aim to incorporate an on-line minicomputer for automatic wall control. Results are presented showing the correctness of the strategies used with manual wall adjustment. Author

N77-11976# Avions Marcel Dassault, Saint-Cloud (France).
ADAPTATION OF THE JOPPA METHOD TO A WIND TUNNEL WITH VARIABLE PERMEABILITY [ADAPTATION DE LA METHODE DE JOPPA A UNE SOUFFLERIE A PERMEABILITE VARIABLE]

Jean-Ch. Vayssaire, M. Langot (Institut Aerotechnique de Saint-Cyr), and M. Menard (Institut Aerotechnique de Saint-Cyr) *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 17 p refs In FRENCH (For primary document see N77-11969 03-01)
Avail: NTIS HC A10/MF A01

The Joppa calculation method divides the walls of a wind tunnel working section into rectangular elements with an unknown vortex ring strength and takes account of the test section dimensions and boundaries. The relative position of the model, as well as its geometry and lift distribution spanwise allow the calculation of the theoretical permeability in any point of the ventilated walls to minimize or cancel its effect in the area of the model. Inside the plenum chambers which are around the test section of the Sigma 4 wind tunnel, flexible, solid, and movable plates are found. The movement of the plates contributes to the variation of the permeability in any point of the working section perforated walls. Author

N77-11977# ARO, Inc., Arnold Air Force Station, Tenn.
AUTOMATIC CONTROL OF A TRANSONIC WIND TUNNEL WITH A REAL-TIME COMPUTER SYSTEM

J. A. Gunn and J. P. Christopher, Jr. *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 6 p ref (For primary document see N77-11969 03-01)
Avail: NTIS HC A10/MF A01

The aerodynamic wind tunnel (4T) real time control and display system is a computerized system which has increased the productivity of the tunnel 4T tests by providing real time displays of test conditions, test condition monitoring, and automatic control. The system is built around a PDP 8/E minicomputer which has a 16K word memory and a hardware floating point processor. The system uses standard tunnel measurements to calculate stream and plant parameters. The program, which is written in the FORTRAN 4 language, is executed three times per second. Computer-driven video displays provide tunnel operators and other control room personnel with test conditions such as Mach number, Reynolds number, and dynamic pressure. The real time system monitors all test parameters, continually checks to determine if test conditions are as requested, and informs the operators of the current plant and test conditions status via the status panel. The real time system automatically controls the test section wall porosity, ejector flaps, wall angle, the tunnel stagnation pressure for most conditions, and the Mach number in the range from 0.2 to 0.9. Author

N77-11978# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
MINIMIZING WALL INTERFERENCE IN CONNECTIONAL TRANSONIC TEST SECTIONS BY USING COMPUTER PARAMETRIC STUDIES

Xavier Vaucheret *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 23 p refs In FRENCH; ENGLISH summary (For primary document see N77-11969 03-01)
Avail: NTIS HC A10/MF A01

Parametric studies by computer, using the programs for the calculation of the wall interference by the analytic method, for perforated wall transonic test sections, allow the determination of using of present test sections, with associated model sizing, so that the wall constraints can be negligible. For tridimensional flow, the following parameters are investigated: test section height/width ratio, model span test section width ratio, wing sweep and horizontal wall porosity, this porosity is assumed to be uniform and the same for floor and ceiling. The model schematization rules, necessary and sufficient to calculate the lift interference coefficients, are given. Author

N77-11979# National Aerospace Lab., Amsterdam (Netherlands).
WIND TUNNEL TESTS AND AERODYNAMIC COMPUTATIONS; THOUGHTS ON THEIR USE IN AERODYNAMIC DESIGN

J. W. Slooff *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 6 p refs (For primary document see N77-11969 03-01)

Avail: NTIS HC A10/MF A01

After comparing the possibilities and limitations of numerical methods and wind tunnel tests, their respective roles in aerodynamic design are discussed. It is concluded that the key problems of aerodynamic design are not solved by substituting numerical methods for the wind tunnel Author

N77-11980# National Aeronautical Establishment, Ottawa (Ontario).

APPLICATION OF COMPUTED SHOCK STANDOFF DISTANCES FOR WINDTUNNEL CALIBRATION AT SUPERSONIC MACH NUMBERS LESS THAN 1.2.

D. J. Jones *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 5 p refs (For primary document see N77-11969 03-01)

Avail: NTIS HC A10/MF A01

Calibration of a wind tunnel in the Mach number range 1 < M < 1.1 was carried out by taking Schlieren photos of the bow shock in front of a sphere. A theory was developed to calculate this bow shock for flows about axisymmetric bodies. By correlating the experimental and theoretical shock waves, the wind tunnel was calibrated. Author

N77-11981# Dornier-System G.m.b.H., Friedrichshafen (West Germany)

THEORETICAL AND EXPERIMENTAL SIMULATION METHODS FOR EXTERNAL STORE SEPARATION TRAJECTORIES

J. VonDerDecken, P. Esch, and P. Fritz *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 5 p refs (For primary document see N77-11969 03-01)

Avail: NTIS HC A10/MF A01

Numerical methods and experimental techniques for the simulation of separation trajectories of external powered and unpowered stores at low and high speed are reviewed. For the theoretical simulation, potential flow methods are used to calculate the quasi-steady loadings on the store while the trajectory itself is determined by solving the equations of the 6-degree-of-freedom motion. Based on the experience of numerous systematic experimental studies gained with the rigid loads and the freedrop technique for unpowered stores, the advantages and limitations of different wind tunnel techniques are demonstrated including a critical discussion of scaling effects. Author

N77-11982*# National Aeronautics and Space Administration, Ames Research Center, Moffett Field, Calif.

EXPERIMENTS PLANNED SPECIFICALLY FOR DEVELOPING TURBULENCE MODELS IN COMPUTATIONS OF FLOW FIELDS AROUND AERODYNAMIC SHAPES

Joseph G. Marvin *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 13 p refs (For primary document see N77-11969 03-01)

Avail: NTIS HC A10/MF A01 CSCL 01A

Building block experiments and companion numerical simulations intended to verify and guide turbulence modeling are described. A series of experiments and computations being used to enhance modeling development for the shock wave turbulent boundary layer interaction problem is emphasized. Results are given for transonic flow over a circular arc airfoil undergoing shock wave induced, boundary layer separation for supersonic flow along a tube wall undergoing normal shock wave induced, boundary layer separation. Experimental data which use the complete Navier-Stokes equations are discussed. Author

N77-11983# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).

THE IMPORTANCE OF EXPERIMENTALLY-DETERMINED CLOSURE CONDITIONS IN TRANSONIC BLADE-TO-BLADE FLOWS CALCULATED BY A TIME-DEPENDENT TECHNIQUE

M. Couston *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 23 p refs (For primary document see N77-11969 03-01)

Avail: NTIS HC A10/MF A01

The use of a time dependent technique to determine inviscid blade-to-blade flow in the transonic regime for axial turbomachines is faced with the problem of closure conditions. The importance of a Kutta condition in subsonic flow calculations is well known but for transonic blades the problem is still more complex. The quasi-discontinuous character of the flow through shock waves and Prandtl-Meyer expansions is then superimposed on the viscous effects which dominate near the trailing edge. In order to get more information about the importance of this problem, a comparison between detailed measurements and calculations is presented. The calculations were performed for several trailing edge flow approximations including experimentally determined conditions. Author

N77-11984# Dornier-System G.m.b.H., Friedrichshafen (West Germany).

NUMERICAL SIMULATION OF THREE DIMENSIONAL TRANSONIC FLOW INCLUDING WIND TUNNEL WALL EFFECTS

W. Schmidt, H.-W. Stock, and W. Fritz *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 8 p refs (For primary document see N77-11969 03-01)

Avail: NTIS HC A10/MF A01

Numerical methods and their practical implementation are presented to compute steady transonic flow fields about wings and wing-body combinations in transonic flow including viscous effects as well as wind tunnel wall effects. The transonic small disturbance potential equation is solved by a mixed finite difference scheme. Wind tunnel wall boundary conditions are incorporated in the relaxation procedure by use of the classical wall condition equations. The three dimensional boundary layer equation is solved by an integral prediction method. Solving potential equation and boundary layer equation iteratively, viscous effects are accounted for by means of the displacement thickness concept. Results showing the influence of Reynolds number and Mach number on pressure distribution and shock position are shown. Author

N77-11985# Laboratoire d'Aerothermique du C.N.R.S., Meudon (France).

FOURIER ANALYSIS AND THE CORRELATION OF SPEED WITH NONSTATIONARY AERODYNAMICS [ANALYSE DE FOURIER ET CORRELATION DE VITESSE EN AERODYNAMIQUE INSTATIONNAIRE]

Pierre Gougat and Francoise Martin *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 7 p refs In FRENCH (For primary document see N77-11969 03-01)

Avail: NTIS HC A10/MF A01

Transition from a laminar to a turbulent state begins with the appearance of natural instabilities made up of sine waves of uncertain intermittance in the midst of the boundary layer. The response of the boundary layer to a local vibration in the wall is studied in order to suppress the uncertain character of the intermittance. The sine wave of deformation of the wall is obtained with the aid of a lock-on displacement loop. The signal of speed fluctuations in the boundary layer is obtained with a hot wire anemometer. These two data are treated separately by real time analysis which permits measuring the harmonic rate of the signal of deformation to determine the spectral density of the power of the fluctuations of speed. The simultaneous treatment of two signals is used for real time correlation. To this correlation is associated a Fourier transformation which provides the mutual spectrum of the two signals. A magnetic recording stores the signals and reads them again at a speed which facilitates the observations and study of the instantaneous phenomena. Transl. by A.H.

N77-11986# Deutsche Forschungs- und Versuchsanstalt fuer Luft und Raumfahrt, Goettingen (West Germany).

PICKING UP AND GRAPHING OF THREE DIMENSIONAL FLOW FIELDS

H.-J. Graefe *In* AGARD Numerical Methods and Windtunnel Testing Oct. 1976 12 p refs (For primary document see N77-11969 03-01)

Avail: NTIS HC A10/MF A01

An efficient test technique is described for three dimensional flow field measurements which was set up in combination with a conventional measurement technique with modern electronical equipment. The test rig is installed in the low speed wind tunnel. Some suggestions for graphic representations of three dimensional flow fields are given. Author

N77-14982# Advisory Group for Aerospace Research and Development, Paris (France).

ELEVENTH AGARD ANNUAL MEETING

Feb. 1976 70 p refs Meeting held at Ottawa, 18 Sep. 1975 (AD-A023909, ISBN-92-835-1212-X) Avail: NTIS HC A04/MF A01

An investigation of aerospace research and development emphasizing the area of short takeoff (STOL) aircraft in Canada was presented. Research into the military air material requirements and the governmental support given was discussed. The government policies concerning research into STOL aircraft and

its military as well as commercial possibilities were studied. Military application of the TEA-CO2 laser was considered, including radar type applications and use of the laser as a weapon. For individual titles, see N77-14983 through N77-14988

N77-14983# Department of National Defence, Ottawa (Ontario)
CANADIAN MILITARY AIR MATERIEL REQUIREMENTS
D W Goss *In* AGARD 11th AGARD Ann Meeting Feb 1976 p 11-14 (For primary document see N77-14982 06-01)
Avail: NTIS HC A04/MF A01

Cold and snow are but two characteristics of Canada which must be accounted for in stating military requirements. The northern magnetic pole is in Canada, and aurora borealis displays are frequent, affecting communications and navigation. When winter's grip relaxes, the insect population emerges making life barely livable without some form of protection. Most of these characteristics must be catered to in stating requirements for material, as they affect all facets of equipment performance, from aircraft range through special navigation requirements through special environmental protection requirements. In addition to purely Canadian conditions, the conditions related to operations in Europe and the material requirements are superimposed. Among these are the extremely corrosive atmosphere which proved particularly troublesome, and less tangible but equally serious differences in the stresses due to a difference in the turbulence regime, differences in bird hazards and so on. As some of the forces are also assigned to the United Nations in the Middle East, conditions of heat, sand and corrosive atmosphere must also be considered in this application of our equipment in this environment. Author

N77-14984# Department of National Defence, Ottawa (Ontario)
RESEARCH AND DEVELOPMENT IN SUPPORT OF CANADIAN MILITARY AIR REQUIREMENTS
E J Bobyn *In* AGARD 11th AGARD Ann Meeting Feb 1976 p 15-18 (For primary document see N77-14982 06-01)
Avail: NTIS HC A04/MF A01

The Department of National Defense in cooperation with other government departments and industry initiated V/STOL aircraft research and development. The bulk of the research and development activity was directed towards sub-systems, acquisition of technical knowledge, human factors in man/machine interface, avionics, systems analysis, surveillance, propulsion devices, landing gear, detection devices, navigation aids, data processors, materials, power supplies, weapon modifications, and other associated components. Author

N77-14985# National Research Council of Canada, Ottawa (Ontario).
CANADIAN RESEARCH AND DEVELOPMENT POLICIES

J D Keys *In* AGARD 11th AGARD Ann. Meeting Feb 1976 p 19-21 (For primary document see N77-14982 06-01)
Avail: NTIS HC A04/MF A01

There is no single science policy suitable for Canada. Instead, it is accepted that the federal government's science policy is the sum of three distinct areas: (1) policies for support of science, (2) policies for application of science and technology; and (3) science as a component of public policy. Author

N77-14986# De Havilland Aircraft Co. of Canada Ltd., Ottawa (Ontario).
STOL DEVELOPMENTS
J. P. Uffen *In* AGARD 11th AGARD Ann Meeting Feb 1976 p 22-41 refs (For primary document see N77-14982 06-01)
Avail: NTIS HC A04/MF A01

The characteristics of STOL aircraft which distinguish them from conventional, CTOL, aircraft are described. Examples of the way in which STOL has evolved are given, with discussion of the features of the de Havilland Dash 7. Looking to the future, developments which retain the short takeoff and landing capability while extending the speed, payload and range of STOL aircraft are described. These have differing characteristics, which permit selection of optional configurations for particular roles. Author

N77-14987# Canadian Air Transportation Administration, Ottawa
OVERVIEW OF THE CANADIAN MINISTRY OF TRANSPORT'S STOL DEMONSTRATION
F. C. Black *In* AGARD 11th AGARD Ann Meeting Feb 1976 p 42-44 (For primary document see N77-14982 06-01)
Avail: NTIS HC A04/MF A01

AIRTRANSIT Canada operates six modified Twin Otter aircraft leased from the Ministry of Transport on a high frequency STOL commuter service between Ottawa and Montreal. The aircraft are operated from convenient STOLports, located close to the central business districts of each city. The aircraft and STOLports are designed to permit scheduled instrument operations using steep gradient approaches on a microwave scanning beam landing guidance system, the first of its kind in commercial service today. In addition, each aircraft is equipped with a three dimensional area navigation system used in conjunction with specially developed control procedures permitting operations in high density terminal areas without active direction on the part of air traffic control. Each aircraft carries a data acquisition system that records information to be used as a data base for the development of future STOL regulations and operating criteria in Canada. Passenger processing was streamlined through the use of STOLmobiles and abbreviated ticketing methods. Reservations are held up to five minutes prior to departure. From the time a passenger disembarks the aircraft at the Montreal STOLport until he arrives in the downtown area averages between 10 and 15 minutes. Author

N77-14988# Defence Research Establishment Valcartier (Quebec).
TRANSVERSELY EXCITED ATMOSPHERE (TEA): CO2 LASER DEVELOPMENT AND APPLICATIONS
J. Gilbert *In* AGARD 11th AGARD Ann. Meeting Feb. 1976 p 45-57 (For primary document see N77-14982 06-01)
Avail: NTIS HC A04/MF A01

Military applications of the TEA-CO2 laser are considered. These are of two main types: radar type applications, and use of the laser as a weapon. In radar we are dealing with relatively low energy transmission over a two way path; in the case of the weapon, high energy is transmitted over a one way path. The factors which must be taken into account in assessing the feasibility of using a laser in a military system are: atmospheric propagation, target characteristics, laser technology, detection technology and, as systems become more sophisticated, countermeasures. Author

N77-16982 Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium)
COLLECTED WORKS OF THEODORE VONKARMAN, 1952 - 1963
1975 393 p refs
Copyright. Avail: Advisory Group for Aerospace Research and Development, Paris

Scientific and technical writings by Von Karman, as well as those of transient or historical significance were collected from various journals and proceedings. Five of the papers reflect his interest in interdisciplinary studies concerned with magnetofluid-mechanics and aerothermochemistry. Editorial comments are presented as introductions to certain papers in order to relate the subject matter to the body of scientific and technical literature in the four volume compilation by Dr. Hugh Dryden. A.H.

N77-16984# Advisory Group for Aerospace Research and Development, Paris (France).
THE AGARD HISTORY, 1952 - 1975
1976 189 p
(ISBN-92-835-1206-5) Avail: NTIS HC A09/MF A01

The evolution of AGARD was presented from the year 1952 through 1975. S.M

N77-16985# Advisory Group for Aerospace Research and Development, Paris (France).
DIRECTOR'S ANNUAL REPORT TO THE NORTH ATLANTIC MILITARY COMMITTEE, 1975
Mar 1976 83 p
Avail: NTIS HC A05/MF A01

Agard publications for 1975 and abstracts of the publications by panel or activity are listed. Aerospace medicine, avionics, electromagnetic wave propagation, flight dynamics, and guidance and control are several of the topics considered. S.M

N77-17948# Advisory Group for Aerospace Research and Development, Paris (France)

NATIONAL DELEGATES BOARD MEETING. TECHNICAL PRESENTATIONS ON SCIENTIFIC AND TECHNOLOGICAL FORECASTING

Jun 1976 31 p In ENGLISH; partly in FRENCH Conf held at Paris, 18 Mar 1976

(ISBN-92-835-0170-0) Avail: NTIS HC A03/MF A01

There are three papers presented on scientific and technological forecasting delivered at the Technical Presentations Session of the AGARD Spring 1976 National Delegates Board Meeting. Author

N76-70246 Advisory Group for Aerospace Research and Development, Paris (France).

AGARD HIGHLIGHTS 75/1, MARCH 1975

20p

(AGARD-HIGHLIGHTS-75/1)

Scientific and technological developments expected in the next 10-15 years in the field of fluid dynamics are discussed. Computational fluid dynamics, wind tunnel scale effects and testing techniques, and design of fuel conservative aircraft are considered. Special emphasis is given to advancement in semiconductor technology and development of microprocessors and charge coupled devices in relation to military applications of such technology to electronic warfare and custom design of large scale integrated circuits J.M.S.

N76-70247 Advisory Group for Aerospace Research and Development, Paris (France).

AGARD HIGHLIGHTS 75/2, SEPTEMBER 1975

Presented at the AGARD Flight Mech. Pannel / Guidance and Control Panel Joint Symposium on the Impact of Active Control Technol. on Airplane Design, Paris, Oct. 1974

25p

(AGARD-HIGHLIGHTS-75/2)

Various aspects of research and development in aerospace sciences are discussed. Specific topics considered include: (1) the impact of active control technology on aircraft design; (2) development of calculation methods for oscillating wings in subsonic flow; (3) technological and economic growth in aeronautics in relation to private and government funded research; and (4) the use of computer programs in aircraft design. J.M.S.

02 AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces, and internal flow in ducts and turbomachinery. For related information see also *34 Fluid Mechanics and Heat Transfer*.

N75-10003# Advisory Group for Aerospace Research and Development, Paris (France)
HINGELESS ROTORCRAFT FLIGHT DYNAMICS
Kurt H. Hohenemser (Washington Univ., St. Louis) and Robert A. Ormiston, ed. (Army Air Mobility R and D Lab., Moffett Field, Calif.) Sep. 1974 60 p refs
(AGARD-AG-197, AGARDograph-197) Avail: NTIS HC $3.75

The state of hingeless rotorcraft research and development in the NATO countries as of 1973 is described. The scope of this report is limited to flight dynamics since most of the hingeless rotorcraft problems have occurred in this area. The special place of the hingeless rotorcraft within the family of rotorcraft is considered. The chapter on the history of hingeless rotorcraft describes the hingeless rotor research and development of the various rotorcraft manufacturers and the hingeless rotor research at government laboratories and universities. A hierarchy of dynamic concepts from isolated blade dynamics to complete rotor/body dynamics is introduced. The effects of the basic rotor design parameters on flight dynamics are traced and certain hingeless rotorcraft problems are treated in some detail. A special chapter is devoted to the alleviation of hingeless rotor flight-dynamics problems by feedback control systems. Analytical modeling techniques, mathematical analysis techniques, and model and flight testing techniques for hingeless rotorcraft are discussed.
Author

N75-13795# Advisory Group for Aerospace Research and Development, Paris (France).
V/STOL AERODYNAMICS
Oct. 1974 355 p refs Partly in ENGLISH and partly in FRENCH Proc. of the Fluid Dyn. Panel Symp., Delft, Netherlands, 24-26 Apr. 1974
(AGARD-CP-143) Avail: NTIS HC $10.00

The proceedings of a conference on the design, development, and flight characteristics of V/STOL aircraft are presented. The subjects discussed include the following: (1) powered high lift systems, (2) mechanical high lift systems, (3) jet lift, (4) ground effect, and (5) aerodynamic prediction methods and simulation requirements. Examples of V/STOL aircraft configurations are illustrated. Specific performance parameters, actual and predicted, are analyzed in graph form. Numerical methods for determining aerodynamic characteristics from wind tunnel and flight tests are developed. For individual titles, see N75-13796 through N75-13821.

N75-13796* National Aeronautics and Space Administration, Ames Research Center, Moffett Field, Calif.
V/STOL AERODYNAMICS: A REVIEW OF THE TECHNOLOGY
David H. Hickey *In* AGARD V/STOL Aerodyn. Oct. 1974 13 p refs (For availability see N75-13795 05-02)
CSCL 01C

An analysis of the development and technological applications of V/STOL aircraft is presented. The use of V/STOL aircraft to overcome the limitations of conventional aircraft is discussed. The aspects of V/STOL aircraft which are considered are: (1) economic penalties of propulsive lift, (2) advantages of propulsive lift, (3) potential improvements in V/STOL aircraft, (4) the aerodynamics of V/STOL aircraft, and (5) proposals for additional research in V/STOL development.
Author

N75-13797 De Havilland Aircraft Co., Ltd., Downsview (Ontario)
RESEARCH INTO POWERED HIGH LIFT SYSTEMS FOR AIRCRAFT WITH TURBOFAN PROPULSION
B. Eggleston *In* AGARD V/STOL Aerodyn. Oct. 1974 17 p refs (For availability see N75-13795 05-02)

The characteristics and applications of powered high lift systems suitable for turbofan powered aircraft are reviewed. Aerodynamic research conducted on high lift systems for use with high bypass ratio turbofan engines are reported. The systems discussed include: (1) mechanical flaps, (2) internally blown flaps, (3) externally blown flaps, and (4) vectored thrust. Tests on two-dimensional and three-dimensional models were conducted and the aerodynamic characteristics are applied to design studies of a turbofan powered short takeoff and landing transport aircraft. The application of computerized three-dimensional potential flow method to lift prediction for a wing with internally blown flaps is described.
Author

N75-13798 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
PREDICTING THE MAXIMUM LIFT OF JET-FLAPPED WINGS
David J. Moorhouse *In* AGARD V/STOL Aerodyn. Oct. 1974 9 p refs (For availability see N75-13795 05-02)

A method for predicting the maximum lift of jet flap configurations is presented. The three parts of the process are described. A theoretical expression for the increment in maximum lift due to blowing on jet-flapped airfoils was obtained that was based on the assumption of a leading-edge stall. For practical application a three-dimensional theory is required, with suitable corrections for finite aspect ratio and part span flaps. The expression shows agreement with measured results for pure jet flaps, internally blown flaps, externally blown flaps, and upper surface blown flaps. It was determined that the results are independent of the actual presence of a leading edge stall, independent of the sweep angle, and applicable to aspect ratios greater than approximately three.
Author

N75-13799 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
WIND TUNNEL INVESTIGATION OF THREE POWERED LIFT STOL CONCEPTS
R. F. Osborn and G. S. Oates *In* AGARD V/STOL Aerodyn. Nov. 1974 12 p refs (For availability see N75-13795 05-02)

A comprehensive, parametric wind tunnel investigation of three short takeoff and landing aircraft concepts was conducted. The three STOL configurations were: (1) the externally blown flap (EBF), (2) internally blown flaps (IBF), and (3) the mechanical flap/vectored thrust (MF/VT). Wind tunnel model characteristics are shown as well as the details of the high lift devices tested. The effect of engine location is discussed and is shown to be the dominant factor in EBF and MF/VT powered lift performance. Wing sweep and aspect ratio effects on lifting performance are analyzed. Performance in ground effect is covered using the test data collected. Incremental changes in the lift, drag, and pitching moment characteristics resulting from in-ground effect operation are explained. A comparison of the aerodynamic performance of the three powered lift systems is included.
Author

N75-13800 National Aeronautical Establishment, Ottawa (Ontario). Low Speed Aerodynamics Lab.
THE SPANWISE LIFT DISTRIBUTION AND TRAILING VORTEX WAKE DOWNWIND OF AN EXTERNALLY BLOWN JET FLAP
R. H. Wickens *In* AGARD V/STOL Aerodyn. Oct. 1974 23 p refs (For availability see N75-13795 05-02)

The aerodynamic characteristics of externally blown flaps (EBF) are presented for configurations of the quasi-two dimensional and reflection-plane type. Force and surface pressure measurements have shown that significant lift increments can be realized by external blowing, and that the spanwise effect of this increase extends outward from the nacelle location. The effective stream tube dimension of the additional lift can be a significant fraction of the wing span. Downstream flow surveys have shown that the presence of mixed regions of propulsive and vortex flows is typical of the EBF, particularly for multi-engined finite wing configurations. The characteristics of wake measurements downwind of a half-model of a multi-engine aircraft of the EBF type are described.
Author

N75-13801 Royal Aircraft Establishment, Bedford (England).
THE FLOW AROUND A WING WITH AN EXTERNAL FLOW JET FLAP
P. R. Ashill and D. N. Foster *In* AGARD V/STOL Aerodyn. Oct. 1974 13 p refs (For availability see N75-13795 05-02)

The main features of the flow around a wing with an externally blown jet flap are discussed. Measurements were made, under wind-on and wind-off conditions, on a half model of a wing-fuselage with an injector powered nacelle mounted under the wing. Analysis of the velocity distributions measured in the jet at the trailing edge of the flap suggests that the turning and spreading process is sensibly independent of forward speed. The sweepback effect on the spanwise distribution of momentum towards the wing tip is investigated. It was determined that the

spanwise distributions of lift and pressure drag, derived from static pressure measurements made under wind-on conditions, exhibit a pronounced nonuniformity in the vicinity of the nacelle. It is stated that the jet flap effect on the total lift is small.
Author

N75-13802 Canadair, Ltd., Montreal (Quebec).
INVESTIGATION OF EXTERNALLY BLOWN FLAP AIRFOILS WITH LEADING EDGE DEVICES AND SLOTTED FLAPS
Fotis Mavriplis and David Gilmore *In* AGARD V/STOL Aerodyn. Oct 1974 12 p refs (For availability see N75-13795 05-02)

An investigation was conducted to provide information on the aerodynamics of externally blown flap systems and to establish the correspondence of such systems, in which the flap is blown by a jet of circular cross section, with two dimensional jet flaps. Wind tunnel tests were conducted with a two dimensional high lift wing model and a tip turbine fan having a diameter-to-wing chord ratio of 0.365. A semi-empirical two dimensional method is also presented which is an extension of the theory for thin multi-element airfoils and a nonlinear jet geometry. The measured data provided useful empirical relationships for estimating the two dimensional C sub L max and C sub D.
Author

N75-13803 Societe Bertin et Cie, Plaisir (France).
PRESENTATION OF AERODYNAMIC AND ACOUSTIC RESULTS OF QUALIFICATION TESTS ON THE ALADIN 2 CONCEPT [PRESENTATION DES RESULTATS AERODYNAMIQUES ET ACOUSTIQUES DES ESSAIS DE QUALIFICATION OU CONCEPT ALADIN 2]
Maurice Collard, Claude Doyotte, and Max Sagner *In* AGARD V/STOL Aerodyn. Oct. 1974 12 p refs In FRENCH (For availability see N75-13795 05-02)

Wind tunnel tests were conducted of a scale model of the Aladin 2 aircraft. The propulsion system configuration is described and the air flow caused by jet ejection is analyzed. Three dimensional flow studies in the vicinity of the engine installation were made. Diagrams of the leading and trailing edge flaps are provided. Graphs are developed to show the aerodynamic performance under conditions of various airspeed and flap deflection.
Author

N75-13804 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THEORETICAL AND EXPERIMENTAL STUDY OF BOUNDARY LAYER CONTROL BY BLOWING AT THE KNEE OF A FLAP
Bernard Monnerie and Guy Lovat *In* AGARD V/STOL Aerodyn Oct. 1974 20 p refs In FRENCH; ENGLISH summary (For availability see N75-13795 05-02)

An investigation of lift augmentation by boundary layer blowing was conducted. The test equipment consisted of a large scale mounting for the study of two dimensional boundary layers. The tests were conducted in a low speed wind tunnel three meters in diameter. The experimental results obtained by probing the jet-boundary layer mixing zone are presented. The results are compared with computations using a turbulence model based on the Nee-Kovasznay equation for the viscosity coefficient.
Author

N75-13805* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
AERODYNAMICS OF JET FLAP AND ROTATING CYLINDER FLAP STOL CONCEPTS
Woodrow L. Cook, David H. Hickey, and Harvey C. Quigley *In* AGARD V/STOL Aerodyn. Oct. 1974 6 p refs (For availability see N75-13795 05-02)
CSCL 01C

The aerodynamic effectiveness of various propulsive lift concepts to provide for the low speed performance and control required for short takeoff and landing aircraft is discussed. The importance of the interrelationship between the propulsion system and aerodynamic components of the aircraft is stressed. The relative effectiveness of different lift concepts was evaluated through static and wind tunnel tests of various aerodynamic models and propulsion components, simulations of aircraft, and in some cases, flight testing of research aircraft incorporating the concepts under study. Results of large scale tests of lift augmentation devices are presented. The results of flight tests of STOL research aircraft with augmented jet flaps and rotating cylinder flaps are presented to show the steeper approach flight paths at low forward speeds.
Author

N75-13806 Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
PROGRESS REPORT ON MECHANICAL FLAPS
P. Perrier and M. Lavenant *In* AGARD V/STOL Aerodyn. Oct 1974 15 p refs In FRENCH; ENGLISH summary (For availability see N75-13795 05-02)

The development of wing lift augmentation for short takeoff aircraft is discussed. The problems associated with powered lift created interest in designing mechanical high lift devices capable of lift coefficient greater than 4. To obtain such a coefficient, computerized techniques were used. A wing with powerful mechanical high lift devices was designed with a combined use of theoretical aerodynamic methods and experience gained in developing the advanced mechanical systems. Comparisons between estimated and test results are provided.
Author

N75-13807 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
A METHOD FOR PREDICTION OF LIFT FOR MULTI-ELEMENT AIRFOIL SYSTEMS WITH SEPARATION
K. Jacob and D. Steinbach *In* AGARD V/STOL Aerodyn Oct. 1974 16 p refs (For availability see N75-13795 05-02)

A numerical procedure is presented for analyzing the performance of high lift devices such as leading edge slats and slotted flaps. The method also makes it possible to predict pressure distributions and lift for many arbitrary airfoil combinations in incompressible flow. The method considers the boundary layer displacement effect and allows for rear separation with a dead air region. The maximum lift can be predicted on the basis of the geometry of the system and the Reynolds number of the flow. The method has been programmed in FORTRAN for the IBM 360-65 computer and has been applied to several airfoil combinations. Diagrams of the flow characteristics of the airfoils under varying conditions are provided. The mathematical models which support the theoretical aspects are developed.
Author

N75-13808 Aeronautical Research Inst. of Sweden, Stockholm.
EXPERIMENTAL HIGH LIFT OPTIMIZATION OF MULTIPLE ELEMENT AIRFOILS
Bjoern L. G. Ljungstroem *In* AGARD V/STOL Aerodyn. Oct. 1974 16 p refs (For availability see N75-13795 05-02)

The application of two dimensional testing and two dimensional wind tunnel techniques for experimental high lift investigations is discussed. The tests conducted on geometrical variations of double and triple slotted mechanical flaps are described. It is shown that an optimum slat position corresponds to a flow with relatively little interaction between the slat wake and the main wing and flap boundary layers. Similar results were also obtained for the trailing edge, where it is found that the different viscous layers should be kept essentially separated from each other. The interrelationship between the flow over the leading-edge slats and that over the trailing-edge flaps is analyzed. The calculation methods consist of a potential flow method and a method in which the boundary layer effects are considered.
Author

N75-13809 British Columbia Univ., Vancouver
THE AERODYNAMICS OF TWO-DIMENSIONAL AIRFOILS WITH SPOILERS
G. V. Parkinson, G. P. Brown, and T. Jandali *In* AGARD V/STOL Aerodyn. Oct. 1974 10 p refs Sponsored by Defence Res. Board of Canada (For availability see N75-13795 05-02)

The development of three incompressible potential flow methods for two dimensional airfoils with upper surface spoilers is discussed. A linearized free stream theory is used to predict the steady and transient lift on thin, single-element airfoils of arbitrary incidence, camber, and thickness, with spoilers of arbitrary position, height, and inclination. Theories for determining the pressure distribution on thick airfoils are reported. Wind tunnel measurements of steady and transient lift and pressure distribution have been made using two different airfoil profiles with several different spoiler sizes, positions, and inclinations.
Author

N75-13810 Politecnico di Milano (Italy). Instituto di Ingegneria Aerospaziale
THE EFFECT OF VORTEX GENERATORS ON THE DEVELOPMENT OF A BOUNDARY LAYER
Sergio DePonte and Arturo Baron *In* AGARD V/STOL Aerodyn. Oct. 1974 5 p refs (For availability see N75-13795 05-02)

The development of computer techniques for predicting the aerodynamic characteristics of an airfoil in the presence of vortex generators is discussed. An experimental program to investigate the turbulent structure of the vortex was conducted. It was

determined that the vorticity profiles are very similar to those characterizing the viscous case, although the vortex was turbulent. A model of vortex-boundary layer interaction was constructed. The model is the basis of many conclusions about the application of vortex generators as a means of boundary layer control.
Author

N75-13811 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany)
JET LIFT PROBLEMS OF V/STOL AIRCRAFT
J. Baiche *In* AGARD V/STOL Aerodyn. Oct. 1974 18 p refs (For availability see N75-13795 05-02)

The effect of jet lift interference on the design of jet-supported V/STOL aircraft is discussed. The basic flow problems which are assumed to be valid for all types of V/STOL aircraft are analyzed. The operational aspects of military V/STOL aircraft are examined. The specific problems of V/STOL operation involving transition flight, pitch control and stability, lateral/direction, control and stability, hovering flight, and recirculation of the jet exhaust are presented.
Author

N75-13812 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany).
SIDESLIP IN VTOL-TRANSITION FLIGHT: A CRITICAL FLIGHT CONDITION AND ITS PREDICTION IN SIMPLE WIND TUNNEL TESTS
B. Ewald *In* AGARD V/STOL Aerodyn. Oct. 1974 13 p refs (For availability see N75-13795 05-02)

Wind tunnel tests were conducted to analyze the performance of the VAK 191 B VTOL aircraft during transition flight. The procedures for conducting the wind tunnel tests are explained. It was determined that the ratio of jet momentum and free stream momentum is the most important scaling parameter for the influence of the jet on the external flow field. The results of the wind tunnel tests are compared with flight test results to determine the extent of agreement. Based on the wind tunnel tests, development of the aircraft automatic altitude control system and a system for pilot training in the flight simulator was completed.
Author

N75-13813 National Aerospace Lab., Amsterdam (Netherlands).
A METHOD FOR THE CALCULATION OF THE FLOW FIELD INDUCED BY A JET EXHAUSTING PERPENDICULARLY INTO A CROSS FLOW
H. Snel *In* AGARD V/STOL Aerodyn. Oct. 1974 16 p refs (For availability see N75-13795 05-02)

A description is given of a method for the calculation of the potential flow field arising from the interaction of a turbulent jet with a uniform free stream. The method is applied to the case of a jet moving perpendicularly into a cross flow. The model assumes the jet to entrain free stream mass together with its free stream momentum. The decay of axial velocity in the jet is used as empirical input. The geometry of the jet surface and jet entrainment follow from the model. A set of quadratic equations, describing mass and momentum transfer from the exterior flow to the jet, consistent with equations used for the jet model, yields the normal velocity distributions and the source strengths of the surface panels.
Author

N75-13814 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio. Prototype Div.
DESIGN AND TEST OF EJECTOR THRUST AUGMENTATION CONFIGURATIONS
S. L. Brown and R. D. Murphy *In* AGARD V/STOL Aerodyn. Oct. 1974 12 p refs (For availability see N75-13795 05-02)

The application of hypermixing primary injection nozzle devices for operational vertical takeoff aircraft is discussed. Preliminary design studies have been directed toward subsonic and supersonic VTOL close air support fighters. In addition to demonstrating the feasibility of the ejector thrust augmentation (EVA), special problems in the areas of engine cycle characteristics, internal aerodynamics, and external dynamics were investigated. Two-dimensional wind tunnel tests were conducted to analyze the external aerodynamic problem areas. One test investigates the vertical flight mode and the other test investigates the transition flight mode.
Author

N75-13815 Ruhr Univ., Bochum (West Germany)
GROUND EFFECT ON AIRFOILS WITH FLAPS OR JET FLAPS
K. Gersten, R. Loehr, and E. Beese *In* AGARD V/STOL Aerodyn. Oct. 1974 12 p refs (For availability see N75-13795 05-02)

The two-dimensional incompressible flow past airfoils with flaps or jet flaps near the ground is investigated. The inviscid flow is calculated by potential theory methods. It is shown that the nonlinear effects due to large angles of attack and flap angles become increasingly important as airfoils approach the ground. For airfoils with jet flaps, wind tunnel tests, including ground simulation, have been carried out. The theoretical results are compared with experiments and with linear theory.
Author

N75-13816* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
MEASUREMENT OF TILT ROTOR VTOL ROTOR WAKE-AIRFRAME GROUND AERODYNAMIC INTERFERENCE FOR APPLICATION TO REAL TIME FLIGHT SIMULATION
Troy M. Gaffey (Bell Helicopter Co., Ft. Worth, Tex.) and Martin D. Maisel *In* AGARD V/STOL Aerodyn. Oct. 1974 12 p refs (For availability see N75-13795 05-02)
CSCL 01C

The hover and low speed rotor wake-airframe-ground aerodynamic characteristics of the XV-15 tilt rotor research aircraft were determined in wind tunnel tests of a scale model. Results of the wind tunnel tests were applied to real flight time simulation. The principal findings of the wind tunnel tests are summarized. The effect of aerodynamic interference on the handling qualities of the aircraft is analyzed. It was determined that aerodynamic interference effects are significant in hover and at low speeds, with the influence being more pronounced in ground effect than out of it. At airspeeds above 60 knots, aerodynamic interference does not have a significant effect on handling characteristics.
Author

N75-13817 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio. Flight Control Div.
US AIR FORCE V/STOL AIRCRAFT AERODYNAMIC PREDICTION METHODS
Henry W. Woolard *In* AGARD V/STOL Aerodyn. Oct. 1974 14 p refs (For availability see N75-13795 05-02)

Analytical methods for the prediction of the aerodynamic characteristics of V/STOL aircraft are reviewed. The aerodynamic characteristics of short takeoff aircraft are discussed with emphasis on high lift systems using internally-blown flaps, under the-wing externally-blown flaps, and mechanical flaps combined with thrust vectoring. The power-induced aerodynamics of lift-jet, lift-fan, and vectored-thrust V/STOL aircraft operating in hover and transition flight regimes are examined. Emphasis is placed on describing selected methods that employ rational analytical modeling of the real aerodynamics in conjunction with empirical modifications as required.
Author

N75-13818 Dornier-System G.m.b.H., Friedrichshafen (West Germany).
PREDICTION OF AERODYNAMIC INTERFERENCE EFFECTS WITH JET-LIFT AND FAN-LIFT VTOL AIRCRAFT
Dieter Welte *In* AGARD V/STOL Aerodyn. Oct. 1974 9 p refs (For availability see N75-13795 05-02)

A guide-line for a rough estimation of the jet induced lift losses of VTOL aircraft configurations with jet-lift and fan-lift engines hovering in and out of ground effect is presented. The nature and magnitude of the aerodynamic jet interference effects is found empirically by dimensional analysis of the flow field and by measurements. Jet induced lift losses and pitching moments with forward speeds are discussed on the basis of wind tunnel measurements.
Author

N75-13819 British Aircraft Corp., London (England). Military Aircraft Div.
A REVIEW OF THE LIFTING CHARACTERISTICS OF SOME JET LIFT V/STOL CONFIGURATIONS
P. G. Knott and J. J. Hargreaves *In* AGARD V/STOL Aerodyn. Oct. 1974 12 p refs (For availability see N75-13795 05-02)

Changes to the wing lift that occur as a result of the interaction between the lifting jet efflux and the free stream are discussed. Attempts to develop empirical models for predicting the aerodynamic characteristics are described. Data correlation attempts are discussed with respect to a curve fitting exercise using data from tests on a finite wing with jet size and position as variables, and a method which approximates the lift to thrust coefficient relationship linearly. It is stated that the location of the lift jets is one of the most fundamental parameters and test results are presented to show some of the lift trends. Results from tests conducted in ground effect in both hover and forward speed are discussed.
Author

N75-13820* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
REQUIREMENT FOR SIMULATION IN V/STOL RESEARCH AIRCRAFT PROGRAMS
Harvey C. Quigley and Curt A. Holzhauser *In* AGARD V/STOL Aerodyn. Oct. 1974 11 p refs (For availability see N75-13795 05-02)
CSCL 01C

The application of flight simulation to aircraft design and development is discussed. The general stages of aircraft development are defined. The application of flight simulation to the following projects is reported: (1) the development and flight research of the Augmented Jet-Flap STOL research aircraft and (2) design studies of advanced VTOL research aircraft. It is stated that the simulation projects proved significant in helping establish criteria for the aircraft design and in facilitating the study of problems associated with new flight profiles, new methods of control, and special emergency conditions. Author

N75-13821 Kingston Polytechnic, Kingston-Upon-Thames (England)
A LITERATURE SURVEY ON JETS IN CROSSFLOW
E. C. P. Ransom and P. M. Wood *In* AGARD V/STOL Aerodyn. Oct. 1974 7 p refs (For availability see N75-13795 05-02)

The important features of a literature survey on the interference effects of jets in cross flow are outlined. The catalog lists the reports reviewed and contains a tabulation of data in terms of the independent variables, dependent variables, and test techniques. The experimental work is considered with respect to the following: (1) the fluid and geometrical properties of the jet and cross flow and (2) the geometrical arrangement of the aerodynamic elements. Author

N75-22280# Advisory Group for Aerospace Research and Development, Paris (France)
AIRCRAFT STALLING AND BUFFETING
Feb. 1975 189 p refs In ENGLISH, partly in FRENCH (AGARD-LS-74) Avail: NTIS HC $6.25

Lectures on the subject of aircraft stalling and buffeting are presented. The scope of the presentations involves recent developments in the understanding of the fluid dynamics of aerodynamic stalling and buffeting, the dynamic response of the aircraft, and techniques for buffet prediction, with consideration of the implications for aircraft design. For individual titles, see N75-22281 through N75-22287.

N75-22281 Royal Aircraft Establishment, Bedford (England)
AIRCRAFT STALLING AND BUFFETING: INTRODUCTION AND OVERVIEW
C. R. Taylor *In* AGARD Aircraft Stalling and Buffeting Feb. 1975 18 p refs (For availability see N75-22280 14-02)

The phenomena of aircraft stalling and buffeting are analyzed with respect to the influence exerted by various aerodynamic configurations. Variations of the lift coefficient of a wing with changes in angle of incidence and Mach number are examined to show the effect on the stalling characteristics. Aerodynamic designs which provide a uniform pressure distribution as a method for delaying the onset of aerodynamic stall are described. Block diagrams are developed to show the relationships of aerodynamic forces and aerodynamic effects for structural buffeting and rigid-body dynamics. The limitations imposed on aircraft maneuverability by the onset of aerodynamic stall are explained. Author

N75-22282 Douglas Aircraft Co., Inc., Long Beach, Calif.
REMARKS ON FLUID DYNAMICS OF THE STALL
A. M. O. Smith *In* AGARD Aircraft Stalling and Buffeting Feb. 1975 33 p refs (For availability see N75-22280 14-02)

An analysis of aerodynamic stalling based on fluid mechanics phenomena is presented. Emphasis is placed on the flow separation which occurs during a stall and flow photographs of such events are provided. Limits to pressure rise for both laminar and turbulent flows are given, as well as their general theory. The effects of Reynolds number, Mach number, and airfoil shape on flow separation are examined. Diagrams of the conditions existing in full aircraft stall and buffeting process are developed. The problem of calculating flows with separation is discussed. Author

N75-22283 Boeing Co., Seattle, Wash.
PREDICTION AND ANALYSIS OF THE LOW SPEED STALL CHARACTERISTICS OF THE BOEING 747
William McIntosh and John K. Wimpress *In* AGARD Aircraft Stalling and Buffeting Feb. 1975 21 p (For availability see N75-22280 14-02)

Wind tunnel tests for estimating the stall speed of the Boeing 747 aircraft were conducted. The test results were adjusted to full scale flight values using correlation factors developed from other transport aircraft designs. Flight results showed a reasonable degree of success in predicting stall speeds. A further analysis was made to show the effects of aeroelastic and airplane dynamics in accurately predicting aerodynamic stall. Author

N75-22284 Office National d'Etudes et de Recherches Aerospatiales, Paris (France)
FLOW SEPARATION AND AERODYNAMIC EXCITATION AT TRANSONIC SPEEDS
B. Monnerie *In* AGARD Aircraft Stalling and Buffeting Feb. 1975 14 p refs In FRENCH; ENGLISH summary (For availability see N75-22280 14-02)

The effects that the birth and growth of separated flow areas on an aerospace vehicle surface have on aerodynamic stalling and buffeting are discussed. The separated flow areas are defined as those points of turbulent flow which produce high level pressure fluctuations and excite the vehicle structure. The influence of strong positive pressure gradients in the transonic regime is analyzed. The computation of buffeting intensity is analyzed with respect to the characteristics of the unsteady pressure field. Author

N75-22285 Royal Aircraft Establishment, Bedford (England).
AIRCRAFT DYNAMIC RESPONSE ASSOCIATED WITH FLUCTUATING FLOW FIELDS
J. G. Jones *In* AGARD Aircraft Stalling and Buffeting Feb. 1975 15 p refs (For availability see N75-22280 14-02)

The interactions of fluctuating flow fields and the dynamic response of aircraft structures which results in buffeting are discussed. A basic feature of the dynamic analysis of buffeting is the closed-loop interaction between the fluctuating fluid motion and the motion of the wing surface. The problem of formulating an appropriate theoretical model for structural buffeting is discussed, together with the analogous situation involving response in rigid-body modes, including the oscillatory motion known as wing-rocking. Author

N75-22286 British Aircraft Corp., Warton (England). Aerodynamics Dept.
PRE-STALL BEHAVIOR OF COMBAT AIRCRAFT
D. E. Shaw *In* AGARD Aircraft Stalling and Buffeting Feb. 1975 18 p refs (For availability see N75-22280 14-02)

High incidence, pre-stall behavior of combat aircraft is discussed in terms of fluid flow characteristics and the corresponding flight dynamic phenomena. Emphasis is placed on the aerodynamic phenomena which are defined as wing-rock. The phenomena are associated with a collapse of the dutch roll characteristics to a divergent rolling oscillation and with the rigid airframe response in the dutch roll mode to the low frequency content of wing buffet. Author

N75-22287 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
CRITICAL REVIEW OF METHODS TO PREDICT THE BUFFET PENETRATION CAPABILITY OF AIRCRAFT
Helmut John *In* AGARD Aircraft Stalling and Buffeting Feb. 1975 29 p refs (For availability see N75-22280 14-02)

A general survey of methods for predicting the buffet penetration capability of various aircraft is presented. The influence of aerodynamic buffeting on the performance and maneuverability of aircraft is discussed. The prediction of buffeting intensity on the basis of mean aerodynamic loads is examined. Mathematical models of the buffet response to determine loads and peak accelerations are developed. Wind tunnel tests for determining stall characteristics using a forced vibration model in one case and a nonlinear flutter model in the second case are described. Author

N75-23485# Advisory Group for Aerospace Research and Development, Paris (France)
AIRFRAME/PROPULSION INTERFERENCE
Mar. 1975 419 p refs In ENGLISH; partly in FRENCH Presented at the Fluid Dyn. Panel Symp., Rome, 3-6 Sep. 1974 (AGARD-CP-150) Avail: NTIS HC $10.50 CSCL 01A

The proceedings are reported of the Fluid Dynamics Panel Symposium held in Rome. Research on airframe/propulsion interference, and the design of combat and trancport aircraft were discussed. For individual titles, see N75-23486 through N75-23513

N75-23486 Office National d'Etudes et de Recherches Aerospatiales, Paris (France)
INTERACTION PROBLEMS BETWEEN AIR INTAKES AND AIRCRAFT [PROBLEMES D'INTERACTIONS ENTRE LA PRISE D'AIR ET L'AVION]
Jacky Leynaert *In* AGARD Airframe/Propulsion Interference Mar 1975 11 p refs In FRENCH (For availability see N75-23485 15-02)

The definition of the interaction terms between the air intake and the airframe, and the theoretical and experimental tools used to study the problem for subsonic or supersonic aircraft are presented. Some examples of the influence of a nonuniform upstream flow on the internal flow characteristics of supersonic intakes are given, and some means of adjusting the inlet to a nonuniform flow, mainly for flight with incidence or yaw, are analyzed Author

N75-23487 Northrop Corp., Hawthorne, Calif.
A CRITERION FOR PREDICTION OF AIRFRAME INTEGRATION EFFECTS ON INLET STABILITY WITH APPLICATION TO ADVANCED FIGHTER AIRCRAFT
Gordon R. Hall *In* AGARD Airframe/Propulsion Interference Mar 1975 15 p refs (For availability see N75-23485 15-02)

A simple criterion for the prediction of the effects of aircraft external flow field on installed inlet stability is presented. Wind tunnel data obtained from model tests of an advanced fighter aircraft are used to provide a base for discussion of installed inlet instability and to demonstrate the instability criterion. Specifically, two sources of supersonic inlet instability are identified, the instability mechanism is discussed and an instability criterion is defined, and application of the criterion is demonstrated. The sources of instability include ingestion of separated fuselage boundary layer at high aircraft attitude and ingestion of a vortex generated by a wing leading edge extension at negative attitude. A common stability criterion accounting for the effect of freestream Mach number, aircraft attitude, and inlet mass flow ratio is postulated and confirmed by available data. This same criterion is discussed in relation to observed cases of subsonic inlet instability and inlet instability resulting from slipstream ingestion. Application of the criterion to evaluate the effects of configuration changes on inlet stability boundaries is demonstrated Author

N75-23488 Aircraft Research Association, Ltd., Bedford (England)
THE MEASUREMENT OF THE TRANSONIC SPILLAGE DRAG OF A SUPERSONIC INTAKE
S A M Thornley and E C Carter *In* AGARD Airframe/Propulsion Interference Mar 1975 13 p refs (For availability see N75-23485 15-02)

The technique is described in current use at the Aircraft Research Association for the measurement of the transonic spillage drag of a two dimensional, ramp intake. The method requires the calibration of the intake duct system for both mass flow and exit momentum. The technique is equally applicable to supersonic testing. The achieved repeatability of the measurements allows intake configuration differentiation to + or - 1% in aircraft drag for a typical supersonic fighter aircraft at high subsonic speed. Theoretically based calculations show satisfactory agreement with the measurements both for a range of intake mass flow and for intake ramp angle changes. The technique is economical and suitable for routine testing. General comments on the merits of methods available for the measurement of spillage drag using the balance mounted and whole model technique are presented together with recommendations for further technique development Author

N75-23489 Grumman Aerospace Corp., Bethpage, N.Y.
AN EXPERIMENTAL INVESTIGATION OF THE COMPONENT DRAG COMPOSITION OF A TWO-DIMENSIONAL INLET AT TRANSONIC AND SUPERSONIC SPEEDS
Clifton J. Callahan *In* AGARD Airframe/Propulsion Interference Mar 1975 16 p refs (For availability see N75-23485 15-02)

An experimental study was performed to establish the separate drag force contributions of the principal components of a rectangular, two-dimensional, external compression type, supersonic air induction inlet system. Concurrently, inlet system performance was measured in terms of engine face total pressure recovery and spacial flow distortion, and the possibility for tradeoff between inlet system drag and performance was explored. A scale model of the forebody, including air inlet and duct systems, of an advanced, twin engine, strike aircraft was employed for the study. The wind tunnel model arrangement utilized a dual-balance technique to measure forebody and the inlet forces separately. The effects on the air induction system and vehicle forebody due to inlet component changes and varying propulsion air flow requirement were identified. The major inlet variables in the investigation included cowling lip and sidewall geometries, boundary layer bleed and air bypass exhaust configuration, and compression surface deflection schedule. The wind tunnel testing was conducted in closed circuit, continuous flow test facilities over a full range of supersonic and transonic speeds and representative ranges of vehicle angles of attack and sideslip. Three significant aspects of the program are addressed: inlet and vehicle configuration integration, wind tunnel model arrangement for force data measurement, and measured drag and performance results. These data can be broadly divided according to cowling, side wall, and bleed/bypass effects in order to display major trends in drag and performance for the investigated transonic and supersonic speed regimes Author

N75-23490 National Aerospace Lab., Amsterdam (Netherlands).
JET INTERFERENCE OF A PODDED ENGINE INSTALLATION AT CRUISE CONDITIONS
B Munniksma and F Jaarsma *In* AGARD Airframe/Propulsion Interference Mar 1975 16 p refs (For availability see N75-23485 15-02)

The results of an experimental wind tunnel test program on the wing-pylon-bypass engine combination of the Airbus A 300 B airplane are presented. Only aerodynamic interference due to the engine jet was considered. For determining the interference drag due to the engine jet as well as to have the possibility to extrapolate the test results from model reference conditions to full scale a test scheme was developed. To prove the validity of the assumptions of this scheme several intermediate steps were made. As the engine jet-airframe interference is mutual, also effects of the external flow on the internal engine nozzle flow causing engine shifting has to be considered. In order to estimate the magnitude of this influence of the external flow field a two-dimensional model of the fan nozzle has been tested using an optical technique. From these tests the specific features of the fan nozzle flow field ranging from subcritical via supercritical to choked conditions are described Author

N75-23491 Avions Marcel Dassault-Breguet Aviation, Saint Cloud (France)
EFFECT OF EXTERNAL CONDITIONS ON THE FUNCTIONING OF A DUAL FLOW SUPERSONIC NOZZLE [EFFET DES CONDITIONS EXTERIEURES SUR LE FONCTIONNEMENT D'UNE TUYERE SUPERSONIQUE DOUBLE-FLUX]
Guy DeRichemont and J Delery (Office Natl. d'Etudes et de Rech. Aerospatiales, Paris) *In* AGARD Airframe/Propulsion Interference Mar 1975 14 p refs In FRENCH; ENGLISH summary (For availability see N75-23485 15-02)

The design of versatile military aircraft implies a very careful study of the propulsion system, taking into account interferences with the external flow. A possible solution to this difficult problem of adaptation is that of a dual flow system consisting of two nozzles with variable sections. Flow regimes where the primary jet impinges on the secondary nozzle are considered. The evolution is analyzed of the phenomena when the external pressure and the distance between primary injector exhaust plane and the nozzle exit are varied. This experimental study shows the influence of the external conditions upon the functioning of the nozzle. Theoretical methods are given which allow a reasonable prediction of nozzle performance under such conditions Author

N75-23492 LTV Aerospace Corp., Dallas, Tex. Vought Systems Div.
SUBSONIC BASE AND BOATTAIL DRAG, AN ANALYTICAL APPROACH
J. K. Quermann *In* AGARD Airframe/Propulsion Interference Mar 1975 12 p refs (For availability see N75-23485 15-02)

Methods of subsonic potential flow were applied to the calculation of base and boattail drag. For configurations with a base the Korst method was extended to subsonic flow by

incorporating a standard family of free streamline shapes and a semi-empirical scheme for selecting the total pressure on the dividing streamline. The potential flow around the shape defined by the body, free streamline, and jet establishes the base and boattail pressures. Significant parts of the drag associated with the base actually appear on the boattail. In the absence of a base, the effect of the jet shape is felt by the boattail. With an underexpanded supersonic jet a portion of the thrust which would otherwise be lost in external expansion is recovered on the boattail. The fraction recovered drops rapidly with increasing jet pressure ratio. Results are compared with flight and wind tunnel tests on the Vought A-7 Airplane. Author

N75-23493 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THEORY OF MIXING FLOW OF A PERFECT FLUID AROUND AN AFTERBODY AND A PROPULSIVE JET [COUPLAGE ENTRE L'ECOULEMENT AUTOUR D'UN ARRIERE-CORPS ET LE JET PROPULSIF EN THEORIE DE FLUIDE PARFAIT]
Roland Maria Subs, Jean-Jacques Chattot, and Georges Gilon *In* AGARD Airframe/Propulsion Interference Mar. 1975 12 p refs In FRENCH, ENGLISH summary (For availability see N75-23485 15-02)

The interference effects between external and internal flows are examined in the framework of the inviscid flow theory. These phenomena are connected mainly with flows around afterbodies. Subcritical axisymmetrical interacting flows are studied. The computation of both internal and external flows is carried out using a finite element method. The results make it possible to determine the shape of the jet using a pseudo-hodographic method, with an iterative procedure. The interference effects of a supersonic internal flow with subsonic or transonic external flows are considered. The supersonic internal jet is computed using the method of characteristics. The coupling conditions between the internal and the external flows are taken into account, using an iterative procedure in a way similar to that proposed by Young, but extended to compressible external flows. A comparison with existing experimental results is presented. Author

N75-23494 New York Univ., N.Y. Aerospace Lab.
LOW SPEED INJECTION EFFECTS ON THE AERODYNAMIC PERFORMANCE AT TRANSONIC SPEED
Renzo Piva *In* AGARD Airframe/Propulsion Interference Mar. 1975 10 p refs Prepared jointly with Rome Univ. (For availability see N75-23485 15-02)
(Grant AF-AFOSR-72-2167)

The problem concerning the possible reduction of the transonic drag for a high speed airplane was studied to enhance the aerodynamic performance at low altitudes when the drag must be minimized. Attention was focused on decreasing the drag forces on the aft portion of the vehicle. An experimental investigation was conducted to determine the effect, on afterbody drag, of the injection of a small amount of air spilled from the propulsive system, having low stagnation pressure, in the rear of the model. The purpose of this injection was to avoid overexpansion of the flow and to increase the average pressure on the aft section. The main problem to be investigated is where the injection is most effective and the amount of air required to avoid downstream reattachment. Some results are presented. It was found that the required amount of air is relatively low, because of the high sensitivity of the interaction region to any small change in the flow regime. Author

N75-23495 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Melun (France).
RESEARCH ABOUT EFFECTS OF EXTERNAL FLOW AND AIRCRAFT INSTALLATION CONDITIONS ON THRUST REVERSERS PERFORMANCES
J. M. Hardy and J. P. Carre *In* AGARD Airframe/Propulsion Interference Mar. 1975 11 p In FRENCH; ENGLISH summary (For availability see N75-23485 15-02)

Development of thrust reversers is generally carried out in engine test cells without external flow. As thrust reversers deviate a significant amount of flow this modifies the aerodynamic field surrounding an aircraft. Inversely, flight speed as well as aircraft installation conditions react on the operating characteristics of thrust reversers. This interaction is contingent on the thrust reversers design arrangement. The interaction mechanisms is analyzed using test data collected with two types of thrust reversers during an investigation carried out on the CONCORDE afterbody. The differences in behavior existing between the reversers are shown as revealed by tests carried out with no external flow, and with external flow in the O.N.E.R.A. wind tunnel installation. An investigation on interaction mechanisms is presented, bringing out a correlation parameter which makes it possible to extrapolate thrust reverser results obtained in static conditions for various running configurations. A balance of deceleration forces are analyzed, and the effects of flight Mach number on the reversers base pressure values are shown. Author

N75-23496 British Aircraft Corp. (Operating) Ltd., Bristol (England). Commercial Aircraft Div.
REVERSE THRUST EXPERIENCE ON THE CONCORDE
A. C. Willmer and R. L. Scotland *In* AGARD Airframe/Propulsion Interference Mar. 1975 15 p refs (For availability see N75-23485 15-02)

Reverse thrust is used as a means of deceleration on many aircraft. Partical limitations to its use are set by the following airframe/propulsion interference of hot gas ingestion, and aircraft handling. The reverse thrust force may also differ from that measured on a test bed due to interference. Model tests to determine these interference effects for the Concorde aircraft were carried out. The several test techniques used are described, the model results are compared with those inferred from tests on the prototype and production aircraft. Author

N75-23497 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
REYNOLDS NUMBER EFFECTS ON FORE- AND AFTBODY PRESSURE DRAG
Felix Aulehla and Geert Besigk *In* AGARD Airframe/Propulsion Interference Mar. 1975 15 p refs (For availability see N75-23485 15-02)

An analysis of a wind tunnel investigation at Mach number 0.8 on a series of axisymmetric bodies showed as a main result that varying Reynolds number produces opposite changes in pressure drag on fore- and aftbody, respectively. It is explained that this result could very well be caused by wind tunnel interference. As a consequence, to determine aftbody drag correctly it will be required either to test in interference free wind tunnels or to take into account the compensating effects on the forebody. Furthermore, it is pointed out that modifications in aftbody geometry affect forebody drag. Results from the commonly used aftbody test rigs with forebodies fixed to the ground therefore need appropriate corrections. Finally, the sensitivity of drag components with respect to the location of split lines is discussed. It is shown that subdividing the boattail is not advisable from an accuracy point of view. Author

N75-23498 Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
THE SUBSONIC BASE DRAG OF CYLINDRICAL TWIN-JET AND SINGLE-JET AFTERBODIES
J. Reid, A. R. G. Mundell, and J. F. W. Crane *In* AGARD Airframe/Propulsion Interference Mar. 1975 13 p refs (For availability see N75-23485 15-02)

The effect was studied of forebody and support interference on the base drag of cylindrical twin-jet afterbodies in wind tunnel tests at subsonic speeds. Two almost identical afterbodies were tested, one in a strong interference field and the other nearly free from interference. The results illustrate the importance of the effect and also serve to test two methods of correction. Supplementary tests show that the base drag of a cylindrical twin-jet afterbody tends to be a slightly greater than that of the equivalent axisymmetric configuration. Finally, a method of correlation is described whereby the base drag of both twin-jet and single-jet models may be expressed in linear form. Author

N75-23499 Tennessee Univ. Space Inst., Tullahoma.
ON SOME PROBLEMS ENCOUNTERED IN A THEORETICAL STUDY OF THE EXTERNAL FLOW OVER A NOZZLE CONFIGURATION IN TRANSONIC FLIGHT
T. H. Moulden, J. M. Wu, and D. J. Spring (Army Missile Command) *In* AGARD Airframe/Propulsion Interference Mar. 1975 12 p refs (For availability see N75-23485 15-02)
(Contract DAAH01-74-C-0183)

Attention is drain to the lack of information, both experimental and theoretical, concerning the transonic flow over an engine configuration operating at various thrust levels. It is shown that the flow is of great complexity. In particular, when the free

stream Mach number is just supersonic, it is found that the confluence between the jet and the external flow is still more nearly subsonic in nature. This observation implies that the usual theories for supersonic base flow are not applicable to this situation. Calculations from such a theory are presented and discussed in the light of experimental evidence. It is recommended that considerable effort be spent in developing theoretical tools based upon solutions to more exact equations and that more fundamental experiments be performed. Author

N75-23500 Air Force Aero Propulsion Lab., Wright-Patterson AFB, Ohio

TWIN JET EXHAUST SYSTEM TEST TECHNIQUES

Ronald J. Glidewell and Arthur E. Fanning *In* AGARD Airframe/Propulsion Interference Mar. 1975 11 p refs (For availability see N75-23485 15-02)

The problem of integrating airframe and propulsion system requires that the various wind tunnel models, used in accomplishing the task, simulate as accurately as possible the internal and external flowfields that will be experienced on the airplane itself. This is particularly true for those models which are tested to define inlet and exhaust system interactions with the airplane flowfield. Exact simulation is, however, prohibited by the limitations of wind tunnel test techniques. For the jet effects model, such limitations include the interference effects associated with the model support system, exhaust plume simulation and the use of inlet fairings in substitution for flowing inlets. Information from a variety of sources is used to assess the impact of these model limitations on the accuracy of afterbody performance measured on twin jet models. Author

N75-23501* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.

AN EXPERIMENTAL STUDY OF JET EXHAUST SIMULATION

William B. Compton, III *In* AGARD Airframe/Propulsion Interference Mar. 1975 11 p refs (For availability see N75-23485 15-02)

Avail: NTIS CSCL 01A

Afterbody drag predictions for jet aircraft are usually made experimentally with the jet exhaust flow simulated. The physical gas properties of the fluid used for the model jet exhaust can affect the accuracy of simulation of the airplane's jet exhaust plume. The effect of the accuracy of this simulation on afterbody drag was investigated by wind-tunnel tests with single engine model. In addition to unheated air as the exhaust gas, the decomposition products of three different concentrations of hydrogen peroxide were utilized. The air jet simulation consistently resulted in higher boattail drag than hydrogen peroxide simulation. The differences in drag for the various exhaust gases are attributed to different plume shapes and entrainment properties of the gases. The largest differences in drag due to exhaust gas properties were obtained for the combination of high transonic Mach numbers and high boattail angles. For these conditions, the current data indicate that the use of air to simulate a nonafterburning turbojet exhaust can result in an increase in afterbody amounting to 20 percent of the nonafterburning turbojet value. Author

N75-23502 Rolls-Royce, Ltd., Derby (England). Installation Aerodynamics Section.

A MODEL TECHNIQUE FOR EXHAUST SYSTEM PERFORMANCE TESTING

T. D. Coombes *In* AGARD Airframe/Propulsion Interference Mar. 1975 12 p refs (For availability see N75-23485 15-02)

An accurate model technique is described that was developed to measure the sum of gross thrust and afterbody drag for nozzle systems with single or two co-axial streams. The rig uses air at ambient temperature and is designed to operate in the 9ft x 8ft transonic wind tunnel of the Aircraft Research Association Limited at Bedford. Model test results are also presented to demonstrate the accuracy and repeatability of the rig and show the considerable progress that has been made in advancing the state of the art on exhaust systems for low specific thrust engines. Author

N75-23503 LTV Aerospace Corp., Dallas, Tex. Vought Systems Div.

ISOLATING NOZZLE AFTERBODY INTERACTION PARAMETERS AND SIZE EFFECTS: A NEW APPROACH

S. C. Walker *In* AGARD Airframe/Propulsion Interference Mar. 1975 8 p refs (For availability see N75-23485 15-02)

A flight test of the A-7E airplane is reported along with associated wind tunnel tests comprising approximately one half of the long range program. The difficulty of controlling parameters in flight was overcome by flying into the data point while allowing only slight variations in ambient pressure. Wind tunnel tests were made in a 1.2 x 1.2 meter blowdown tunnel. Models were run with both hot and cold exhaust. One model was a wingless body of revolution, the second was a geometric representation of the airplane. The flight test demonstrated the practicability of parameter control testing, and showed applicability of stream thrust parameter to inflight engine performance evaluation. Wind tunnel data show trends and general levels comparable to flight, and have verified some areas in which development of corrections is necessary. Author

N75-23504 ARO, Inc., Arnold Air Force Station, Tenn.

EXHAUST PLUME TEMPERATURE EFFECTS ON NOZZLE AFTERBODY PERFORMANCE OVER THE TRANSONIC MACH NUMBER RANGE

C. E. Robinson, M. D. High, and E. R. Thompson *In* AGARD Airframe/Propulsion Interference Mar. 1975 16 p refs Sponsored in part by AEDC (For availability see N75-23485 15-02)

Results of an experimental research investigation on nozzle/afterbody drag are presented. Experimental afterbody (and boattail) drag coefficients and pressure distributions are discussed for an isolated, strut-mounted nozzle/afterbody model for the Mach number range from 0.6 to 1.5. The experimental data were obtained for the basic model with an air-cooled and a water-cooled ethylene/air combustor to provide hot-jet duplication as well as cold-jet simulation. The temperature of the nozzle exhaust gas was varied from 530 R (294.4 K) (burner-off) to approximately 2500 R (1388.9 K) for several nozzle pressure ratios from jet-off to those corresponding to a moderately under-expanded exhaust plume. The differences between the cold-jet and hot-jet results are significant, and adjusting the cold-jet pressure ratio to correct for the changes in the jet specific heat ratio with temperature will account for most of the differences observed. Author

N75-23505 Boeing Co., Wichita, Kans.

THE INFLUENCE OF NACELLE AFTERBODY SHAPE ON AIRPLANE DRAG

Walter J. Rohling *In* AGARD Airframe/Propulsion Interference Mar. 1975 14 p refs (For availability see N75-23485 15-02)

A program to design and flight test quiet nacelles suitable for installation on JT3D powered 707 airplanes was conducted. Design requirements for the quiet nacelle stated that the nacelle shall be flightworthy, flight weight, capable of being certificated to airworthiness standards, and appropriate to the aircraft type. The cruise performance flight tests and the additional performance diagnostic flight tests indicated an unnecessary performance penalty due to the nonoptimum aft translating sleeve and fan nozzle configuration. An unfavorable angle-of-attack-sensitive interplay between the wing and nacelle aft sleeve flow fields was found at all cruise Mach numbers. This penalty was the only significant item discovered during the flight test program which required correction to provide a viable retrofit nacelle configuration. The diagnostic performance flight tests, wind tunnel and exhaust system model tests are described that were conducted to define the required change and to obtain data on the cruise performance benefits that resulted from the change. Author

N75-23506* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

REYNOLDS NUMBER EFFECTS ON BOATTAIL DRAG OF EXHAUST NOZZLES FROM WIND TUNNEL AND FLIGHT TESTS

Fred A. Wilcox and Roger Chamberlin *In* AGARD Airframe/Propulsion Interference Mar. 1975 15 p refs (For availability see N75-23485 15-02)

Avail: NTIS CSCL 01A

A family of nacelle mounted high angle boattail nozzles was tested to investigate Reynolds number effects on drag. The nozzles were flown on a modified F-106B and mounted on scale models of an F-106 in a wind tunnel. A 19- to 1-range of Reynolds number was covered as a result of the large size differences between models and by flying over a range of altitude. In flight the nozzles were mounted behind J-85 turbojet engines. Jet boundary simulators and a powered turbojet engine simulator were used on the wind tunnel models. Data were taken at Mach numbers of 0.6 and 0.9. Boattail drag was found to be affected

by Reynolds number. The effect is a complex relationship dependent upon boundary layer thickness and nozzle boattail shape. As Reynolds number was increased from the lowest values obtained with scale models, boattail drag first increased to a maximum at the lowest flight Reynolds number and then decreased. Author

N75-23507 Boeing Aerospace Co., Seattle, Wash.
ACCOUNTING OF AERODYNAMIC FORCES ON AIRFRAME/PROPULSION SYSTEMS
Michael E. Brazier and William H. Ball *In* AGARD Airframe/Propulsion Interference Mar. 1975 15 p refs (For availability see N75-23485 15-02)

Proper accounting, prediction, and measurement of propulsion system installation corrections are essential for the successful development of advanced military aircraft. The results are reported of recent studies which evaluate the methods used to predict, measure and integrate the aerodynamic and propulsion forces within a force accounting procedure that provides maximum element visibility and accuracy, and is applicable throughout an entire airplane development cycle. Improved analysis techniques are described which provide more comprehensive and accurate predictions of inlet performance and nozzle/afterbody drag early in the preliminary design process. Inlet analysis techniques make use of standardized data maps for obtaining complete inlet performance characteristics. Nozzle/afterbody drag calculations are performed using a newly-developed truncated integral mean slope technique. Effects of strut interference, blockage, model split-line locations and other factors which introduce uncertainties into airframe/propulsion system data are presented. Author

N75-23508 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
AIRFRAME/PROPULSION SYSTEM FLOW FIELD INTERFERENCE AND THE EFFECT ON AIR INTAKE AND EXHAUST NOZZLE PERFORMANCE
G. K. Richey, L. E. Surber, and J. A. Laughrey *In* AGARD Airframe/Propulsion Interference Mar. 1975 31 p refs (For availability see N75-23485 15-02)

The interference between the airframe flow field and the internal/external flow in the air intakes and exhaust nozzles of high performance tactical aircraft is shown to have a significant impact on the performance and operating characteristics of these components, and hence on overall aircraft performance. The internal flow characteristics of an inlet system closely integrated with the airframe are strongly influenced by flow field nonuniformities generated by the airframe forebody and wing, particularly at the higher angles of attack or yaw which modern tactical aircraft are capable of. Comparisons are made of the inlet ambient (capture plane) flow field, and pressure recovery, steady state and dynamic inlet distortion at the simulated engine compressor face for both integrated (side mounted and fuselage or wing-shielded) and isolated inlet systems to quantitatively assess the airframe interference effects. For the engine exhaust nozzles of closely integrated propulsion system/airframe configurations, the major influence of the airframe flow field is associated with the alteration of the viscous and inviscid external flow in the nozzle region, and its effect on external afterbody/nozzle drag. A detailed discussion, supported by experimental data, shows the effects on airframe afterbody/nozzle pressure distributions and nozzle installed performance with respect to twin jet interference, wing flow, aircraft tail/control surfaces, interfairings and free stream flow conditions. Author

N75-23509 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (West Germany).
DETAILED EXPERIMENTAL AND THEORETICAL ANALYSIS OF THE AERODYNAMIC INTERFERENCE BETWEEN LIFTING JETS AND THE FUSELAGE AND WING
G. Schulz and G. Viehweger *In* AGARD Airframe/Propulsion Interference Mar. 1975 13 p refs (For availability see N75-23485 15-02)

An aircraft model of simple shape for pressure distribution measurements is used, which allows the variation of all main geometrical parameters. The jets reach Mach number 1. Measurements of the velocity directional flow field are added. The pressure distributions as well as the flow directional field allow the physical interpretation of the several aerodynamic effects. By integration of the pressure field, the forces and moments caused by the jets are obtained. The integration of the directional field leads to the stream lines of the complicated field of cross blown jets. Theoretical momentum considerations enable the calculation of the jet path and lead to transcalculation rules for flow directional fields (downwash) from one dynamic pressure ratio to another. Author

N75-23510 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
PREDICTION OF THE OPTIMUM LOCATION OF A NACELLE SHAPED BODY ON THE WING OF A WING-BODY CONFIGURATION BY INVISCID FLOW ANALYSIS
S. R. Ahmed *In* AGARD Airframe/Propulsion Interference Mar. 1975 12 p refs (For availability see N75-23485 15-02)

Some results of a basic study are presented which aims at the prediction of optimum location of a pylon-mounted engine nacelle on the wing of a wing-body configuration with the help of inviscid flow analysis. The options considered are the underwing and overwing positions of the nacelle. Varied parameters are its spanwise and chordwise location along the wing. The criterion for the choice of the optimum location is the minimum possible induced drag of the wing-body-pylon-nacelle configuration. The theoretical calculation of the inviscid flow is done by the so-called 'panel method'. Feasibility of these predictions for subcritical flow is checked on the basis of extensive pressure and force measurements in a wind tunnel. Author

N75-23511 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany).
AIRFRAME: ENGINE INTERACTION FOR ENGINE CONFIGURATIONS MOUNTED ABOVE THE WING, PART 1: INTERFERENCE BETWEEN WING AND INTAKE JET
G. Krenz *In* AGARD Airframe/Propulsion Interference Mar. 1975 32 p refs (For availability see N75-23485 15-02)

Advanced technology of airframe-propulsion-integration confirm the feasibility for over-the-wing engine installation of transport aircraft. Basic areas of interaction between wing and engine flows are described together with specific investigations associated with fore and aft engine locations. For the aft location, W/T results are presented with flight test data including stall and high speed flight characteristics. Further, low speed tunnel investigations of aircraft configurations with engine intakes well in front of wing L.E., result in increasing lift as well as improving the lift/drag ratio during T/O and landing. A theoretical approach was conducted, using the well established panel method, and comparison of theoretical and experimental pressure distributions proved well for spacing of one nozzle diameter between the wing and nozzle-jet sheet. Author

N75-23512 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany).
AIRFRAME: ENGINE INTERACTION FOR ENGINE CONFIGURATIONS MOUNTED ABOVE THE WING, PART 2: ENGINE JET SIMULATION PROBLEMS IN WIND TUNNEL TESTS
B. Ewald *In* AGARD Airframe/Propulsion Interference Mar. 1975 17 p refs (For availability see N75-23485 15-02)

A test technique developed for the VFW-Fokker low speed wind tunnel is presented. In this technique the airframe model is mounted to the external mechanical balance (wire suspension). The engine pod is mounted separately on a tail sting suspension system. Due to the design of this tail sting system its angle of attack axis of rotation coincides with the corresponding axis of the external balance. So separate mounting of airframe and engine with very small gaps is possible. The air is fed to the engine pod with high pressure (up to 20 atmospheres). This pressure is decreased to the required nozzle exit pressure ratio by perforated plates very close to the nozzle exit. Calibration results of this nozzle arrangement are given. Typical test results (force measurements, wing pressure distribution) are presented for several engine locations (over-wing, on-wing, under-wing). Author

N75-23513 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
AERODYNAMIC ASPECTS AND OPTIMISATION OF THRUST REVERSER SYSTEMS
Kurt Lotter and Wolfgang Kurz *In* AGARD Airframe/Propulsion Interference Mar. 1975 22 p ref (For availability see N75-23485 15-02)

The present generation of commercial aircraft and future advanced military aircraft require thrust reversal for reduction of landing distances, especially for wet or icy runways. The various design and integration features for jet deflection are summarized, and the requirements and problem areas discussed under special consideration of a target type reverser system. The important engine/airframe interference problems and aerodynamic aspects associated with thrust reversal are considered. Parametric investigation of thrust reverser geometry on efficiency, reingestion

structure heating and longitudinal stability during ground roll is presented. Results are based on an intensive wind tunnel test program using various types of scale models with cold and hot jets, intake suction and fixed and moving ground simulation. Emphasis is given to the overall optimization of often conflicting requirements from parameters like for example thrust reverser performance and reingestion. The essential influence of appropriate thrust reverser operation and landing techniques at or shortly before touch-down on landing distance is shown. Author

N75-28011# Advisory Group for Aerospace Research and Development, Paris (France)
SPECIALISTS MEETING ON WING-WITH-STORES FLUTTER
Apr 1975 134 p refs Partly in FRENCH and partly in ENGLISH Presented at 39th Meeting of the Struct. and Mater. Panel, Munich, 6-12 Oct. 1974
(AGARD-CP-162) Avail: NTIS HC $6.75

This conference proceedings consists of nine papers which deal with the difficult problem of wing store flutter. The latest state-of-the-art is examined. Improved methods for avoiding restrictive placarding and for rapidly and economically evaluating the many possible store combinations are presented, and possibilities for optimizing the design procedure with regard to wing/store combinations are discussed. For individual titles, see N75-28012 through N75-28020.

N75-28012 Royal Aircraft Establishment, Farnborough (England). Structures Dept.
CALCULATION METHODS FOR THE FLUTTER OF AIRCRAFT WINGS AND EXTERNAL STORES
T. Niblett and J. C. A. Baldock *In* AGARD Specialists Meeting on Wing-With-Stores Flutter Apr. 1975 7 p refs (For availability see N75-28011 19-02)

Theoretical work at RAE on the wing-with-stores problem is reported which was in the fields of structural representation, the solution of the flutter equations and the prediction of flutter characteristics from structural properties. The subjects covered are: (1) a comparison of the normal modes calculated for a wing-with-stores from some of the normal modes of the bare wing and discrete-load modes with those calculated from the full flexibility matrix; (2) the basis of a computer program which traces the loci of constant flutter speeds when two structural parameters vary; and (3) the interpretation of the loci of constant flutter speed in terms of modal shapes and frequencies with the object of assessing the most critical store combinations. Author

N75-28013 British Aircraft Corp., Warton (England).
UK JAGUAR EXTERNAL STORE FLUTTER CLEARANCE
C. G. Lodge and M. Ormerod *In* AGARD Specialists Meeting on Wing-With-Stores Flutter Apr. 1975 24 p (For availability see N75-28011 19-02)

The flutter clearance of U.K. Jaguar using a combination of mathematical modelling, ground resonance and flight testing leading ultimately to clearance of a wide range of under wing stores. Some improvements in modal modelling techniques are outlined. These should enable reductions in future ground and flight testing times to be made. Author

N75-28014 Office National d'Etudes et de Recherches Aerospatiales, Paris (France)
FLUTTER OF WINGS EQUIPPED WITH LARGE ENGINES IN POD
R. Destuynder *In* AGARD Specialists Meeting on Wing-With-Stores Flutter Apr. 1975 12 p refs In FRENCH, ENGLISH summary (For availability see N75-28011 19-02)

Calculations and measurements of unsteady aerodynamic forces performed in subsonic flow on a model equipped with an engine in pod showed that the interference between engine and wing remains negligible. It was also shown that the aerodynamic forces induced on the engine itself by its own oscillation are important and give a significant contribution to the generalized forces. Account was taken of these two remarks and the aerodynamic forces were calculated separately on the engine which was assimilated to a thin walled cylinder with internal and external flow in the axial direction. An application to a flutter case shows the importance of the contribution of the forces on the engine. A good agreement was obtained between theory and experiment at Mach number M = 0.80. Author

N75-28015 National Aerospace Lab., Amsterdam (Netherlands)
CALCULATION OF AERODYNAMIC LOADS ON OSCILLATING WING/STORE COMBINATIONS IN SUBSONIC FLOW
B. Bennekers, R. Roos, and R. J. Zwaan *In* AGARD Specialists Meeting on Wing-With-Stores Flutter Apr. 1975 13 p refs (For availability see N75-28011 19-02)

A method for the calculation of aerodynamic loads on wing store configurations oscillating in subsonic flow is presented. In this method the linearized equation for subsonic compressible flow is transformed into two sets of integral equations for the steady and a superimposed unsteady flow field. The wing loads are represented by dipole distributions (wing thickness is neglected) and the store loads by source distributions. Discretizing these distributions into lifting lines and source panels of constant strength results into a set of algebraic equations. These are solved for the unknown distributions by forcing the flow to be tangential to the surfaces of the oscillating wings and bodies in a set of control points. The solution enables the calculation of pressure distributions on the wings and stores and of generalized aerodynamic coefficients. Calculated results are presented and compared with experiments. Author

N75-28016 National Aerospace Lab., Amsterdam (Netherlands)
ANALYSIS OF MEASURED AERODYNAMIC LOADS ON AN OSCILLATING WING-STORE COMBINATION IN SUBSONIC FLOW
L. Reinink *In* AGARD Specialists Meeting on Wing-With-Stores Flutter Apr. 1975 15 p refs (For availability see N75-28011 19-02)

An analysis is given of aerodynamic loads measured with an oscillating wind tunnel model representing a wing with a tip tank and a removable pylon with store. Attention is paid to the interference effects on the wing load and to the pylon store load in low and high subsonic flow. Author

N75-28017 Messerschmitt-Boelkow G.m.b.H., Ottobrunn (West Germany).
WING WITH STORES FLUTTER ON VARIABLE SWEEP WING AIRCRAFT
O. Sensburg, A. Lotze, and G. Haidl *In* AGARD Specialists Meeting on Wing-With-Stores Flutter Jul. 1945 19 p refs (For availability see N75-28011 19-02)

Wing mounted stores with varying mass and inertia are discussed in conjunction with variable wing geometry for fighter aircraft. Modified branch mode techniques were used to obtain the frequencies and modeshapes of the coupled system. It is shown that only free dynamically scaled total aircraft models give good correlation when turning effects occur. F.O.S.

N75-28018 Aeritalia, Turin (Italy).
A PARAMETRIC STUDY OF WING STORE FLUTTER
L. Chesta *In* AGARD Specialists Meeting on Wing-With-Stores Flutter Apr. 1975 12 p refs (For availability see N75-28011 19-02)

The influence of different parameters on the flutter of wings with stores was studied in more than 3000 wind tunnel configurations. The parameters studied include store mass, store radius of inertia, store c.g., pylon pitch stiffness, and wing sweep angle. Results indicate: (1) Flutter is induced by the coupling of the wing fundamental bending and the store pitch modes; (2) Flutter speed decreases with increasing store radius of inertia until the frequency of the store pitch mode is higher than that of the fundamental bending; (3) For all sweep angles, the forward c.g. shifting produces a slight reduction of the minimum flutter speed. F.O.S.

N75-28019 Grumman Aerospace Corp., Bethpage, N.Y.
RECENT OBSERVATIONS ON EXTERNAL-STORE FLUTTER
Eugene F. Baird and William B. Clark *In* AGARD Specialists Meeting on Wing-With-Stores Flutter Apr. 1975 8 p refs (For availability see N75-28011 19-02)

The problem of wing flutter with external stores is discussed in terms of flutter prevention when designing aircraft. General guidelines for the optimum arrangement of external stores on wings are given, and the mission-loading requirements for a new aircraft are considered. Other topics discussed include pylons, flutter model tests, ground vibration tests, and flight-flutter tests. F.O.S.

N75-28020 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio
RECENT ANALYSIS METHODS FOR WING-STORE FLUTTER
Walter J. Mykytow *In* AGARD Specialists Meeting on Wing-With-Stores Flutter Apr. 1975 15 p refs (For availability see N75-28011 19-02)

A summary of a brief review for some of the literature on the practical aspects of wing-store flutter prediction and prevention. Brief comments are given on the advantages and disadvantages of various aspects of analytical and test procedures. Descriptions of improved analytical procedures developed for the United States Air Force is then given. Two methods are described in some detail and the results of the investigators are outlined. One is a rapid special purpose wing-store flutter analysis program called FACES. It has data storage and retrieval capabilities which together with a diagnostic and interpolation/extrapolation procedure estimate the flutter speed of new, similar stores. The system can be coupled to a cathode ray tube to increase man/machine interaction and reduce decision times. The other analysis method described is based on the perturbation approach. Computation times can be reduced 90% by using the previously available data. The method produces good results when the mass or stiffness changes are small so that in turn, eigenvalue and eigenvector changes are small. A graph of flutter speed versus important parameters can be produced in one minute on a modern computer. Author

N76-30108# Advisory Group for Aerospace Research and Development, Paris (France).
VORTEX WAKES OF CONVENTIONAL AIRCRAFT
Coleman duP. Donaldson (Aeron. Res. Assoc. of Princeton, Inc., N. J.), Alan J. Bilanin (Aeron. Res. Assoc. of Princeton, Inc., N. J.), and R. H. Korkegi, ed. (ARL) May 1975 85 p refs (AGARD-AG-204) Avail: NTIS HC $4.75

The present state of knowledge of vortex wakes of conventional aircraft is presented. Topics discussed include roll-up of trailed vorticity, aircraft wake geometry, sinusoidal instability and vortex breakdown, aging of vortices, persistance of vortices in the atmosphere, and aircraft design techniques to minimize wake hazard. Author

N76-32014# Advisory Group for Aerospace Research and Development, Paris (France).
RECOMMENDED PROCEDURES FOR PROCESSING ACCELERATION DATA OBTAINED BY AIRCRAFT DURING ATMOSPHERIC TURBULENCE ENCOUNTER
John C. Houbolt (Aeron. Res. Assoc. of Princeton, Inc., N. J.) Jul. 1975 15 p refs
(AGARD-R-631) Avail: NTIS HC $3.25

Recommendations are given for processing vertical acceleration data obtained during turbulence encounter of aircraft in service operation to obtain useful structural design information for gust encounter. Specific data reduction procedures are recommended. A key point in the recommendations is that all data processing be done on a consistent basis. Charts and steps for data reduction are presented to achieve this goal. Author

N76-32015# Advisory Group for Aerospace Research and Development, Paris (France).
MATHEMATICAL MODELING AND RESPONSE EVALUATION FOR THE FLUCTUATING PRESSURES OF AIRCRAFT BUFFETING
John C. Houbolt (Aeron. Res. Assoc. of Princeton, Inc., N. J.) Jul. 1975 14 p
(AGARD-R-630) Avail: NTIS HC $3.25

The mathematical modeling used to describe the pressure fluctuations in various turbulent flow problems is reviewed; attention is focused mainly on statistical description, such as are involved in power spectral approaches. These models were used as building blocks to synthesize a mathematical model describing the turbulent pressure fluctuations during buffeting of an airplane wing. Means for evaluating the dynamic response of the structure due to the buffeting forces were developed. An example treatment shows that the dynamic response may be an appreciable percent of an associated reference static deflection. It is recommended that a series of controlled buffet tests be made to check on the validity of the equations, and to establish their parameters. Author

N76-16019# Advisory Group for Aerospace Research and Development, Paris (France)
FORCE MEASUREMENTS IN SHORT DURATION HYPERSONIC FACILITIES
Leonard Bernstein (Queen Mary Coll.) and R. C. Pankhurst, ed. Nov. 1975 224 p refs
(AGARD-AG-214, AGARDograph-214) Avail: NTIS HC $7.75

Attention is drawn to the principle whereby the aerodynamic forces on a model in a wind tunnel are determined by measuring the reactions to them. The discussion is based upon a division of such reactions into two basic classes, depending on the restraints imposed. Where no restraints exist, the model flies freely and the forces may be inferred from the accelerations, either measured directly or derived from displacement vs time data. When the model is supported, the forces are determined from measurements of the mechanical strains induced in suitably designed supports. Hybrid techniques, where these extreme cases of no restraint or nearly complete restraint cannot be assumed, are also discussed. A detailed discussion of transducer sensing elements and their incorporation into measuring systems is given. Some particular systems are also described. For individual titles, see N76-16020 through N76-16022.

N76-16020 Advisory Group for Aerospace Research and Development, Paris (France).
SOME FUNDAMENTAL PRINCIPLES
In its Force Meas. in Short Duration Hypersonic Facilities Nov. 1975 p 7-50 (For availability see N76-16019 07-02)

The motion produced by the action of forces on a system is described by the equations of motion for the system, these equations are formulated using the Newtonian and Lagrangian approaches. Topics discussed include aerodynamic data from the analysis of unrestrained motion, aerodynamic data from measurements of the reaction in supports, hybrid techniques, aerodynamic characteristics, aerodynamic forces and moments, and degrees of freedom. M.J.S

N76-16021 Advisory Group for Aerospace Research and Development, Paris (France)
FORCE BALANCE TECHNIQUES
In its Force Meas. in Short Duration Hypersonic Facilities Nov. 1975 p 52-104 (For availability see N76-16019 07-02)

The design of a force balance for transient measurements takes into account both its static and its dynamic performance. The properties are reviewed of those solid state materials which are useful as electromechanical transducers in force balances having a sufficiently good high-frequency performance of use in short duration hypersonic wind tunnels. Other topics discussed include general aspects of force-balance design, electrical systems for signal generation and processing, data recording, and calibration techniques. M.J.S

N76-16022 Advisory Group for Aerospace Research and Development, Paris (France)
FREE-FLIGHT TECHNIQUES
In its Force Meas. in Short Duration Hypersonic Facilities Nov. 1975 p 104-214 refs (For availability see N76-16019 07-02)

Methods are discussed for acquiring force data based on studies of the motion of models 'flying' under laboratory conditions. The model presented is potentially free of all extraneous influences from supports, and premature boundary layer separation and inaccurate representation of the base region are avoided. In addition to those problems arising from vibration of the supports. The design and manufacture of models, model suspension, launching and capture systems, position and attitude as a function of time, velocity measurements, and acceleration measurements are also discussed. M.J.S

N76-17030# Advisory Group for Aerospace Research and Development, Paris (France).
FLOW SEPARATION
Nov. 1975 584 p refs In ENGLISH; partly in FRENCH Presented at the Fluid Dyn. Panel Symp., Goettingen, Germany, 27-30 May 1975 Original contains color illustrations
(AGARD-CP-168) Avail: NTIS HC $13.75

Two dimensional and three dimensional laminar and turbulent separation phenomena in subsonic, transonic, and supersonic flows are reported. For individual titles, see N76-17031 through N76-17070.

N76-17031 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany)
AN ACCOUNT OF THE SCIENTIFIC LIFE OF LUDWIG PRANDTL
H. Schlichting *In* AGARD Flow Separation Nov. 1975 32 p refs (For availability see N76-17030 08-02)

After an introduction on Prandtl's professional career the following are dealt with in Part I. Boundary layer theory, wing theory at subsonic and supersonic speeds, theory of stability of

laminar flow. Furthermore, in this section the following problems are touched on briefly: Fully developed turbulent flow with application to boundary layers, pipe flow and meteorology. Prandtl's contributions to development of wind tunnel techniques are also mentioned. In Part II some remarks are made on the large number of doctoral theses which have been supervised by Prandtl. Author

N76-17032 Office National d'Etudes et de Recherches Aerospatiales, Paris (France)
LAMINAR SEPARATION AT A TRAILING EDGE
Jean-Pierre Guiraud and Rene Schmitt *In* AGARD Flow Separation Nov. 1975 5 p refs (For availability see N76-17030 08-02)

A model of incipient separation is provided for the trailing edge of a thin wing in incompressible very high Reynolds number flow. The model of separated flow, with a (small) recirculation zone, of streamwise length, is consistent with a matched asymptotic expansion scheme of solution of the Navier-Stokes equations in the vicinity of the trailing edge. The structure of the flow involves a triple deck of Sytchev's type very close to separation, embedded in another triple deck, of Stewartsons' type, which is relevant to the overall separated flow. Ignoring angle of attack effects, the flow depends on two constants: the value of vorticity in the recirculation zone and the precise position of separation, which is known already as far as order of magnitude is concerned. Author

N76-17033 Michigan Univ., Ann Arbor. Dept. of Aerospace Engineering
LAMINAR SEPARATION: A LOCAL ASYMPTOTIC FLOW DESCRIPTION FOR CONSTANT PRESSURE DOWNSTREAM
A. F. Messiter *In* AGARD Flow Separation Nov. 1975 10 p refs (For availability see N76-17030 08-02)
(Contract DAHC04-68-C-0033)

A theoretical model is proposed for the description of two dimensional, steady, incompressible, laminar boundary layer flow near a separation point. It is assumed that the pressure just downstream of separation is approximately constant, and asymptotic solutions are then sought for large Reynolds number and small distance. The first two terms of the complex perturbation velocity in the external flow are shown to imply a pressure gradient upstream which is generally favorable, and adverse only for a short distance. This representation is no longer valid in a small neighborhood of the separation point where an interaction of the boundary layer with the external flow must be taken into account. Solutions are obtained for the boundary layer just upstream and, with an additional assumption, for the region of backflow just downstream of this region. A brief review and extension are also given for an asymptotic model of the complete wake behind a circular cylinder, with the assumption of nonzero drag at infinite Reynolds number. Author

N76-17034 Ruhr Univ., Bochum (West Germany)
DEPENDENCE OF LAMINAR SEPARATION ON HIGHER ORDER BOUNDARY LAYER EFFECTS DUE TO TRANSVERSE CURVATURE, DISPLACEMENT, VELOCITY SLIP AND TEMPERATURE JUMP
A. Wehrum *In* AGARD Flow Separation Nov. 1975 12 p refs (For availability see N76-17030 08-02)

The laminar compressible higher order boundary layer along a circular cylinder in an axial parallel supersonic flow is studied according to the method of matched asymptotic expansions. A weak constant mass flow is injected into the boundary layer through the surface of the cylinder. As a consequence of the homogeneous mass injection the first order boundary layer solution already leads to separation of the boundary layer within a finite distance from the leading edge. In a second order theory the influence of higher order boundary layer effects, such as transverse curvature, displacement, velocity slip and temperature jump, on the wall shear stress and the location of the separation point is studied. As numerical results show, transverse curvature and low density effects due to velocity slip and temperature jump at the wall increase the wall shear stress and therefore lead to a downstream shifting of the separation point. Displacement effect increases the wall shear stress near the leading edge. Author

N76-17035 Cincinnati Univ., Ohio.
EVALUATION OF SEVERAL APPROXIMATE MODELS FOR LAMINAR INCOMPRESSIBLE SEPARATION BY COMPARISON WITH COMPLETE NAVIER-STOKES SOLUTIONS
K. N. Ghia, U. Ghia, and W. A. Tesch (GE, Co., Evendale, Ohio) *In* AGARD Flow Separation Nov. 1975 15 p refs (For availability see N76-17030 08-02)
(Grant NSF GK-35514)

Several approximate mathematical models have been analyzed for studying laminar separation for incompressible flow, for which the Navier-Stokes equations comprise an exact mathematical model. Two model flow configurations have been used. The first configuration considered consists of the flow in the boundary layer on a two dimensional semi-infinite slab with a vertical leading face and shoulders, with varying degree of bluntness, forming an external corner on the body. The second flow configuration represents a class of two dimensional bodies with an internal corner and a more pronounced separation region; this configuration is used for only one approximate model so far. Results obtained with the various approximate models are evaluated by comparison with the corresponding Navier-Stokes solutions. All the models considered lead to improved results as the Reynolds number is increased. Author

N76-17036 Queen Mary Coll., London (England).
NUMERICAL INVESTIGATION OF REGULAR LAMINAR BOUNDARY LAYER SEPARATION
H. P. Horton *In* AGARD Flow Separation Nov. 1975 12 p refs (For availability see N76-17030 08-02)

An accurate numerical procedure of the differential difference type for the solution of the incompressible laminar boundary layer equations is presented. The procedure is applicable to both direct problems, in which the pressure distribution is prescribed, and inverse problems of the type in which the wall shear is prescribed. Some examples computed by this procedure show that, by prescribing the wall shear to be regular in the vicinity of separation, the usual singularity at separation is avoided. Results are also presented in which downstream marching with prescribed wall shear has been continued to considerable distances beyond separation, including an example in which both regular separation and re-attachment occur. In other cases no solution to the inverse problem can be found beyond a short distance after separation, but by smoothly joining a prescribed pressure distribution to that calculated in the inverse problem upstream, it has been found possible to continue the computation as a direct problem. Questions of stability and uniqueness of the solutions are discussed. Author

N76-17037 Cincinnati Univ., Ohio. Dept. of Aerospace Engineering.
FINITE DIFFERENCE SOLUTIONS FOR SUPERSONIC SEPARATED FLOWS
M. J. Werle, A. Polak, V. N. Vatsa, and S. D. Bertke *In* AGARD Flow Separation Nov. 1975 12 p refs (For availability see N76-17030 08-02)
(Contracts F33615-73-C-4014; N00019-73-C-0223; N60921-74-C-0203)

Laminar and turbulent separation bubbles are addressed for a wide range of geometries using an implicit finite difference technique to solve the interacting boundary layer equations. Solutions are presented for laminar compression ramps at $M = 4$ and 6, wall temperature ranges of 0.2 to 1.0 and angles of sweep (yaw) relative to the mainstream of up to 60 deg. In addition, solutions for laminar flow over wavy walls with multiple separation bubbles are given here for $M = 3$. Application of the approach to turbulent separated flows ahead of a compression ramp at $M = 3$ is also considered. Author

N76-17038 Centre National de la Recherche Scientifique, Meudon (France). Lab. d'Aerothermique.
SEPARATION BUBBLE PRODUCED BY A SHALLOW DEPRESSION IN A WALL UNDER LAMINAR SUPERSONIC FLOW CONDITIONS [BULBE DE DECOLLEMENT PRODUIT PAR UNE FAIBLE DEPRESSION DE PAROI EN ECOULEMENT LAMINAIRE SUPERSONIQUE]
E. Prunet-Foch, F. Legay-Desesquelles, and G. B. Diep *In* AGARD Flow Separation Nov. 1975 9 p refs In FRENCH; ENGLISH summary (For availability see N76-17030 08-02)

In supersonic flow, a shallow deformation on a flat plate induces a small separated bubble in the boundary layer. In order to predict this laminar separation and reattachment process including heat transfer phenomena at the wall, a theoretical study was built up, using Dorodnitsyn integral's method as well as expressions suggested by Nielsen for the velocity and temperature profiles. Thereby the calculation can be carried out up to the reattachment point. Simultaneously experiments were made in a wind tunnel. Experimental and predicted results are in good agreement. Author

N76-17039 Ohio State Univ., Columbus. Dept. of Aeronautical Engineering
ASYMPTOTIC THEORY OF SEPARATION AND REATTACHMENT OF A LAMINAR BOUNDARY LAYER ON A COMPRESSION RAMP
Odus R. Burggraf *In* AGARD Flow Separation Nov. 1975 9 p refs (For availability see N76-17030 08-02)
(Contract N00014-07-A-0232-0014)

Laminar boundary layer separation and reattachment is here considered for adiabatic flow over a compression ramp with supersonic mainstream. For large ramp angle, calculations based on the Stewartson-Williams triple deck theory show that the regions of separation and reattachment become distinct, with an intervening (plateau) region of nearly constant pressure. The mathematical description of each of these distinct regions is given, and simple formulas derived for a number of quantities of interest, including the plateau pressure, conditions at separation and reattachment, and the geometry of the separated region. Detailed comparisons of the theoretical results with available experimental data show favorable agreement. Author

N76-17040 Technische Hogeschool, Delft (Netherlands).
ON THE CALCULATION OF LAMINAR SEPARATION BUBBLES IN TWO-DIMENSIONAL INCOMPRESSIBLE FLOW
J. L. Vaningen *In* AGARD Flow Separation Nov. 1975 16 p refs (For availability see N76-17030 08-02)

A new laminar boundary layer calculation method is presented which combines the simplicity of Thwaites' method for the prediction of the momentum loss thickness with the accuracy of Stratford's two layer method for the prediction of the position of laminar separation. Calculated boundary layer characteristics for arbitrarily prescribed pressure distributions in general show a singular behavior at separation. It is shown that a real separating flow tends to adjust itself in such a way that the resulting pressure distribution prevents singular behavior of the boundary layer. An earlier method for the prediction of transition in attached boundary layers, based on linear stability theory, is extended to the case of separated flows. Two methods are discussed which might be used to predict whether reattachment of the turbulent shear layer will occur. Finally some results are discussed of wind tunnel experiments on the FX 66-S-196-V1 Wortmann airfoil, and on a circular cylinder with a tapered tail. Author

N76-17041 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
TURBULENT SEPARATION IN TWO-DIMENSIONAL FLOW [DECOLLEMENT TURBULENT EN ECOULEMENT BIDIMENSIONNEL]
Maurice Sirieix *In* AGARD Flow Separation Nov. 1975 27 p refs In FRENCH; ENGLISH summary (For availability see N76-17030 08-02)

The general features of separated turbulent flow regions are defined and in particular a discussion is made on the physical reality of strictly two dimensional turbulent flows. The three fundamental problems which occur in the detailed experimental analysis of a separated zone, i.e., separation, reattachment and coupling, are considered successively and the main factors of influence which rule these phenomena according to the subsonic-transonic-supersonic nature of the flow are presented. Lastly, a rapid review of the methods of prediction currently available is made. Author

N76-17042 Queen Mary Coll., London (England).
MEASUREMENTS IN SEPARATING TWO DIMENSIONAL TURBULENT BOUNDARY LAYERS
J. Chu and A. D. Young *In* AGARD Flow Separation Nov. 1975 12 p refs Sponsored by Min. of Defence (For availability see N76-17030 08-02)

Two different types of pressure distribution resulting in separation were induced in the flow over a flat plate zero incidence. Measurements were made of velocity distributions, skin friction, turbulence components and shear stress distributions at various stations both prior to and just after separation. The results have been compared with the predictions of various theories. Of these only those of Bradshaw and of Kuhn and Nielson showed good agreement for integral quantities with the measurements right up to the separation point, the predictions of the remaining methods tended to depart radically from the measurements some little distance ahead of separation. Significant differences were found, however, between the measured shear stress distributions near separation and the predictions of Bradshaw's method, these differences indicate where improvements to the method may be made. With certain important provisos the methods of Stratford and Townsend for predicting the separation position are shown to be fairly reliable. Author

N76-17043 Southern Methodist Univ., Dallas, Tex. Dept. of Civil and Mechanical Engineering
CHARACTERISTICS OF A SEPARATING INCOMPRESSIBLE TURBULENT BOUNDARY LAYER
Roger L. Simpson *In* AGARD Flow Separation Nov. 1975 14 p refs (For availability see N76-17030 08-02)
(Grants DA-ARO(D)-31-124-72-G31, DAHC04-74-G-0024, DAHC04-75-G-0051)

Laser and hot film anemometer measurements upstream and downstream of the separation zone are presented for a nominally two dimensional incompressible turbulent boundary layer for an airfoil type flow. The directionally sensitive laser anemometer measurements indicate that the location of intermittent separation as defined by Sandborn is the proper location of where the flow first deflects from the wall to relieve the imposed pressure gradient. Upstream of separation the correlations of Perry and Schofield for mean velocity profiles are supported within the uncertainty of the data. The separated flow field shows some profile similarity for all measured quantities. The normal stress terms in the momentum and turbulence energy equations are shown to be important near separation and cannot be neglected for the close prediction of the separation location. Author

N76-17044 McGill Univ., Montreal (Quebec). Dept. of Mechanical Engineering.
THE PREVENTION OF SEPARATION BY BLOWING IN TWO-DIMENSIONAL FLOW
B. G. Newman and H. P. A. H. Irwin (Natl. Res. Council of Can.) *In* AGARD Flow Separation Nov. 1975 13 p refs *(For availability see N76-17030 08-02)*

Two methods have been developed for calculating the jet momentum required to prevent the separation of the two dimensional incompressible turbulent boundary layer in adverse pressure gradients. The first was a strip integral method for plane wall; the shear stress at each limit being based on measurements in self preserving wall jets. The second is an extension of differential methods which uses four model equations for the individual Reynolds stresses and one equation for the rate of turbulence dissipation. In general, the differential method is more accurate particularly when the outer wake is large. However, as used, this method required more input data and was about three times more expensive to run. The integral method is therefore still useful and is not limited to low curvature. Author

N76-17045 Boeing Commercial Airplane Co., Seattle, Wash. Aerodynamics Research Unit.
THE ANALYSIS OF FLOW FIELDS WITH SEPARATION BY NUMERICAL MATCHING
G. W. Brune, P. E. Rubbert, and C. K. Forester *In* AGARD Flow Separation Nov. 1975 8 p refs (For availability see N76-17030 08-02)
(Contract F33615-73-C-3037)

A computing method is reported for flow fields characterized by the presence of viscous, separated regions interacting strongly with a surrounding inviscid flow. The procedure is to divide the flow field into several regions, each dominated by a particular type of fluid physics, and to analyze each region by using the numerical solution technique that is computationally optimum for the dominant type of flow. The paper specifically addresses the problem of matching a numerical solution of the Navier-Stokes equations for a region containing separated flow with another numerical solution appropriate for an adjacent region of inviscid flow. A key feature of the method presented is the placement of the matching boundary in space occupied by purely inviscid flow and remote from local areas of strong viscous/inviscid interactions. A detailed study and numerical substantiation of the method are presented for axisymmetric flow over an ellipsoid of revolution with laminar separation. Author

N76-17046 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
EXPERIMENTAL AND THEORETICAL INVESTIGATIONS OF TWO-DIMENSIONAL REATTACHMENT IN TURBULENT INCOMPRESSIBLE FLOW [ETUDE EXPERIMENTALE ET THEORIQUE DU RECOLLEMENT BIDIMENSIONNEL TURBULENT INCOMPRESSIBLE]
Jean-Claude LeBalleur and Jean Mirande *In* AGARD Flow

Separation Nov 1975 13 p refs In FRENCH, ENGLISH summary (For availability see N76-17030 08-02)

Turbulent reattaching flow downstream of a backward facing step has been experimented using a two dimensional plane incompressible configuration, with possibility to induce favorable or adverse pressure gradients in the potential flow near reattachment. A whole calculation has been performed by obtaining self induced interaction in matching a wall dissipative layer with an inviscid and irrotational external flow. Except for weak viscous interaction regions, an inverse calculation process is used to avoid singularities following the Klineberg's method for transonic aerofoils. Wall pressure distribution then results of an integral boundary layer calculation, whose failure for strongly separated regions is easily overcome by substitution of an empirical pressure law Author

N76-17047 Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace and Ocean Engineering.

THREE DIMENSIONAL DISTURBANCES IN REATTACHING SEPARATED FLOWS

G. R. Inger *In* AGARD Flow Separation Nov 1975 12 p refs (For availability see N76-17030 08-02)

Two possible causes of the pronounced periodic spanwise disturbances that have been observed in nominally two dimensional or axi-symmetric reattaching laminar and turbulent separated flows are studied theoretically. Approximate analytical compressible small disturbance flow models for both a local vortex instability mechanism and the effect of a row of incoming streamwise vortices are set up, solved and compared with available experimental data on surface disturbance pattern, pressure and heat transfer. The results on all counts confirm the predictions of the vortex instability model. It is also shown that Reynolds analogy does not apply to the disturbance skin friction and heat transfer. Author

N76-17048 Naval Surface Weapons Center, White Oak, Md.

AN EXPERIMENTAL INVESTIGATION OF THE COMPRESSIBLE TURBULENT BOUNDARY LAYER SEPARATION INDUCED BY A CONTINUOUS FLOW COMPRESSION

Robert L. P. Voisinet *In* AGARD Flow Separation Nov. 1975 11 p refs (For availability see N76-17030 08-02)

Flow field measurements of a compressible turbulent boundary layer on nozzle wall separation are presented. A continuous compression of the nozzle flow was imposed on the thick nozzle wall boundary layer to produce a streamwise pressure rise of sufficient strength to cause separation. The effects of Reynolds number on the separation phenomena are presented. For Reynolds numbers below 8. x 100,000 the separation length was found to increase with increasing Reynolds number, whereas for Reynolds numbers above 8. X 100,000 the reverse trend was observed. This reversal in the separation length versus Reynolds number trend was consistent with the reversal observed for incipient separation versus Reynolds number correlations. Author

N76-17049 Cranfield Inst of Technology (England) Aero-Jynamics Div.

LAMINAR AND TURBULENT BOUNDARY LAYER SEPARATION AT SUPERSONIC AND HYPERSONIC SPEEDS

John L. Stollery *In* AGARD Flow Separation Nov. 1975 11 p refs (For availability see N76-17030 08-02)

A number of theoretical and experimental investigations of shock boundary layer interaction are discussed. Both laminar and turbulent layers are considered, growing over two dimensional and axisymmetric bodies. For laminar flow a simplified version of the momentum integral method has been developed and used to predict incipient separation. A number of comparisons between experiment and theory for attached, incipient and well separated flows are included. For turbulent flow the three layer model proposed by Elfstrom is shown to give good quantitative estimates of incipient separation and to explain the Reynolds number trend found experimentally. Since the turbulent boundary layer is more resistant to shock interference a very simple attached flow theory is derived, which gives good predictions of both pressure and heat transfer at hypersonic speeds. Author

N76-17050 Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).

INCIPIENT SEPARATION OF A COMPRESSIBLE TURBULENT BOUNDARY LAYER

C. Appels and B. E. Richards *In* AGARD Flow Separation Nov. 1975 12 p refs (For availability see N76-17030 08-02)

The separation of a turbulent boundary layer is studied that developed on nozzle walls induced by a compression corner at Mach numbers of 3.6 and 5.4 over a range of Reynolds numbers based on boundary layer thickness of 100,000 to 1 million. Careful application of liquid line and schlieren flow visualization techniques were used to detect separated length down to one tenth of boundary layer thickness. In this way separation was detected at lower flap angles than has been previously found at these conditions. The related finding of low incipient separation angle implies that flow reversal may occur initially only in the laminar sublayer, and this is confirmed by applying simple laminar correlations to this layer. This measured value of alpha sub i is found to be little dependent on Mach number and it is concluded that the large dependence of alpha sub i on this parameter found earlier is explained by each experiment detecting a different degree of onset of separation. The measured variation of alpha sub i with Reynolds number appears to follow the trend of development of the wake component in the undisturbed boundary layer. Author

N76-17051* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

ON THE CALCULATION OF SUPERSONIC SEPARATING AND REATTACHING FLOWS

John D. Murphy, Leroy L. Presley, and William C. Rose *In* AGARD Flow Separation Nov. 1975 12 p refs (For availability see N76-17030 08-02)

CSCL 01A

A method is developed for solving the laminar and turbulent compressible boundary layer equations for separating and reattaching flows. Results of this method are compared with experimental data for two laminar and three turbulent layer, shock wave interactions. Several Navier-Stokes solutions are obtained for each of the laminar boundary layer, shock wave interactions considered. Comparison of these solutions indicates a first order sensitivity in C sub f to the computational mesh selected in both the viscous and inviscid portions of the flow. Comparison of the present boundary layer solutions with the Navier-Stokes solutions and with data for a given Mach number indicates that as long as the separation bubble is small, the boundary layer approximation yields solutions whose accuracy is comparable to the Navier-Stokes solutions. Author

N76-17052 Aerospace Research Labs., Wright-Patterson AFB, Ohio.

SUPERSONIC TURBULENT SEPARATED FLOWS UTILIZING THE NAVIER-STOKES EQUATION

J. S. Shang and W. L. Hankey, Jr. *In* AGARD Flow Separation Nov. 1975 13 p refs (For availability see N76-17030 08-02)

A modified eddy viscosity model is incorporated into the compressible Navier-Stokes equations and numerical solutions obtained for separated flows. The modification attempts to reproduce the response of a turbulent boundary layer to a severe pressure gradient by introducing a simple rate equation to account for the relaxation phenomenon. The system of equations is solved by MacCormack's time splitting explicit numerical scheme for a series of compression corner configurations. Computations are performed for ramp angle varying from 15 to 25 degrees at a Mach number of 2.96 and Reynolds number of 10 to the 7th power. An incident oblique shock impingement case is also computed at these same conditions and included for comparison with a ramp induced separation case. Calculations utilizing the modified eddy viscosity for the interacting turbulent flow compare very well with experimental measurements for the compression ramps, particularly, in the prediction of the upstream pressure propagation and location of the separation and reattachment points. Good agreement is also attained between the measured and the calculated density profiles in the viscous inviscid interaction region Author

N76-17053* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

AN EXPERIMENTAL AND NUMERICAL INVESTIGATION OF SHOCK WAVE INDUCED TURBULENT BOUNDARY LAYER SEPARATION AT HYPERSONIC SPEEDS

J. G. Marvin, C. C. Horstman, M. W. Rubesin, T. J. Coakley, and M. I. Kussoy *In* AGARD Flow Separation Nov. 1975 13 p refs (For availability see N76-17030 08-02)

CSCL 01A

A thoroughly documented experiment is reported that was specifically designed to test and guide computations of the interaction of an impinging shock wave with a turbulent boundary layer. Detailed mean flow field and surface data are presented

for two shock strengths which resulted in attached and separated flows, respectively. Numerical computations are used to illustrate the dependence of the computations on the particulars of the turbulence models. Models appropriate for zero pressure gradient flows predicted the overall features of the flow fields, but were deficient in predicting many of the details of the interaction regions. Improvements to the turbulence model parameters were sought through a combination of detailed data analysis and computer simulations which tested the sensitivity of the solutions to model parameter changes. Computer simulations using these improvements are presented and discussed. Author

N76-17054 Nielsen Engineering and Research, Inc., Mountain View, Calif.
PREDICTION OF TURBULENT SEPARATED FLOW AT SUBSONIC AND TRANSONIC SPEEDS INCLUDING UNSTEADY EFFECTS
Gary D. Kuhn and Jack N. Nielsen *In* AGARD Flow Separation Nov. 1975 16 p refs (For availability see N76-17030 08-02)

An integral boundary layer method is extended to calculation of separated turbulent boundary layers in steady flow and to unsteady turbulent boundary layers. Separated boundary layers are calculated by treating the pressure as a dependent variable and prescribing the wall shear variation. The boundary layer method and a suitable potential flow method are used in an iterative procedure to produce a method for predicting the characteristics of separated flows. Good comparisons are shown between the theory and data for a separated turbulent boundary layer on the wall of a transonic wind tunnel. Analytical solutions developed from a small perturbation analysis indicate the method is valid for unsteady flow over a certain range of frequencies. Good comparisons were obtained between the linearized theory and results produced by a finite difference solution of the complete nonlinear unsteady boundary-layer equations. Examination of the nature of the integral equations in the vicinity of a point of zero wall shear stress indicates that the shear stress gradient decreases approaching the point of zero shear. Author

N76-17055 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
VISCOUS INTERACTIONS WITH SEPARATION UNDER TRANSONIC FLOW CONDITIONS [INTERACTION VISQUEUSE AVEC DECOLLEMENT EN ECOULEMENT TRANSONIQUE]
J. Delery, J. J. Chattot, and J. C. LeBalleur *In* AGARD Flow Separation Nov. 1975 13 p refs In FRENCH; ENGLISH summary (For availability see N76-17030 08-02)

Strong viscous interactions which are present in transonic flows past airfoils give rise to an important thickening of the boundary layer with the frequent formation of a separated region. Under such conditions, the calculation of the flow must call upon rapid interaction theories whose application for the case of a turbulent boundary layer is examinated in conjunction with experimental analysis. A detailed analysis of the flow field has been made by using interferometry and a method of calculation similar to Klineberg's approach. The principle of this theory is to divide the flow into two domains: a weak interaction region where the pressure gradient is moderate, and a rapid interaction region if separation is likely to occur. Author

N76-17056 Technische Hochschule, Aachen (West Germany).
UNSTEADY SHOCK WAVE-BOUNDARY LAYER INTERACTION ON PROFILES IN TRANSONIC FLOW
Klaus Finke *In* AGARD Flow Separation Nov. 1975 11 p refs (For availability see N76-17030 08-02)

Many unsteady flows are characterized by the interaction of shock waves with separated boundary layers. In particular shock oscillations occur on thick airfoils at high angles of attack and transonic free stream Mach numbers. Measurements were carried out in an intermittent indraft tunnel to study shock oscillations on various two dimensional wings. Alternating separation and attachment at the leading edge is the observed severest type of the unsteady flow conditions. For this case multispark interferograms show periodical oscillations of the circulation of the wing, accompanied by the same oscillation of the circulation in the opposite sense in the wake. Large periodical disturbances exist throughout the entire flow field with defined phase shifts. The primary source of the observed instability is the shock induced separation of the boundary layer on the profile. Author

N76-17057 Max-Planck-Institut fuer Stroemungsforschung, Goettingen (West Germany).
SHOCK INDUCED FLOW OSCILLATIONS
G. E. A. Meier *In* AGARD Flow Separation Nov 1975 9 p refs (For availability see N76-17030 08-02)

The physical system consisting of a shock wave and the downstream separated flow causes oscillatory instabilities in three cases described here: transonic flow in a curved channel; flow over a symmetric profile at angle of attack; and flow in a Laval nozzle. The shock boundary layer interaction creates or displaces a separation bubble, thereby changing the flow field downstream of the shock root. This process usually strengthens the shock wave by increasing the back pressure. The shock wave then becomes unsteady, moving the separation point with it in an upstream direction, so that a self preserving instability occurs, thus reducing the flow velocity in the whole transonic field. By means of the later reattachment of the boundary layer, the entire flow is accelerated and tends to return to the initial condition, i.e., the process is cyclic. The length of the oscillation periods can be estimated. Author

N76-17058 National Aerospace Lab., Amsterdam (Netherlands).
EXPERIMENT ON TRANSONIC SHOCK WAVE BOUNDARY LAYER INTERACTION
J. W. Kool *In* AGARD Flow Separation Nov. 1975 10 p refs (For availability see N76-17030 08-02)

An experiment is described in which a normal shock interacts with a two dimensional turbulent boundary layer in an uniform flow with a Mach number of 1.4. The wall pressure distribution in the interaction region was measured and detailed pitot and static pressure surveys were made. The flow field was analyzed and no supersonic tongue was found downstream of the shock. The velocity profiles were integrated to obtain the integral properties whereas the skin friction was derived from Clauser plots. From the distribution of skin friction and the behavior of the integral properties it has been concluded that the boundary layer separated at the foot of the shock and reattached 4.5 undisturbed boundary layer thickness downstream of the separation point. The velocity profiles at the start of the interaction and downstream of the reattachment point correlate well with the logarithmic velocity distribution in the wall region. Author

N76-17059 Royal Aircraft Establishment, Farnborough (England).
A REVIEW OF SEPARATION IN STEADY, THREE-DIMENSIONAL FLOW
J. H. B. Smith *In* AGARD Flow Separation Nov. 1975 17 p refs (For availability see N76-17030 08-02)

An attempt is made to present a unified view which leads from a consideration of the structure of the problem and the role of modelling, through the partial solutions which have been found, to some illustrations of the application of three dimensional flow separation in aircraft design. Much of the work reported is only partially three dimensional, in the sense that boundary layers are calculated for flows over cones or infinite sheared wings and that slender body theory is used to calculate the separated flow. These treatments reveal the limitations of some two dimensional concepts like reattachment and present an exciting range of problems and possibilities. Author

N76-17060* R and D Associates, Santa Monica, Calif.
LAMINAR SEPARATION ON A BLUNTED CONE AT HIGH ANGLES OF ATTACK
Stephen C. Lubard *In* AGARD Flow Separation Nov. 1975 11 p refs (For availability see N76-17030 08-02)
(Contract NAS2-8113)

A new technique is reported for calculating the entire flow field on spherically blunted cones at high angles of attack and high laminar Reynolds numbers. An approximate system of parabolic equations obtained from the steady Navier-Stokes equations by assuming the viscous, streamwise derivative terms are small compared to the viscous normal and circumferential derivatives is the basis of the calculations. These equations are valid for both the inviscid and viscous regions, including the circumferential separation zone that develops on the leeward side at high angles of attack. Two different methods are used to obtain the initial conditions for these equations at the sphere cone tangency plane. For small nose Reynolds numbers, an axisymmetric merged layer solution around a sphere is rotated to provide a three-dimensional initial plane of data. For large nose Reynolds numbers, the nose region is solved using an inviscid, three dimensional time dependent solution combined with a boundary layer solution for the viscous flow. The computed flowfield including the leeward separation region is described and compared with data for a 7 deg half angle cone at 10 deg angle of attack, and a blunt 15 deg half angle cone at 15 deg angle of attack. Author

N76-17061 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
CALCULATION OF THE THREE DIMENSIONAL LAMINAR BOUNDARY LAYER AROUND BODIES OF REVOLUTION AT INCIDENCE AND WITH SEPARATION
Wolfgang Geibler *In* AGARD Flow Separation Nov. 1975 11 p refs (For availability see N76-17030 08-02)

A numerical method is presented to calculate the three dimensional laminar incompressible boundary layer over bodies of revolution at incidence. The inviscid flow velocities used for the boundary condition at the outer edge of the boundary layer are determined numerically by a singularity method. The boundary layer calculation is carried out in a streamline coordinate system. The coordinates are fixed to the streamlines and equipotential lines of the inviscid flow. The boundary layer equations are integrated by an implicit finite difference method. As a result of the numerical calculation process the velocity profiles in directions of streamlines and equipotential lines are known for each mesh point of the coordinate system. It is shown that this method can be used to determine the separation lines on the body surface. Author

N76-17062 National Aerospace Lab., Amsterdam (Netherlands).
THREE DIMENSIONAL SEPARATION OF AN INCOMPRESSIBLE TURBULENT BOUNDARY LAYER ON AN INFINITE SWEPT WING
A. Eisenaar, B. VandenBerg, and J. P. F. Lindhout *In* AGARD Flow Separation Nov. 1975 15 p refs (For availability see N76-17030 08-02)

A three dimensional boundary layer flow under infinite swept wing conditions is simulated. A description is given of the development of the boundary layer in a region of an adverse pressure gradient leading to increased cross flows and finally terminating in a three dimensional separation. Measurements are reported of the mean velocity profiles, the wall shear stress and the components of the Reynolds stress tensor. These measurements reveal a decreasing mixing length with increased cross flow and a substantial difference between the direction of the shear stress and the velocity gradient. After the separation line a region with an almost spanwise flow is observed. Calculations are presented of the boundary layer development with a finite difference method using semi-empirical shear stress relations based on the turbulent energy equation. This method fails to predict separation. When empirical modifications, based on the experimental results are introduced, the agreement improves. Close to separation, however, the calculations are very sensitive to the pressure distribution and this might be related to a Goldstein-type singularity at separation. Author

N76-17063* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
THREE DIMENSIONAL BOUNDARY LAYER SEPARATION IN SUPERSONIC FLOW
William D. Bachalo and Maurice Holt *In* AGARD Flow Separation Nov 1976 13 p refs Prepared in cooperation with Calif Univ., Berkeley (For availability see N76-17030 08-02)
CSCL 01A

An account is given of a detailed experimental investigation of three dimensional boundary layer separation in supersonic flow. In investigating three dimensional effects on supersonic separation, models were chosen which exhibited departures from two dimensional flow in the simplest way. The plane compression corner was replaced by a plate attached to a swept back wedge formed by two obliquely intersecting planes. Maintaining a constant tunnel Mach number of 2.5, surface pressure measurements were made on these models at static orifices spaced along the centerline and along three parallel lines. The flow parameters in the boundary layer and separated regions adjacent to the model surface were measured by traversing hot wire and pitot probes. The traverses were taken across the boundary layer and reversed flow regions in a direction normal to the body surface, they were made in several vertical planes, including the plane of symmetry. Author

N76-17064 Salford Univ. (England). Dept of Mechanical Engineering
PRESSURE RISE TO SEPARATION IN CYLINDRICALLY SYMMETRIC SHOCK WAVE, TURBULENT BOUNDARY LAYER INTERACTION
D. F. Myring *In* AGARD Flow Separation Nov 1975 14 p refs (For availability see N76-17030 08-02)

Integral equations governing the three dimensional flow in a cylindrically symmetric shock wave - turbulent boundary layer interaction are written in the form of momentum equations for directions normal to and aligned with the line of the shock, plus an entrainment equation. By neglecting the contributions of surface friction and mass entrainment, direct dependence on spatial derivatives is removed and solutions are obtained using the Mager cross flow profiles and power law profiles for the streamwise flow. Results are produced for angles of sweep greater than 45 deg which show good agreement with experimental measurements of pressure rise to separation. For smaller angles of sweep the theory suggests that the skin friction becomes vanishingly small at separation, which in turn suggests the need for a modified separation criterion. Author

N76-17065 Ballistic Research Labs., Aberdeen Proving Ground, Md.
THE STRUCTURE OF THREE DIMENSIONAL SEPARATED FLOWS IN OBSTACLE, BOUNDARY LAYER INTERACTIONS
Raymond Sedney and Clarence W. Kitchens, Jr. *In* AGARD Flow Separation Nov. 1975 15 p refs (For availability see N76-17030 08-02)

The turbulent boundary layer on the wall of a continuous supersonic wind tunnel is studied. Sizeable separated flow regions can be studied since the wall width is 38 cm and the boundary layer is typically 2.5 cm thick. The large scale of the experiment is required to resolve the fine details of the flow structure. The flow visualization techniques are discussed. The variation of primary separation distance is presented as a function of M, R, and obstacle dimensions. Some scaling laws that have been proposed are not supported by our results. The structure of the separated flow upstream of the obstacle changes with relatively small changes in R; the number of vortices varies from 6 to 4 to 2 as R changes. Data are presented for large and small protuberances, but the latter are emphasized. Author

N76-17066 Rutgers Univ., New Brunswick, N.J. Dept. of Mechanical, Industrial, and Aerospace Engineering.
CINEMATOGRAPHIC STUDY OF SEPARATED FLOW REGIONS
R. H. Page and C. E. G. Przirembel *In* AGARD Flow Separation Nov. 1975 7 p refs (For availability see N76-17030 08-02)

A cinematographic study utilizing high speed motion picture photography was carried out for a series of supersonic separated flow configurations. A two dimensional variable Mach number wind tunnel was used to produce flow fields about several sting supported models, including a sphere, a blunt body with a leading spike and a missile. Color Schlieren and shadowgraph techniques were the primary diagnostic tools used in these studies. For some film sequences, these flow visualization techniques were enhanced by the addition of small particles. The chief results of these studies are presented in a 16mm color motion picture film. Excellent qualitative descriptions of various supersonic, separated flow fields have been obtained by viewing these high speed motion pictures on a reduced time scale or on a frame-by-frame basis. Author

N76-17067 Office National d'Etudes et de Recherches Aerospatiales, Paris (France)
PHENOMENOLOGICAL INVESTIGATIONS OF SEPARATED FLOW USING HYDRODYNAMIC VISUALIZATIONS [ETUDE PHENOMENOLOGIQUE A PARTIR DE VISUALISATIONS HYDRODYNAMIQUES]
Henri Werle *In* AGARD Flow Separation Nov 1975 14 p refs In FRENCH, ENGLISH summary (For availability see N76-17030 08-02)

Thanks to flow visualizations obtained at a water tunnel since many years, it has been possible to undertake the physical study of separations around a broad variety of obstacles. From these results, obtained at low speed, emerge a number of fundamental schemes which correspond to the main types of separations observed in two- or three-dimensional flow, their detailed analysis emphasizes their singularities as well as their transitional, vortex like and unsteady aspects. A synthesis is proposed aiming at the characterization of three dimensional separations as compared to those occurring in plane or axisymmetrical flow. Author

N76-17068 National Aeronautical Establishment, Ottawa (Ontario)
THE THREE DIMENSIONAL SEPARATION OF A TURBULENT BOUNDARY LAYER BY A SKEWED SHOCK WAVE AND ITS CONTROL BY THE USE OF TANGENTIAL AIR INJECTION
David J Peake and William J Rainbird (Carleton Univ) *In* AGARD Flow Separation Nov 1975 34 p refs (For availability see N76-17030 08-02)

The three dimensional interaction of a skewed shock wave with a turbulent boundary layer, that is generated by a variable angle wedge standing normal to a flat test wall, has been systematically investigated at nominal mainstream Mach numbers of 2 and 4, up to and beyond shock strengths sufficient to cause incipient three dimensional separation In the Mach number 2 flowfield, with wedge deflection angles of 8 and 11.5 deg, blowing air at Mach 3 was introduced upstream of the interaction and tangential to the wall The objective was to control and remove the three dimensional separation. The jet excess momentum for this control situation was slightly more than the momentum deficit of the undisturbed boundary layer. In addition to the control of the magnitude of the blowing momentum, the direction of the wall jet could also be changed by rotating the line of the jet efflux. The optimum direction of blowing was found to be along a line somewhere between the deflected surface of the wedge and the line of the oblique shock wave. Author

N76-17069 Princeton Univ., N.J.
AN EXPLORATORY OF A THREE DIMENSIONAL SHOCK WAVE BOUNDARY LAYER INTERACTION AT MACH 3
B. Oskam, I. E. Vas, and S. M. Bogdonoff *In* AGARD Flow Separation Nov. 1975 14 p refs (For availability see N76-17030 08-02)

An exploratory experimental investigation has been carried out on the three dimensional flow fields caused by the interaction of oblique shock waves and a planar turbulent boundary layer. The study was performed at a free stream Mach number of 2.95, a Reynolds number per inch of 1.6 x 106 and near adiabatic wall conditions. The interaction was studied on two experimental configurations having different initial boundary layer thicknesses. Both surface measurements as well as complete flow field surveys were performed. The main contributions of the present investigation are two experimentally derived flow field models for shock generator angles of 4 deg and 10 deg. Based upon both static pressure and surface flow patterns, as well as heat transfer data, the interaction region can be characterized as quasi-two-dimensional along the shock direction in the region studied. A critical examination of the occurance of ordinary flow separation and its character was carried out It was concluded that McCabe's criterion is not a sufficient condition to determine the onset of flow separation. Author

N76-17070 General Dynamics/Convair, San Diego, Calif.
THE MANY FACETS OF 3D TRANSONIC SHOCK INDUCED SEPARATION
H. Yoshihara and D Zonars (AF Flight Dynamics Lab) *In* AGARD Flow Separation Nov 1975 8 p refs (For availability see N76-17030 08-02)

Pressure distributions obtained in wind tunnel tests on several wing fuselage configurations at high subsonic Mach numbers are used to illustrate several shock induced separation scenarios that are essentially 3D in nature Pearcey's Type B interactions, distinguished by prior history effects, appear in several different forms. The described results in general are characteristic primarily of aft-cambered airfoils. Author

N76-18059# Advisory Group for Aerospace Research and Development, Paris (France)
COMMENTS ON TRANSONIC AND WING-STORE UNSTEADY AERODYNAMICS
H Tijdeman (NLR) and R. Destuynder (ONERA) Jan 1976 42 p refs In ENGLISH and partly in FRENCH
(AGARD-R-636) Avail NTIS HC $4.00

Papers given in September 1975 before the Structures and Materials Panel Sub-Committee on Aeroelasticity and Unsteady Aerodynamics, are presented. The first presents an in-depth review of the present state-of-the-art in transonic unsteady aerodynamics Some of the most advanced methods are discussed and evaluated An illustration of typical effects occurring in high subsonic and transonic flow around oscillating airfoils and wings is presented Some useful conclusions are drawn The second paper contains a description of measurements made on a variety of wing-store combinators, and compares these measurements with theoretical values derived from two different methods, one developed by ONERA and the other by NLR. A conclusion regarding the main factor effecting variation in lift coefficients of wings-with-stores is drawn For individual titles, see N76-18060 through N76-18063

N76-18060 Advisory Group for Aerospace Research and Development, Paris (France)
CHARACTERISTICS OF 2-D UNSTEADY TRANSONIC FLOW
In its Comments on Transonic and Wing Store Unsteady Aerodyn Jan 1976 p 2-5 (For availability see N76-18059 09-02)

Characteristics of unsteady high subsonic and transonic flow are illustrated by use of experimental results from a 2-D airfoil with a sinusoidally steady and unsteady airloads. The results of the wind tunnel tests on an airfoil with oscillating flap, and unsteady flow field are discussed along with periodical shock wave motion The calculation methods for 2-D unsteady flow are reviewed F O S

N76-18061 Advisory Group for Aerospace Research and Development, Paris (France).
EVALUATION OF CALCULATION METHODS FOR 2-D UNSTEADY TRANSONIC FLOW
In its Comments on Transonic and Wing-Store Unsteady Aerodyn Jan 1976 p 5-7 (For availability see N76-18059 09-02)

The methods for solving the problem of two-dimensional unsteady transonic flow are discussed for oscillating airfoils The thickness effects and influence of the boundary layer are considered along with the unsteady shock wave motion F.O.S.

N76-18062 Advisory Group for Aerospace Research and Development, Paris (France).
UNSTEADY TRANSONIC FLOW
In its Comments on Transonic and Wing-Store Unsteady Aerodyn Jan. 1976 p 7-8 (For availability see N76-18059 09-02)

The transonic flow around oscillating finite three-dimensional wings is discussed The experimental evidence that supports the development of prediction methods for three-dimensional flow is reviewed, and the calculation methods for 3-D unsteady flow are analyzed F O S.

N76-18063 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
UNSTEADY PRESSURE MEASUREMENTS IN WING-WITH-STORE CONFIGURATIONS
Roger Destuynder *In* AGARD Comments on Transonic and Wing-Store Unsteady Aerodyn Jan 1976 p 30-37 refs In FRENCH; ENGLISH summary (For availability see N76-18059 09-02)

Measurements are made at various Mach numbers on a semi-span model oscillating in pitch. Several kinds of stores, differing in size and position, were mounted In each case, the characteristic values due to the store itself, those due to the interaction between wing and store, and lastly the values relative to the clean wing were measured Calculations were performed in order to compare theory and experiment Two methods were applied the first one, developed by ONERA, is a semi-empirical method making use of Mach number fields, the other one, used by the NLR Amsterdam, is more complete as it determines directly the interaction between wing and store, introducing source and doublet distributions on the store, the pylon and the wing. In all cases, it appears that the main term is the interaction created by the store on the wing, which can entail a variation of up to 15% of the lift coefficient. Author

N76-18064# Advisory Group for Aerospace Research and Development, Paris (France)
COMPARISON BETWEEN THE CALCULATED AND MEASURED TRANSFER FUNCTIONS FOR THE CONCORDE AIRCRAFT [COMPARAISON DES FONCTIONS DE TRANSFERT CALCULEES ET MESUREES SUR LAVION CONCORDE]
J. Roustan Jan 1976 21 p In FRENCH
(AGARD-R-637) Avail NTIS HC $3.50

A comprehensive and detailed analysis is presented of the comparison between calculations and actual in-flight measurements of the transfer functions of the Concorde Supersonic Transport aircraft through atmospheric turbulence at differing altitudes and speeds Numerous graphs and charts are included Results indicate that the aircraft presently defies as effective analysis of its response to turbulence Recommendations for future research are discussed Author

N76-21163# Advisory Group for Aerospace Research and Development, Paris (France)
TECHNICAL EVALUATION REPORT OF AGARD SPECIALISTS MEETING ON WINGWITH-STORES FLUTTER
Walter J Mykytow (AFFDL) Feb 1976 13 p refs Meeting held at Munich, 9 oct 1974 during 39th Meeting of Struct and Mater Panel
(AGARD AR 98, ISBN 92 835 1209 X) Avail NTIS HC $3 50

The carriage of stores on wings significantly changes their dynamic characteristics and often adversely affects their flutter properties as a result of reduced wing frequencies and the introduction of critical frequency ratios together with inertial, elastic and aerodynamic coupling between loads Adverse flutter characteristics and significantly lowered flutter speeds occur and these restrictions severely constrain the speed - altitude performance envelope that can be achieved by an aircraft. The variety of stores that can be carried on modern tactical airplanes generates a need to accurately evaluate the literally thousands of possible store combinations which can be carried by such aircraft Results are presented from a conference on information and procedures in use in the various NATO nations to solve the flutter problems associated with the carriage of external stores on wings Nine presentations were given and are summarized Recommendations concerning possible future efforts on the subject are given Author

N76-23163# Advisory Group for Aerospace Research and Development, Paris (France).
A COMPARISON OF METHODS USED IN INTERFERING LIFTING SURFACE THEORY
W P. Rodden Feb 1976 88 p refs
(AGARD-R-643-Suppl; ISBN-92-835-1210-3) Avail: NTIS HC $4.50

Flow field prediction methods for interfering lifting surfaces cover subsonic and supersonic aerodynamic loads. For individual titles, see N76-23164 through N76-23168.

N76-23164 Advisory Group for Aerospace Research and Development, Paris (France).
INTERFERENCE AND NONPLANAR LIFTING SURFACE THEORIES
William P. Rodden (La Canada, Calif.) *In its* A Comparison of Methods Used in Interfering Lifting Surface Theory Feb. 1976 p 2-5 (For availability see N76-23163 14-02)

The latest prediction methods for unsteady aerodynamic forces acting on interfering lift configurations are discussed The collocation method and finite element analysis are applied to subsonic flows Supersonic procedures include the box integration method, the box collocation method, and the collocation method. G.G

N76-23165 Advisory Group for Aerospace Research and Development, Paris (France).
THE NONPLANAR KERNEL FUNCTIONS
William P. Rodden (La Canada, Calif.) *In its* A Comparison of Methods Used in Interfering Lifting Surface Theory Feb 1976 p 5-9 (For availability see N76-23163 14-02)

Nonplanar acceleration potential aspects for the kernels of the lifting surface integral equation are developed for the subsonic case. A velocity potential kernel is applied to supersonic flow analysis. G.G

N76-23166 Advisory Group for Aerospace Research and Development, Paris (France).
SUBSONIC METHODS
William P. Rodden (La Canada, Calif.) *In its* A Comparison of Methods Used in Interfering Lifting Surface Theory Feb. 1976 p 9-12 (For availability see N76-23163 14-02)

Kernel function and Doublet-Lattice Method (DLM) applications for solving subsonic lifting surface problems are outlined. The first method uses chordwise collocation points to evaluate downwash, and the second method applies finite element analysis to obtain downwash expressions G.G

N76-23167 Advisory Group for Aerospace Research and Development, Paris (France)
SUPERSONIC METHODS
William P. Rodden (La Canada, Calif.) *In its* A Comparison of Methods Used in Interfering Lifting Surface Theory Feb 1976 p 12-13 (For availability see N76-23163 14-02)

Refined Mach box integration procedures are reported for numerical analysis of supersonic lifting surface interference effects G.G

N76-23168 Advisory Group for Aerospace Research and Development, Paris (France)
PREFACE TO FIGURES AND TABLES
William P. Rodden (La Canada, Calif.) *In its* A Comparison of Methods Used in Interfering Lifting Surface Theory Feb. 1976 p 13-25 refs (For availability see N76-23163 14-02)

Data are compared from three different solutions of the lifting surface problem The first task is the determination of the flow field, i.e., the velocity components in the field surrounding the oscillating wing. The second task is the calculation of the interference loading, i.e., lift and moment coefficients, on two surfaces induced by the motion of the forward surface The third task is the calculation of the generalized forces resulting from the motions of the various components of an interfering wing-horizontal tail-fin configuration. The computation of each of these derived quantities from the solution of the basic lifting surface problem is indicated below. Author

N76-24146# Advisory Group for Aerospace Research and Development, Paris (France)
UNSTEADY AERODYNAMICS
Mar. 1976 91 p refs Presented at the Fluid Dyn. Panel Round Table Discussion on Unsteady Aerodyn., Goettingen, West Germany, May 1975
(AGARD-R-645) Avail NTIS HC $5.00

Five papers are presented covering such topics as calculation methods in unsteady aerodynamics, recent research results in flutter suppression, transonic flow, unsteady rotor blade aerodynamics, wind tunnel test techniques, and recent research efforts in aeroelasticity and unsteady aerodynamics at the U.S. Air Force Flight Dynamics Laboratory. These papers gave a succinct review of the present state of aeroelasticity-oriented unsteady aerodynamics For individual titles, see N76-24147 through N76-24151.

N76-24147 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
UNSTEADY AERODYNAMIC PREDICTION METHODS APPLIED IN AEROELASTICITY
B Laschka *In* AGARD Unsteady Aerodyn Mar 1976 31 p refs (For availability see N76-24146 15-02)

A brief survey is given on the basic prediction methods in unsteady aerodynamics needed in aeroelasticity. After an introductory outline of some of the most important aeroelastic phenomena, some representative concepts applied to calculate unsteady aerodynamic forces in subsonic and supersonic flow are described. Then, attention is drawn to areas which are not yet covered adequately by the presently existing theories These aeas comprise effects of gap geometry between fixed wing and control surfaces, of mean incidence about which a wing or control surface is oscillating, of wing thickness, of Reynolds number, etc Furthermore, some not yet published results related to interfering multiple lifting configurations are presented These results include thrust calculations on oscillating tandem wings in incompressible flow, wing induced unsteady tail loads and some downwash evaluations behind wings in supersonic flow Author

N76-24148 National Aerospace Lab., Amsterdam (Netherlands)
SOME REMARKS ON UNSTEADY TRANSONIC FLOW
H Tijdeman *In* AGARD Unsteady Aerodyn. Mar. 1976 11 p refs (For availability see N76-24146 15-02)

A general discussion of unsteady transonic aerodynamics is presented A simple example of an airfoil having an oscillating trailing edge flap was chosen for the discussion. Results are presented from wind tunnel tests performed on the airfoil to illustrate the interactions of steady flow fields on unsteady flow fields Topics discussed include: (1) various calculation methods used to compute unsteady transonic flow (finite difference theory), and (2) boundary layer interactions, and shock wave interactions causing aerodynamic loading. It is shown at high subsonic and transonic speeds that unsteady airloads are influenced considerably by steady and unsteady flow fields and shock wave interactions. J.R.T

N76-24149 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
UNSTEADY AERODYNAMICS OF HELICOPTER BLADES

Rolland Dat *In* AGARD Unsteady Aerodyn Mar 1976 6 p refs In FRENCH; ENGLISH summary (For availability see N76-24146 15-02)

A method that predicts the unsteady periodic aerodynamic forces on helicopter blades in forward flight is described. The blade sections are assimilated to airfoils; the lift at high angle attack is given by a mathematical model and the three-dimensional interferences between blades and between separate sections of the same blades are given by the linearized lifting surface theory. The comparison between theoretical and experimental results is satisfactory. The range of applications of the method used to synthetize the three-dimensional theory and the experiments in two-dimensional flow is not restricted to helicopters. Author

N76-24150 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. fuer Aeroelastik.

WIND TUNNEL TEST TECHNIQUES FOR THE MEASUREMENT OF UNSTEADY AIRLOADS ON OSCILLATING LIFTING SYSTEMS AND FULL-SPAN MODELS

H. Foersching *In* AGARD Unsteady Aerodyn. Mar. 1976 24 p refs (For availability see N76-24146 15-02)

The main features of wind tunnel test techniques in current use for the measurement of dynamic stability derivatives, flutter coefficients and unsteady aerodynamic pressure distributions are described. The presentations are illuminated by some typical test results. Author

N76-24151 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio. Vehicle Dynamics Div.

BRIEF OVERVIEW OF SOME AIR FORCE FLIGHT DYNAMICS LABORATORY RESEARCH EFFORTS IN AEROELASTICITY AND AERO-ACOUSTICS

Walter J. Mykytow *In* AGARD Unsteady Aerodyn. Mar. 1976 13 p refs (For availability see N76-24146 15-02)

The feasibility of extending active feedback control technology to flutter suppression in wings and external stores is discussed. Flight tests of a B-52 full scale model are described. A computer program for flutter optimization is discussed. The use of composite materials in flutter suppression is examined. J.R.T.

N76-32126# Advisory Group for Aerospace Research and Development, Paris (France)

UNSTEADY PRESSURES DUE TO CONTROL SURFACE ROTATION AT LOW SUPERSONIC SPEEDS: COMPARISON BETWEEN THEORY AND EXPERIMENT

C. G. Lodge (British Aircraft Corp. Limited, Lanshire) and H. Schmid (Messerschmitt-Bolkow-Blohm GmbH, Munich) Sep. 1976 21 p refs Presented at the 42d Meeting of the Structures and Materials Panel, Ottawa, 5 Apr. 1976

(AGARD-R-647; ISBN-92-835-1223-5) Avail: NTIS

Most aircraft flutter problems have featured control surfaces, and it is necessary that unsteady aerodynamic forces generated by their motions should be accurately predicted. Therefore theoretical and experimental studies were conducted on a planform with part span control surface oscillating in the control surface rotation mode at low supersonic Mach numbers. The results are presented and discussed. It is shown that these studies must be of a high accuracy so that the more critical aerodynamic coefficients, such as hinge moment damping, are determined with confidence. Author

N77-12013# Advisory Group for Aerospace Research and Development, Paris (France).

THROUGH-FLOW CALCULATIONS IN AXIAL TURBOMACHINERY

Oct. 1976 237 p refs Proceedings held at Cologne, West Germany, 20-21 May 1976

(AGARD-CP-195; ISBN-92-835-0179-9) Avail: NTIS HC A11/MF A01

An axisymmetric approach is used in considering flow distributions at design and off-design conditions in single and multi-stage turbomachines. For individual titles, see N77-12014 through N77-12026.

N77-12014# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche (France).

MODELS FOR CALCULATING FLOW IN AXIAL TURBOMACHINERY [MODELES DE CALCUL DE L'ECOULEMENT DANS LES TURBOMACHINES AXIALS]

Jean-Marine Thiaville *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 16 p refs In FRENCH (For primary document see N77-12013 03-02)

Avail. NTIS HC A11/MF A01

The problem of calculating axial flow in turbomachines is approached using the model of current surfaces S1 and S2 of C. H. Wu. Viscous effects are introduced under the form of loss and the effects of displacement. The boundary layer theory is accepted. The simplified model is used to analyze the connection of the estimates of surfaces S1 and S2. Transonic flow is studied. Diagrams of loss and of angles beyond adaptation are provided. Blocking and secondary flow are considered. Applications in which the model is defective are discussed and methods for resolving the difficulties are suggested. Transl. by A.H.

N77-12015# Durham Univ. (England). Dept. of Engineering Science.

THROUGH-FLOW CALCULATIONS IN AXIAL TURBOMACHINERY: A TECHNICAL POINT OF VIEW

H. Marsh *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 19 p refs (For primary document see N77-12013 03-02)

Avail: NTIS HC A11/MF A01

The through-flow theory for turbomachines and a detailed discussion on the methods of streamline curvature and matrix through-flow are reported. These two methods of solution are shown to be two different techniques for calculating the flow on a mean stream surface. The Mach number limitations are outlined and the lack of a rigorous definition for the mean stream surface is discussed. The use of a consistent loss model leads to an improved form of the matrix method. Recent advances in the calculation of wall boundary layers and secondary flows are reported. Work on time marching techniques is reviewed. Author

N77-12016# Carleton Univ., Ottawa (Ontario).

THROUGH-FLOW CALCULATIONS BASED ON MATRIX INVERSION: LOSS PREDICTION

W. Roland Davis (Davis and Associates, Ottawa) and D. A. J. Millar *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 12 p refs (For primary document see N77-12013 03-02)

Avail: NTIS HC A11/MF A01

The inviscid flow field in the meridional (hub-to-shroud) plane of an axial compressor is solved by a finite difference technique which employs matrix inversion. The viscous flow effects are accounted for by using empirical data, and the performance of the compressor is determined by an interactive solution. This describes the loss and deflection system which is used to model the effects of blade passage and end wall losses, and of blade passage deflection of the working fluid. The manner in which this system interacts with the matrix inviscid solution is described. Author

N77-12017# Detroit Diesel Allison, Indianapolis, Ind.

THROUGH-FLOW CALCULATIONS: THEORY AND PRACTICE IN TURBOMACHINERY DESIGN

John E. Caruthers and Theodore F. McKain *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 14 p refs (For primary document see N77-12013 03-02)

Avail: NTIS HC A11/MF A01

The through-flow calculation is an integral and vital element of any effective turbomachinery design and development process. The assumptions involved with typical formulation of the basic equations and the solution techniques employed in such areas as boundary condition specification, numerical evaluation of derivatives and numerical stability are presented. Experimental verification of the theory, using turbomachinery applications, is presented to demonstrate the accuracy of the calculation. Finally, the normal compressor design and development cycle is reviewed to stress the importance of the through-flow calculation in this process. Author

N77-12018# Vrije Universiteit, Brussels (Belgium). Dept. of Fluid Mechanics

FINITE ELEMENT METHOD FOR THROUGH-FLOW CALCULATIONS

Ch. Hirsch *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 18 p refs (For primary document see N77-12013 03-02)

Avail: NTIS HC A11/MF A01

The finite element method is applied to the radial equilibrium equation in the form obtained after introduction of the stream function. A short presentation of the basic features of the F.E.M.

is given and the particular aspects of its application to the through-flow problem in turbomachines are described. A comparison with an analytic solution for an axisymmetric transitional annulus with swirl allows an estimation of the numerical accuracy of the method. Other examples of results include a transonic axial compressor and an axial turbine. The coupling with an end-wall boundary layer calculation for axial compressors is also briefly described. Author

N77-12019*# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.

THREE-DIMENSIONAL FLOW CALCULATION FOR A TRANSONIC COMPRESSOR ROTOR

William T. Thompkins, Jr. and David A. Oliver. *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 18 p refs (For primary document see N77-12013 03-02)
(Grant NGL-22-009-383)
Avail: NTIS HC A11/MF A01

A numerical calculation of the steady, inviscid, three dimensional flow in a isolated transonic compressor rotor has been completed using MacCormack's second order accurate time-marching scheme. This rotor has a tip Mach number of 1.2, an overall diameter of 2 feet, and inlet hub/tip ratio of 0.5. The computed rotor total pressure ratio is 1.82. Comparisons between the numerical solution, measurements of the intra-blade static density field obtained by gas fluorescence, and time resolved exit flow measurements showed that the inviscid computation accurately models transonic rotor aerodynamics and rotor blade pressure distributions in the upstream portions of the blade passages, the viscous effects influencing mainly the downstream flow. Author

N77-12020# GEC Turbine Generators Ltd., Manchester (England). Theoretical Aerodynamics Group.

THROUGH-FLOW CALCULATION PROCEDURES FOR APPLICATION TO HIGH SPEED LARGE TURBINES

H. J. A. Cox. *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 13 p refs (For primary document see N77-12013 03-02)
Avail: NTIS HC A11/MF A01

Major difficulties arise in the evaluation of through-flow solutions relevant to conditions existing within the rear stages of large modern low pressure steam turbines. The highly loaded stage designs in which convergent-divergent profiles are used require computation procedures which can accurately allow for supersonic Mach numbers at both guide and runner blade outlet, high values of streamline slope in the meridional plane and varying quantities of mass flow tapped off between stages. The consequent effect of these conditions on turbine performance and various methods by which they can be incorporated into a streamline curvature computation process are discussed together with the use of steam thermodynamic data. Procedures which can be employed to obtain numerical stability and convergence in the computation process are suggested and further problems concerned with the evaluation of off-design solutions are briefly considered. Author

N77-12021# Brown, Boveri and Co., Ltd., Baden (Switzerland). Dept. of Gas Turbines.

DESIGN OF TURBINE, USING DISTRIBUTED OR AVERAGE LOSSES; EFFECT OF BLOWING

D. K. Mukherjee. *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 14 p refs (For primary document see N77-12013 03-02)
Avail: NTIS HC A11/MF A01

The design of a multi-stage turbine begins with one dimensional calculations. Flow field computations which then follow are invaluable as they allow to determine velocity triangles at different radii and to design the blades. In these calculations, aerodynamic losses and outlet angle deviations due to secondary and tip clearance flow, as well as the influence of coolant on the main stream expansion are taken into account. Author

N77-12022# Northern Research and Engineering Corp., Cambridge, Mass. Fluid Dynamic Systems Group.

A CRITICAL REVIEW OF TURBINE FLOW CALCULATION PROCEDURES

A. F. Carter. *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 7 p refs (For primary document see N77-12013 03-02)
Avail: NTIS HC A11/MF A01

Blade row performance parameters, such as total-pressure-loss coefficients and flow deviations, remain the weak assumptions in most of the otherwise sophisticated calculations of turbine flow conditions. Some of the areas are reviewed in which further efforts are needed. Since a turbine's performance ultimately depends on the detailed design of the balding, the paper concentrates on this aspect of turbine design and analysis. Author

N77-12023# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).

COMPRESSOR DESIGN AND EXPERIMENTAL RESULTS

H. B. Weyer. *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 15 p refs (For primary document see N77-12013 03-02)
Avail: NTIS HC A11/MF A01

After an introduction to current techniques available to evaluate the axisymmetric flow field in turbomachines at design and off-design conditions, research was concentrated primarily on proving these calculation methods by comparing the results with corresponding experimental data from real test machines. Considered were: (1) A single-stage transonic compressor without inlet guide vanes, (2) a three-stage transonic compressor without inlet guide vanes, and (3) a 4-stage compressor with inlet guide vanes. Complete geometrical data and test results are provided. G.G.

N77-12024# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).

COMPARISON BETWEEN THE CALCULATED AND THE EXPERIMENTAL RESULTS OF THE COMPRESSOR TEST CASES

H. B. Weyer and R. Dunker. *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 26 p refs (For primary document see N77-12013 03-02)
Avail: NTIS HC A11/MF A01

For the calculation of the compressor's overall performance, one-dimensional techniques as well as duct flow and through-flow methods were used. No characteristic differences encounter from the various methods indicating that a severe effect of a more or less complete physical flow model does not exist. The deviations as far as observed with respect to the experiments are primarily due to the inaccuracy of the flow loss and flow turning predictions, particularly at off-design operating conditions. The duct-flow and through-flow calculation techniques were mainly utilized to compute in detail the compressor internal flow. Streamline curvature, matrix, and finite element methods thereby served as numerical procedures to resolve the flow equations. Concerning the flow parameters calculated outside of the blade rows no evident superiority was observed for any method even for the through-flow techniques although their physical background seems to be more accomplished taking for instance into account the effects of blade thickness, blade turning, a s.o. Discrepancies in the experimental results are believed to be caused by an inexact estimation of the wall boundary-layer blockage, and by 3-dimensional flow effects which are not accounted for in the 2-dimensional calculation techniques. Author

N77-12025# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).

TURBINE TEST CASES: PRESENTATION OF DESIGN AND EXPERIMENTAL CHARACTERISTICS

J. Chauvin and C. Sieverding. *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 19 p (For primary document see N77-12013 03-02)
Avail: NTIS HC A11/MF A01

Full geometric data are presented for a two-stage, two-shaft HP-IP turbine for advanced gas turbine engines. Traverse data are available before and after each blade row, for total pressure, total temperature, static pressure and absolute angle. Author

N77-12026# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).

TURBINES: PRESENTATION OF CALCULATED DATA AND COMPARISON WITH EXPERIMENTS

J. Chauvin. *In* AGARD Through-Flow Calculations in Axial Turbomachinery Oct. 1976 24 p refs (For primary document see N77-12013 03-02)
Avail: NTIS HC A11/MF A01

Performance test results together with geometric design data for two axial flow turbomachines are detailed. Data include nominal 2pm and nominal mass flow as well as nominal pressure ratios and efficiencies. General information on utilized computer programs and calculation methods is included. G.G.

N77-14997# Advisory Group for Aerospace Research and Development, Paris (France).

STATE-OF-THE-ART IN UNSTEADY AERODYNAMICS

William P. Rodden Nov 1976 12 p refs Presented at the 43d Structures and Materials Panel Meeting, London, Sep. 1976

(AGARD-R-660; ISBN-92-835-1230-9) Avail: NTIS HC A02/MF A01

A brief survey of new developments in unsteady aerodynamics is made as a proposal for establishing another comparative computational AGARD program. Candidate topics include supersonic interference, transonic flow, wing-body interference, control surfaces, rotary loads on T-tails, interference effects of vortex shedding, and rotating blades. A selected bibliography is presented for each topic to illustrate the present state-of-the-art and its near term future potential. Author

03 AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations, and aircraft accidents. For related information see also *16 Space Transportation* and *85 Urban Technology and Transportation*.

N74-20756# Advisory Group for Aerospace Research and Development, Paris (France)
ESCAPE PROBLEMS AND MANOEUVRES IN COMBAT AIRCRAFT
Walton L. Jones, ed. (NASA, Washington, D. C.) Feb. 1974 121 p refs Papers Presented at Aerospace Med. Panel Specialists, Soesterberg, Netherlands, 4 Sep. 1973
(AGARD-CP-134) Avail: NTIS HC $9.25

The proceedings of a conference on the subject of problems of escape from rotary wing and V/STOL aircraft are presented. The purpose of the meeting was to delineate the important aspects of the escape problems and to review new concepts in escape technology. The subjects covered was broad ranging from biomedical issues in air combat mishaps in high performance aircraft to human factors and engineering aspects of inflight escape in all types of aircraft. For individual titles, see N74-20757 through N74-20772.

N74-20757* National Aeronautics and Space Administration, Washington, D.C.
TECHNICAL EVALUATION OF THE AEROSPACE MEDICAL PANEL SPECIALISTS MEETING ON ESCAPE PROBLEMS AND MANOEUVRES IN COMBAT AIRCRAFT
Walton L. Jones *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 6 p (For availability see N74-20756 12-05)

A technical evaluation of the papers presented at a conference on escape systems for helicopters and V/STOL aircraft was made. The subjects discussed include the following: (1) bioengineering aspects of spinal injury during ejection, (2) aerodynamic forces acting on crewman during escape, (3) operational practicality of fly away ejection seats, (4) helicopter survivability requirements, (5) ejection experience from V/STOL aircraft, and (6) research projects involving escape and retrieval systems. Author

N74-20758 Bureau of Medicine and Surgery, Washington, D.C.
SPECIFIC BIOMEDICAL ISSUES IN THE ESCAPE PHASE OF AIR COMBAT MISHAPS DURING SOUTHEAST ASIA OPERATIONS
Robert E. Kinneman, Jr., Martin G. Every (BioTechnology, Inc., Falls Church, Va.), and James F. Parker, Jr. (BioTechnology, Inc., Falls Church, Va.) *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 7 p refs (For availability see N74-20756 12-05)

Escape and rescue data were collected from Navy airmen downed over Southeast Asia in order to isolate significant biomedical problems associated with the combat mishap. Subjects consisted of naval aviators flying fixed-wing jet aircraft who were forced to eject as a direct result of enemy action. One hundred and fifteen survivors of such an occurrence were located and administered an extensive questionnaire covering the circumstances associated with the escape and all events prior to and during rescue. Particular attention was given to the adequacy of escape and rescue systems under Southeast Asia combat conditions. This paper deals with the analyses that were conducted in order to determine specific cause and effect relationships for injuries incurred during the ejection phase of this event. Conclusions of the study deal with the adequacy of escape equipment and procedures, under the conditions and stresses inherent in combat situations. Author

N74-20759 Naval Aerospace Medical Research Lab., New Orleans, La.
BIOENGINEERING ASPECTS OF SPINAL INJURY IN THE OV-1 (MOHAWK) AIRCRAFT
Channing L. Ewing and Daniel J. Thomas *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 9 p refs (For availability see N74-20756 12-05)

An investigation of non-fatal ejection vertebral fracture encountered during ejection from military aircraft was conducted. The causes for the injuries are analyzed. Laboratory procedures for determining the factors which contribute to spinal injuries during ejection are reported. It was concluded that the restraint harness used in the OV-1 aircraft was responsible for the high incidence of spinal injuries encountered by crewmen ejecting from this aircraft. Author

N74-20760 Naval Aerospace Medical Research Lab., New Orleans, La.
HEAD CLEARANCE ENVELOPE FOR EJECTION SEATS DURING NEGATIVE G sub x IMPACT ACCELERATION
Channing L. Ewing *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 3 p refs (For availability see N74-20756 12-05)

Living volunteers from the U.S. Army participated in a research program designed to determine response of the living human head and neck to impact acceleration in 1967-1969. The restraint system used was typical of that described above and included a 3-inch lap belt, and inverted V, and shoulder straps. The seat was an experimental seat with the level steel seat pan parallel with the ground and the steel seat back vertical to the seat pan. The shoulder harness in all cases came straight out from the seat back to the shoulder via an adjustable spreader and then downward across the clavicles to the lap belt. The subjects so restrained were given a minus G sub x impact acceleration with fixed rate of onset and with fixed peak acceleration. The run selected for this study was that performed by an 88th percentile sitting height subject (relative to U.S. Navy pilot data), at 10G, 800G/sec with a triangular pulse, lasting about 400 ms. The subject was fitted with transducer mounts on the top of the head; mouth; and base of the neck. These mounts were rigidly attached to the anatomy and photographic targets were attached to each mount, with two targets separated by several inches attached to the neck mount. Author

N74-20761 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
AN ASSESSMENT OF AERODYNAMIC FORCES ACTING ON THE CREWMAN DURING ESCAPE
James W. Brinkley and Peter R. Payne (Payne, Inc., Annapolis) *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 10 p refs (For availability see N74-20756 12-05)

The results of analytical and experimental research accomplished to determine the magnitude of the aerodynamic forces acting on the crewman during emergency escape are summarized. The work has been directed toward the definition of the mechanisms of aerodynamic flail injury and the acquisition of data required for the development of protective countermeasures. The results of a study of noncombat ejection experience within the U.S. Air Force during the period of 1964 to 1972 are also reviewed. This study was conducted to identify injuries attributed to aerodynamic loads and to statistically describe the probability of these injuries as a function of aircraft speed at the time of ejection. Wind tunnel experiments are described which were conducted to measure the forces acting on body segments using volunteer human subjects. Both open ejection seat and tractor rocket extraction egress systems were studied. The data collected from these experiments includes whole body and body segment aerodynamic forces. Operational variables such as arm and leg position and clothing were evaluated to determine their relative effects on the aerodynamic loads acting on the subject's limbs. Author

N74-20762 Naval Aerospace Recovery Facility, El Centro, Calif.
AEROMEDICAL RESEARCH AND EVALUATION SUPPORT OF EXISTING AND PROPOSED ESCAPE AND RETRIEVAL SYSTEMS AT THE NAVAL AEROSPACE RECOVERY FACILITY
Donald H. Reid *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 8 p refs (For availability see N74-20756 12-05)

A research facility for conducting physiological research with parachutists and for investigating hardware system/human

performance interface problems is described. The objective of the research projects has been to contribute data which are needed by the engineering disciplines in designing and developing new generation retardation and recovery systems which are acceptable from the human engineering standpoint. Specific programs in human factors engineering of emergency equipment for air crew use are reported. Author

N74-20763 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
OPERATIONAL PRACTICALITY OF FLY AWAY EJECTION SEATS
R. Harley Walker, Jr. *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 15 p refs (For availability see N74-20756 12-05)

In the interest of improving the current escape/rescue capability, a concept which provides the ejectee with increased time available for rescue by allowing him to remain airborne out of small arms fire range and to fly with a high degree of maneuverability to a more secure, accessible area for landing and pickup is being investigated. This advanced Crew Escape and Rescue Capability, AERCAB, system provides the aircrewman with a secondary flight vehicle capable of gaining or maintaining altitude and permits him to assist in his own rescue by navigating over a limited range at a specified cruise speed out of the hostile target area toward predetermined safe sites where terminal pickup by friendly forces can be made with the least jeopardy. Thus, the AERCAB or fly away ejection system is a new dimension in airborne escape. An assessment of the potential operational practicality and effectiveness of the AERCAB system is presented. The advantages and disadvantages of the fly away escape concept in the operational environment are discussed including any penalties imposed on the tactical aircraft and missions. The probability of rescue is shown to be improved with an AERCAB system. The approach for determining the effective cost of a deployed AERCAB system is discussed.
Author

N74-20764 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
EJECTION EXPERIENCE FROM VTOL MILITARY AIRCRAFT
D. C. Reader *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 3 p (For availability see N74-20756 12-05)

A statistical analysis of ejections from the Harrier aircraft is presented. The data are contained in a table which describes the conditions for the fourteen successful and four fatal ejections on record. It is stated that the majority of the ejections occurred at low speed and low altitude with the aircraft sinking and/or banked.
Author

N74-20765 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
CLEARANCE OF EJECTION PATH BY THE USE OF EXPLOSIVE CORD
A. J. Sarwood *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 6 p (For availability see N74-20756 12-05)

The use of miniature detonating cord (MDC) for removing an aircraft canopy prior to ejection is discussed. The design of the MDC and the installation on specific aircraft are described. The main points in favor of using MDC are: (1) it rapidly clears the ejection path, (2) it breaks the central area of the canopy into small fragments thus avoiding major impact on ejecting crew members, and (3) all canopy debris flies outward. Author

N74-20766 Naval Air Development Center, Warminster, Pa. Crew Systems Dept.
ADVANCED CONCEPTS FOR ROTARY WING AND V/STOL AIRCRAFT ESCAPE SYSTEMS
William G. Law *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 5 p refs (For availability see N74-20756 12-05)

The requirements for ejection seats to provide safe egress from helicopters and V/STOL aircraft are discussed. The limitations of existing ejection seats for such applications are defined. The desirability of a display device for indicating safe ejection conditions to the crew members is expressed. The research projects which have been conducted in an effort to develop a more satisfactory ejection system are reported. Author

N74-20767 Naval Air Systems Command, Washington, D.C.
HELICOPTER PERSONNEL SURVIVABILITY REQUIREMENTS
T. Stephen Musk *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 6 p ref (For availability see N74-20756 12-05)

Current provisions for countering helicopter in-flight emergencies are discussed and their inadequacies are noted. To assess the need for improved helicopter occupant survivability, a review is presented of U. S. Navy, Marine Corps and Army helicopter fatal accident data. Analyses of these data have identified the survival mechanisms which could have prevented these fatalities. Practicable combinations of these survival mechanisms - (1) emergency in-flight egress, (2) improved crash impact protection, (3) improved fire protection and (4) improved flotation - could have averted more than 80 percent of the fatalities analyzed over a 17 year period.
Author

N74-20768 Army Aeromedical Research Lab., Fort Rucker, Ala.
PARACHUTE ESCAPE FROM HELICOPTERS
William P. Schane *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 3 p refs (For availability see N74-20756 12-05)

A series of parachute jumps were made from an autorotating helicopter. The exit and separation of the parachutist from the helicopter were documented by 16mm motion pictures taken at 32 frames per second with a motion picture camera and by 35mm slides taken four frames per second by a motorized Nikon camera. The photo platform was a chase helicopter flying precise formation with the jump helicopter. Data were obtained with frame by frame analysis of the motion pictures measuring the distance separating the parachutist from a reference point on the helicopter. The distance from the most anterior portion of the nose to the most posterior portion of the tail boom of the jump helicopter was used as a reference length. Approximate rates of descent of the jump helicopter during test were established using the vertical speed indicator aboard the jump helicopter. Precise rate of descent at the moment of parachutist exit was determined using a recording radar altimeter which provides precise altitude information above ground level.
Author

N74-20769 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
HUMAN FACTORS ASPECTS OF IN-FLIGHT ESCAPE FROM HELICOPTERS
D. C. Reader *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 4 p refs (For availability see N74-20756 12-05)

A review of the accident statistics from some helicopters users of the NATO forces has shown that helicopter operations impose a greater risk to their crews compared with fixed-wing aircraft. Cost analyses have shown that the crew cost more to replace than their aircraft. Thus, it is considered that a strong case exists for in-flight escape from helicopters. Some human factors to be considered when designing such a system are described. Human tolerance to acceleration, egress path requirements, center of gravity data, restraint and parachute requirements, blast, noise, fragmentation and toxic hazards, and vision and egress time requirements are discussed.
Author

N74-20770 Institut fuer Flugmechanik, Brunswick (West Germany).
ESCAPE MEASURES FOR COMBAT HELICOPTER CREWS
H. D. Melzig and U. Schmidt *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 11 p refs (For availability see N74-20756 12-05)

Flight-control malfunction, loss of control, loss of main or tail rotor, mid-air collision, fire explosion and transmission freeze-up occur relatively often and cause emergency conditions which can not be followed by an auto-rotation landing. Together with a very high percentage of pilot error as the responsible reason for the emergency and the operational requirements for combat helicopters with low altitude and speed, in a relatively high number of accident fatalities could have only been avoided by means of an escape system. Although the technology of capable escape systems is highly developed, its application to a helicopter causes great difficulties because of the rotating blades. A comparative analysis is made for the different modes of downward, sideward, forward and upward ejection or extraction in correlation to the expected percentage of rescue from emergencies and a number of other factors, like development cost and time, reliability, human tolerance, adaptability for retrofit and others. Author

N74-20771 Army Aeromedical Research Lab., Fort Rucker, Ala.
ARMY AUTOROTATIONAL ACCIDENTS
Kent A. Kimball, Donald F. Harden, and Mark A. Hofmann *In* AGARD Escape Probl. and Manoeuvres in Combat aircraft Feb. 1974 10 p (For availability see N74-20756 12-05)

A study reviewing autorotation accidents was initiated to ascertain the relative contributions that certain factors had in such accidents. The active Army, for fiscal years 1970 through 1972, was reviewed and a total of 790 accidents, or 42.3% of all accidents, were of the autorotational type. They accounted for over 89 million dollars in aircraft damage, 92 aircrew fatalities and 882 aircrew injuries. Of these 790 accidents, it was determined that personnel error alone accounted for 32.7% of the accidents, while materiel failure alone accounted for 31.4%. Of the remaining accidents (35.9%), 19.9% were attributed to a combination of personnel error and materiel failure, while the remaining 15% were attributed to other causative factors. Though the total number and rate of rotary wing accidents was found to be declining over the time for frame considered, the number of autorotation accidents attributed solely to personnel error was found to be on the increase, with fiscal year 1972 approximately 10% higher than 1970. The study also reviews autorotation accidents in light of total accidents, rates, geographical areas, aircraft, cost, fatalities, and injuries. It also provides impact data with regard to the reduction of certain parameters. Author

N74-20772 Naval Air Development Center, Warminster, Pa.
IN-FLIGHT ESCAPE SYSTEM FOR HEAVY HELICOPTERS
William Ogden and Gary Davis (Naval Air Systems Command) *In* AGARD Escape Probl. and Manoeuvres in Combat Aircraft Feb. 1974 9 p refs (For availability see N74-20756 12-05)

The design and development of a helicopter escape and personnel survival system (HEPS) are discussed. The system contains four primary functions: (1) in flight escape, (2) crash impact energy attenuation, (3) fuel fire suppression, and (4) flotation. The configuration of the system is illustrated. Results of flight tests are reported. Author

N75-31042# Advisory Group for Aerospace Research and Development, Paris (France).
STORE SEPARATION
L. H. Schindel (Naval Surface Weapons Center, Silver Spring, Md.) Jun. 1975 109 p refs
(AGARD-AG-202, AGARDograph-202) Avail: NTIS HC $8.25

This AGARDograph is a systematic collection of experimental results for use by engineers and designers, limited to externally carried, unpowered, unguided stores. In the sections dealing with store trajectories, the physical situation is described, the method of solution is indicated, and the final results are presented. Emphasis is on store motion in traversing the parent aircraft flowfield, with criteria for safe separation and methods of calculating flight path. Windtunnel test techniques are described, and some information on flight testing is given. Analytical treatment is compared with flight and tunnel results. There are brief mentions of ejection systems and the effect of stores on aircraft performance. Author

N76-14059# Advisory Group for Aerospace Research and Development, Paris (France).
AIRCRAFT FIRE SAFETY
Oct. 1975 330 p Partly in ENGLISH, partly in FRENCH Presented at the 45th Meeting of the AGARD Propulsion and Energetics Panel, Rome, 7-11 Apr. 1975
(AGARD-CP-166) Avail: NTIS HC $10.00

Fire, toxic, and explosion hazards associated with aircraft accidents and fires are reviewed. Specific areas discussed include: prevention techniques; the impact of changes in fuel specifications on aircraft fire safety; and evaluation of test techniques for flame propagation and extinguishment. Actual aircraft accidents are also reviewed and analyzed. For individual titles, see N76-14060 through N76-14067.

N76-14060 Royal Aircraft Establishment, Farnborough (England). Materials Dept.
SAFETY FUEL RESEARCH IN THE UNITED KINGDOM
R. E. Miller *In* AGARD Aircraft Fire Safety Oct. 1975 10 p refs (For availability see N76-14059 05-03)

Aircraft fuels which resist fire in a crash are investigated. Emphasis is placed on polymeric additives which prevent fuel mist condition. At 0.3% concentration these additives prevent kerosene fires under realistic crash conditions with both flame and heated duct ignition sources. High internal phase ratio emulsions gave no fire resistance in these tests. Methods of introducing the additive and the possible extent of water compatibility and filtration problems are discussed. Author

N76-14061 Southwest Research Inst., San Antonio, Tex. US Army Fuels and Lubricants Research Lab.
STATUS OF RESEARCH ON ANTIMIST AIRCRAFT TURBINE ENGINE FUELS IN THE UNITED STATES
W. D. Weatherford, Jr. and E. R. Wright *In* AGARD Aircraft Fire Safety Oct. 1975 12 p refs (For availability see N76-14059 05-03)

The physical, compatibility, and fire safety characteristics of fuel blends containing polymeric antimist agents are discussed in terms of reducing the frequency of in-flight and post-crash aircraft fires. The experimental bench and larger scale evaluation procedures used and the experimental results obtained with several polymeric antimist additives are described. Both fire safety and systems compatibility characteristics and problems are included. Projections are made regarding the future direction of research on such antimist aircraft turbine fuels. Author

N76-14062 National Research Council of Canada, Ottawa (Ontario). Fuels and Lubricants Lab.
WIDE-CUT VERSUS KEROSENE FUELS: FIRE SAFETY AND OTHER OPERATIONAL ASPECTS
R. B. Whyte and L. Gardner *In* AGARD Aircraft Fire Safety Oct. 1975 20 p refs (For availability see N76-14059 05-03)

The relationships between fuel properties and safety and aircraft operation are summarized. The specifications are compared for wide-cut and kerosene type fuels with emphasis on the properties which can affect operation and safety. The difference in volatility and effects on ignition, combustion, and explosion are discussed as well as other properties (fluidity, cleanliness, and vapor release) which can affect aircraft operations. Ground operations (handling, maintenance and engine starting) and flight operations (fire hazard, engine relight, fuel system icing and freezing, range and payload) are considered. It is concluded that, provided all necessary precautions are diligently enforced the risks involved in using wide-range fuel are at worst only marginally greater than with kerosene. Author

N76-14063 Royal Aircraft Establishment, Farnborough (England).
SYSTEMS PROBLEMS ASSOCIATED WITH THE USE OF SAFETY FUELS
R. H. Walsh, E. A. Timby, and D. J. R. Robinson *In* AGARD Aircraft Fire Safety Oct. 1975 12 p (For availability see N76-14059 05-03)

The performance of components in aircraft fuel systems is investigated when using crash-fire-resistant antimisting aircraft fuels. The effect that the systems have on the fuels is also considered. It is found that the use of safety fuels could result in a continual degradation of their crash-fire-resistant properties. The degradation in the major components of the system is measured and the results are used to program a computer study to predict the state of the fuel remaining in the aircraft on landing following a full range flight. Author

N76-14064 Societe Nationale Industrielle Aerospatiale Toulouse (France)
IGNITION PROOFING OF FUEL TANKS [INERTAGE DES RESERVOIRS DE CARBURANT]
Georges Frechou *In* AGARD Aircraft Fire Safety Oct. 1975 7 p In FRENCH (For availability see N76-14059 05-03)

The following topics were discussed (1) causes of fires and flammability of fuels, (2) precautions taken to reduce the risks and the resulting problems for the aircraft designers in view of the ever more stringent competitive requirements within the aviation industry, (3) the advantage of ignition proofing fuel tanks. It is shown that an effective way to ignition proof fuel tanks is to reduce the percentage of oxygen in the gaseous mixture above the fuel, since this mixture will not be explosive if the oxygen percentage is below 9 or 10%. This however requires that the fuel tanks be pressurized to prevent outside air from entering and, furthermore, that the gases dissolved in the fuel should contain less than 10% oxygen. It was concluded that the resulting design and operational problems do not outweight the expected benefits. Y.J.A.

N76-14065 Societe Intertechnique, Plaisir (France).
IGNITION PROOFING OF FUEL TANKS WITH OXYGEN-DEFICIENT AIR OBTAINED BY DIFFUSION THROUGH A SEMI-PERMEABLE MEMBRANE [INERTAGE DES RESERVOIRS DE CARBURANT AVEC DE L'AIR APPAUVRI EN OXYGENE PAR PERMEATION]
Jean Tugaye *In* AGARD Aircraft Fire Safety Oct. 1975 5 p In FRENCH (For availability see N76-14059 05-03)

The possibility of using oxygen-deficient air in the ignition proofing of fuel tanks was successfully tested in the laboratory. The oxygen-deficient air is obtained by diffusing air under pressure through a special synthetic semi-permeable membrane 0.2 micron thick, supported by a porous plate of the same material 0.2 mm thick. Depending on the temperature, oxygen will diffuse two or three times more rapidly through such a system than nitrogen. High pressure air contained within such a system will therefore become oxygen-deficient. A practical airworthy system utilizing this concept inside fuel tanks must include the following systems: heat exchangers, auxiliary air compressor, and fuel deoxygenating device. The proposed system would be primarily advantageous on aircraft undergoing a large number of landings and takeoffs between refuellings, since it would then be lighter and less bulky than a system using liquid nitrogen. Y.J.A.

N76-14066 National Research Council of Canada, Ottawa (Ontario). Fuels and Lubricants Lab.
FLAME PROPAGATION IN AIRCRAFT VENT SYSTEMS DURING REFUELLING
L. Gardner and J. K. S. Wong *In* AGARD Aircraft Fire Safety Oct. 1975 9 p refs (For availability see N76-14059 05-03)

An investigation was made to determine if ignition at the fuel system vent box of a large commercial aircraft during refuelling could result in flame propagation through the vent system and cause an explosion inside one of the fuel tanks. The program was initiated as the result of an explosion during a commercial refuelling and was confined to investigating the type of series of aircraft involved utilizing a simulation of part of the vent system leading to the tank where the explosion originated. The ability of the flame to propagate was demonstrated using wide-cut fuel and a 50/50 mixture of wide-cut fuel and kerosene. No propagation occurred with kerosene nor with wide-cut fuel that had lost 5% of its light ends. Flame propagation and explosion intensity were found to depend on mixture temperature, fuel/air ratio, mixture flow velocity, and oxygen content of the air. Author

N76-14067 Falcon Research and Development Co., Denver, Colo.
DYNAMIC MODELING OF AIRCRAFT FUEL TANK ENVIRONMENTS AND VULNERABILITY
Levelle Mahood *In* AGARD Aircraft Fire Safety Oct. 1975 9 p refs (For availability see N76-14059 05-03)

The environments, hazards, and vulnerability of regions adjacent to and within aircraft fuel tanks are discussed along with the importance and difficulties of developing fuel tank environment models to assess aircraft combat vulnerability and operating safety. Various approaches to modeling the flammability of the ullage of an aircraft fuel tank are described. Examples are given to illustrate various ways that dynamic effects radically alter equilibrium vapor conditions in the ullage. The method of applying the fuel tank ullage environment model to computerized aircraft vulnerability programs is described. Author

N76-14068 Societe Nationale Industrielle Aerospatiale, Suresnes (France).
CABIN FINISHING MATERIALS IN CIVIL PASSENGER AIRCRAFT [LES MATERIAUX D'INTERIEUR CABINE DANS LES AVIONS DE TRANSPORT CIVILS]
Andre Blavy *In* AGARD Aircraft Fire Safety Oct. 1975 3 p In FRENCH (For availability see N76-14059 05-03)

A review of the various types of cabin finishing materials used inside civil passenger aircraft and their properties was presented, with special focus on their flammability and generation of toxic fumes when set fire. The following facts were summarized: (1) materials from which fires may be easily extinguished generally emit more smoke, (2) fire-proof materials often emit toxic fumes, (3) combustion of these materials, due to their self-extinguishing properties, result in oxygen depletion and carbon monoxide formation, the primary cause of intoxication. The primary emphasis should be placed on rapid extinguishing of any incipient fire. Y.J.A.

N76-14069* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
FIRE DYNAMICS OF MODERN AIRCRAFT FROM A MATERIALS POINT OF VIEW
John A. Parker, Demetrius A. Kourtides, Richard H. Fish, and William J. Gilwee, Jr. *In* AGARD Aircraft Fire Safety Oct. 1975 11 p refs (For availability see N76-14059 05-03)

A general approach for selecting polymers to increase fire safety in aircraft is described. It is shown that polymer flammability and thermal protection capability are related to the molecular structure of the polymer and its thermochemical properties. These criteria are used to develop advanced fire-resistant materials which can achieve increased survivability in both post-crash and in-flight fires. The degree of fire hardening of materials depends greatly on the available heat load and fire threat present. It is shown that improvements in fire safety can be achieved by the use of polymers possessing certain basic thermochemical parameters such as high char yield. Author

N76-14070 Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost. Jr. Engineer Materials and Processes Group.
CRITICAL EVALUATION OF TODAYS FIREPROOF TESTING OF AEROSPACE MATERIALS
L. M. Godfried *In* AGARD Aircraft Fire Safety Oct. 1975 10 p (For availability see N76-14059 05-03)

The usefulness of the requirements and methods of tests for the judgement of materials or materials combinations in aerospace vehicle application is discussed. It is shown that the application, test requirements, and test methods criteria for materials sometimes provide questionnable fire safety. Author

N76-14071 Commissariat a l'Energie Atomique, Toulouse (France).
MEASUREMENT AND ANALYSIS OF SMOKE AND TOXIC GASES RESULTING FROM THE COMBUSTION OF AIRCRAFT CABIN FINISHING MATERIALS [MESURE DES FUMEES ET ANALYSE DES GAZ TOXIQUES PROVOQUES PAR LA COMBUSTION DES MATERIAUX D'AMENAGEMENT DE CABINE D'AVION]
J. Auvinet *In* AGARD Aircraft Fire Safety Oct. 1975 12 p In FRENCH (For availability see N76-14059 05-03)

The results of studies and research on the combustion of aircraft cabin finishing materials and the resulting smoke generation and production of toxic gases were reported. Results of tests measuring the concentration of the various gases resulting from the combustion of these materials were first presented, based on burning small samples under controlled conditions. Next, a near full-size mockup of a simulated aircraft cabin section, divided into passenger and freight sections by a horizontal floor, was constructed and instrumented for more realistic combustion tests. This mockup was equipped with ventilation, safety, fire extinguishing, heat protection, pressurization, lighting, and chemical analysis systems. Preliminary tests were undertaken with this mockup and were reported. Y.J.A.

N76-14072 Royal Aircraft Establishment, Farnborough (England). Materials Dept.
SOME ASPECTS OF SMOKE AND FUME EVOLUTION FROM OVERHEATED NON-METALLIC MATERIALS
A. J. Christopher *In* AGARD Aircraft Fire Safety Oct. 1975 12 p refs (For availability see N76-14059 05-03)

A dynamic system for assessing the smoke and fume emission characteristics of nonmetallic materials is described. A sample of the material under examination is heated from ambient to 500 C in a stream of air. The behavior of the material under in-flight electrical overheating conditions is simulated. Sample temperature, smoke density, and electrode response in a water bubbler are monitored. Results obtained for various materials are presented and discussed. Author

N76-14073 Utah Univ., Salt Lake City. Flammability Research Center

ANALYSIS OF THE PRODUCTS OF THERMAL DECOMPOSITION OF AN AROMATIC POLYAMIDE FABRIC USED AS AN AIRCRAFT INTERIOR MATERIAL

I. N. Einhorn, D. A. Chatfield, and R. W. Mickelson *In* AGARD Aircraft Fire Safety Oct. 1975 13 p refs (For availability see N76-14059 05-03)

The thermochemistry of an aromatic polyamide fabric used in the interior of wide-bodied commercial jet aircraft was explored using several analytical techniques. The principal emphasis was to identify the products resulting from pyrolysis, oxidative degradation, and flaming combustion. The pyrolysis data was used to obtain a material balance between the elemental composition of the original polymer and the degradation products. Author

N76-14074 Princeton Univ., N.J. Guggenheim Labs.

FLAME SPREADING ACROSS MATERIALS: A REVIEW OF FUNDAMENTAL PROCESSES

William A. Sirignano *In* AGARD Aircraft Fire Safety Oct. 1975 12 p refs (For availability see N76-14059 05-03)

A critical review of the existing researches on flame spread above solid combustible materials is given; both theory and experiment are considered. Special attention is given to the determination of the rate-controlling mechanism for energy transfer ahead of the flame and therefore to the determination of the flame spreading rate. The mechanism could be either gas-phase conduction, radiation, gas-phase convection, or some combination of these. Important factors discussed include: natural convective flows, orientation of the direction of flame spread with respect to gravity, thickness of the burning material, and the values of the conductivity, diffusivities, heats of reaction and pyrolysis, chemical kinetic constants, and ambient oxygen concentration. It is indicated how changes in these factors can produce changes in the rate-controlling mechanism. Author

N76-14075 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (West Germany).

ON THE APPLICABILITY OF RETICULATED FOAMS FOR THE SUPPRESSION OF FUEL TANK EXPLOSIONS

R. Fiala, K. Dusse, and G. Winterfeld *In* AGARD Aircraft Fire Safety Oct. 1975 12 p refs (For availability see N76-14059 05-03)

The flame suppression properties of polyurethane foams with varying cell size were studied by means of a flame tube and an explosion vessel. Results on the thickness of the foam layer necessary for flame quenching are given, depending on pore size, fuel-air ratio, and on pressure. The behavior of reticulated foam during explosion in a closed vessel is discussed, as well as its mechanical behavior. Conclusions with respect to the application of foam structures in tanks are presented. Author

N76-14076 Royal Aircraft Establishment, Farnborough (England). Engineering Physics Dept.

FIRE PROTECTION OF FUEL SYSTEMS IN COMBAT AIRCRAFT

J. A. MacDonald and H. W. G. Wyeth *In* AGARD Aircraft Fire Safety Oct. 1975 15 p ref (For availability see N76-14059 05-03)

The conditions which affect fire and explosion probability within aircraft fuel tanks and surrounding bays are examined. Particular attention is given to the effect of fuel type, target construction, and other environmental conditions. From a knowledge of the physical effects following projectile attack, systems are suggested which could significantly reduce the risk of fire and explosion. Author

N76-14077 Air Force Aero Propulsion Lab., Wright-Patterson AFB, Ohio. Fuels and Lubrication Div.

AIRCRAFT FIRE PROTECTION TECHNOLOGY

B. P. Botteri *In* AGARD Aircraft Fire Safety Oct. 1975 15 p refs (For availability see N76-14059 05-03)

Aircraft fire protection under natural and hostile (combat) flight environment conditions is discussed. Achievement of fire protection capability is dependent upon a knowledge of ignition, flammability, and reaction severity characteristics of the combustible materials present and use of this knowledge in the design of the aircraft. Specific areas discussed include: fire and explosion hazard assessment (including fire safe fuels), fire prevention design measures, advanced fire and overheat detection systems, void space and dry bay fire suppression techniques, and fuel tank fire and explosion protection systems. Author

N76-14078 British Aircraft Corp., Warton (England).

FIRE PROTECTION OF MILITARY AIRCRAFT

John Vincent *In* AGARD Aircraft Fire Safety Oct. 1975 15 p (For availability see N76-14059 05-03)

The problems associated with 'classical' engine bay fire detection and suppression systems are examined along with airframe design constraints. The primary and secondary fire problem is considered. Statistical evidence from modern war shows that the highest proportion of aircraft kills is due to primary and secondary fire. The application of possible fire suppressant methods is discussed. The current structural and system design philosophy is questioned with respect to achieving improved fire protection of military aircraft. Author

N76-14079 Pisa Univ. (Italy).

THE USE OF ROCKETS AGAINST CRASH FIRES IN AIRPORT AREAS

M. Andreanucci *In* AGARD Aircraft Fire Safety Oct. 1975 12 p refs (For availability see N76-14059 05-03)

The use of rockets is proposed as a means of fighting crash fires, due to their quickness, easy operation, and ability to reach sites not readily accessible by other means. Possible vehicle configurations are discussed along with system operating modes. Details are given of a simulation study, intended for providing the major specifications for the system components performance with respect to efficacy, reliability, and safety requirements. Cost factors are considered. Author

N76-14080 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (West Germany).

FIRE FIGHTING AGENTS FOR LARGE AIRCRAFT FUEL FIRES

R. Fiala and K. Dusse *In* AGARD Aircraft Fire Safety Oct. 1975 10 p refs (For availability see N76-14059 05-03)

For a critical evaluation of the properties of the different types of agents experiments were carried out using standardized small and large fuel fires (4 sq m and 200 sq m). The time until extinguishment occured and the amount of agent needed, were measured. Additionally, the time which, after a deliberate reignition, elapsed until the whole fuel surface was on fire again, was measured. Results are discussed. Author

N76-14081 Joint Fire Research Organization, Boreham Wood (England). Extinction Section.

THE EXTINCTION OF AIRCRAFT CRASH FIRES

P. Nash *In* AGARD Aircraft Fire Safety Oct. 1975 13 p refs (For availability see N76-14059 05-03)

The problems are discussed of the aircraft crash fire, including the difficulty of arrival of the fire-fighting services in time to save life. The different fire fighting agents available are appraised. Fire fighting foams are shown to be the only satisfactory primary fire fighting agents for major crash fire use. The research and development of foam liquids and the means used to assess their performance are discussed in terms of the physical properties of the foam liquid. The development of foam making equipment and appliances in order to put the foam liquid to best use to meet the operational requirement is examined. Author

N76-14082 Federal Aviation Administration, Atlantic City, N.J.

CHARACTERISTICS OF HALON 1301 DISPENSING SYSTEMS FOR AIRCRAFT CABIN FIRE PROTECTION

Constantine P. Sarkos *In* AGARD Aircraft Fire Safety Oct. 1975 16 p refs (For availability see N76-14059 05-03)

A cabin fire protection system using Halon 1301, an extinguishing agent previously tested and shown to be effective in suppressing and controlling fires in a simulated transport cabin section and a cargo compartment is investigated. Tests were conducted in an obsolete but completely furnished DC-7 passenger cabin equipped with two candidate Halon 1301 dispensing systems: modular nozzle and perforated tube. Under no-fire conditions, continuous measurements were made of the Halon

1301 concentration at approximately 20 locations; measurements were also made of temperature, noise, pressure, and visibility. The modular nozzle system was judged to be best by virtue of its producing more rapid and effective agent distribution resulting in greater potential fire protection capability. Halon 1301 was found to rapidly permeate all cabin airspaces, including those shielded from the discharge streamlines. Author

N76-14083 Karlsruhe Univ. (West Germany).
A LABORATORY TEST METHOD OF EVALUATING THE EXTINGUISHING EFFICIENCY OF DRY POWDERS
Paul G. Seeger *In* AGARD Aircraft Fire Safety Oct. 1975 9 p refs (For availability see N76-14059 05-03)

The laboratory test method of evaluating the estinguishing efficiency of dry powders is based on the burning velocity of a laminar premixed methane-air flame. The dry powder being tested is fed into the premixed fuel gas-air flow by a vibrating ahute. The powder particles reach the test flame and reduce the burning velocity more or less depending on their extinguishing efficiency. The burning velocity is determined by the nozzle method and by schlieren photography. The evaluation of the measurements shows that the square of the burning velocity is a linear function of the mass flow of the dry powder fed into the fuel gas-air flow. The theoretical minimum value of the mass flow of the dry powder necessary to extinguish the test flame may be determined by the slope of the straight line. Author

N76-14084 Pinkel (I. Irving), Fairview Park, Ohio.
DYNAMIC EFFECTS IN THE SETTING OF AIRPLANE CRASH FIRES
I. Irving Pinkel *In* AGARD Aircraft Fire Safety Oct. 1975 4 p (For availability see N76-14059 05-03)

The principal features of airplane crash dynamics are described. Factors considered include: fuel spillage; movement of spilled fuel to main ignition sources; propagation modes of fire to the main spillage and the fuel tank opening. Some of the main factors in the ignition and spread of fire are illustrated with slow motion pictures of full-scale airplane crashes. Author

N76-14085 Cranfield Inst. of Technology (England).
FIRE, FUEL AND SURVIVAL: A STUDY OF TRANSPORT AIRCRAFT ACCIDENTS, 1955 - 1974
A. F. Taylor *In* AGARD Aircraft Fire Safety Oct. 1975 14 p refs (For availability see N76-14059 05-03)

Accident summaries and reports are examined together with existing papers on the various aspects of fire safety, the aim being to piece together a complete picture of the part fire has had in determining overall fatality rates in transport aircraft accidents. Note is taken of the sensitivity of the fire death ratio to the number of high impact accidents with no chance of survival and of how this sensitivity may have clouded some past comparisons between fuels of different volatility. It is indicated that in post impact fires the higher volatility fuels, gasoline and wide-cut gasoline, have been responsible for proportionately more fire deaths than has low volatility kerosine, thus confirming predictions based on theory and experiment. Author

N76-14086 Swissair, Zurich (Switzerland).
PASSENGER AIRCRAFT CABIN FIRES
Willi Schurter *In* AGARD Aircraft Fire Safety Oct. 1975 5 p (For availability see N76-14059 05-03)

After a brief review of the established findings on the crash of a Swissair Coronado CV-990A in Wurenlingen, Switzerland, on February 21, 1970, an analysis of the cabin fire preceding the crash is given, including origin of fire, its propagation and effects on the aircraft systems. A method of establishment of elevated local temperatures in cargo compartment and cabin by means of uncommon fractures as found in the wreckage is described. The role played by the major aircraft systems is discussed. Furthermore, since the smoke spreading in cabin and cockpit is considered the factor rendering the aircraft uncontrollable under the prevailing conditions, the results of tests carried out simulating the smoke conditions are given. Author

N76-14087 Secretariat General a l'Aviation Civile, Paris (France).
CRASH OF THE PP-VJZ AIRCRAFT [L'ACCIDENT DU PP-VJZ]
P. Guillevic *In* AGARD Aircraft Fire Safety Oct. 1975 6 p In FRENCH (For availability see N76-14059 05-03)

The results of investigations that followed the crashes of two aircraft (a Caravelle in 1968 and a Boeing 707 in 1973) following fires that started in rear washrooms were reported. In both cases, it was concluded that fatalities were primarily caused by intoxication resulting from the inhalation of carbon monoxide and highly acidic toxic vapors such as chlorhydric acid and cyanhydric acid originating in the combustion of cabin finishing materials. Y.J.A.

N76-29187# Advisory Group for Aerospace Research and Development, Paris (France)
ADVANCED TECHNIQUES IN CRASH IMPACT PROTECTION AND EMERGENCY EGRESS FROM AIR TRANSPORT AIRCRAFT
R. G. Snyder (Michigan Univ., Ann Arbor) Jun. 1976 320 p refs
(AGARD-AG-221; AGARDograph-221; ISBN-92-835-1218-9) Copyright. Avail: NTIS

Analysis of all NATO member air transport accidents, 1964-1975, revealed that injuries and fatalities, when such information could be determined, were primarily due to the post-crash effects of fire, smoke and toxic fumes, and secondarily to crash impact. Future air transport design trends were reviewed, and approximately 150 advanced crash-impact and emergency-egress concepts, devices, and state-of-the-art techniques were evaluated. These included occupant restraints, smoke hoods, aisle and egress emergency lighting, passenger warning systems, escape slides and devices, heat shields, high-energy emergency egress systems, and emergency inflight egress systems. It was concluded that rear-facing passenger seats, the NASA Ames (21 + 6 sub x sub 45 + 6 sub z) airline seat, and the production sheldahl smoke hood can provide significantly improved occupant protection, while high-energy emergency egress systems appear promising for future aircraft. More research is needed to improve passenger warning and public address systems. Concepts of emergency inflight egress are not yet feasible, although technically within the state-of-the-art. Author

04 AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control. For related information see also *17 Spacecraft Communications, Command and Tracking* and *32 Communications*.

N74-33534# Advisory Group for Aerospace Research and Development, Paris (France).
THE PHYSIOLOGY OF COLD WEATHER SURVIVAL
A. Borg, ed. (Roy. Norweg. Air Force) and J. H. Veghte, ed. (AMRL, Wright-Patterson AFB, Ohio) Jun. 1974 99 p refs (AGARD-R-620) Avail: NTIS HC $8.00

Physiological factors and emergency life sustaining measures are outlined for aircrew survival in a cold winter region. For individual titles, see N74-33535 through N74-33545.

N74-33535 Oslo Univ. (Norway).
THERMOGENETIC MECHANISMS INVOLVED IN MAN'S FITNESS TO RESIST COLD EXPOSURE
K. Lange Anderson *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 1-6 refs (For availability see N74-33534 23-04)

The main factor by which man's fitness to resist cold exposure can be varied, appears to be thermogenesis. The biological variation of BMR, shivering, a possible non-shivering thermogenesis, and the maximal aerobic power is reviewed. BMR of an individual can vary with diet, general health, habitual physical activity, as well as various environmental conditions, conceivably including cold exposure. A definite inter- and intra-individual variation in shivering threshold exists. Man's capability to raise his metabolism in muscular exercise is an important part of his fitness to resist cold exposure. This capability can be assessed by measurement of maximal oxygen uptake. Maximal oxygen uptake is influenced by age, sex, health, diet and habitual physical activity. Author

N74-33536 Oslo Univ. (Norway).
PERIPHERAL CIRCULATORY ADJUSTMENT TO COLD
John Krog *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 7-15 refs (For availability see N74-33534 23-04)

Measurements of blood circulation in the hands and faces of Arctic people are compared with those on Norwegian lumberjacks and city dwellers. Obtained data for time of onset of vasodilation, amount of vasodilation, and pressure response following cold stimulation indicate that the greater tolerance to cold in Arctic people is due to an adjustment of the vasomotor control in the pheripheral tissue, in such a way that the initial vasoconstriction response is less severe and lasts shorter. G.G.

N74-33537 Royal Norwegian Air Force, Oslo.
INTRODUCTION TO WINTER SURVIVAL
Rolf A. Grimsrud and Claus Moelbach-Thellessen *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 17-28 (For availability see N74-33534 23-04)

In winter man cannot stay in the open and expect to live unless he is on the move. He needs a shelter of some kind even if it is only a hole in the snow. It should be kept in mind that a wind of 10 knots equals a fall in temperature of approximately 30 deg celsius on the skin compared with that experienced in quiet weather. The type of shelter to be built will depend on: (1) tools and material available; (2) snow conditions; and (3) the length of time of expected residence in that particular location. Aircrew must remember to adjust their clothing while working. Sweating should be avoided. Emergency signalling equipment should be readily available at all times and the camp site should be made as conspicuous as possible from the air. Author

N74-33538 Oslo Univ. (Norway).
METHODS IN CIRCULATORY RESEARCH
John Krog *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 29-39 (For availability see N74-33534 23-04)

The principles of indirect methods and direct methods for determining human peripheral circulation are discussed in connection with planning for research in aviation medicine. The former are based on body tissue temperature measurements, changes in oxygen tension, and elimination of metabolic inert substances; the latter category includes plethysmography and flow meters. G.G.

N74-33539 Oslo Univ. (Norway). Human Adaptability Section.
LOCAL EFFECTS OF ACCLIMATIZATION TO COLD IN MAN
Bjorn Hellstrom *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 41-51 refs (For availability see N74-33534 23-04)

The mechanisms underlying local manifestations of cold acclimatization are not fully known, but point to a central nervous habituation to cold exposure. This primitive type of learning is characterized by a diminishing response upon repeated stimulation. It is common experience that the discomfort caused by cold is reduced by repeated or prolonged cold exposures. There is also ample evidence that shivering is reduced with repeated cold exposures. These reductions of physiological reactions to cold upon repeated exposures to low ambient temperatures point towards a central nervous habituation as the main mechanism of cold acclimatization in man. Author

N74-33540 Oslo Univ. (Norway). Inst. of Work Physiology.
A PHYSIOLOGICAL COMPARISON OF THE PROTECTIVE VALUE OF NYLON AND WOOL IN A COLD ENVIRONMENT
Kaare Rodahl, Fredric A. Giere, Peer H. Staff, and Bertil Wedin *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 53-57 refs (For availability see N74-33534 23-04)

Similar inner garments of nylon pile and of wool pile were compared in paired experiments at rest for one hour and during two hours fairly strenuous physical activity (treadmill walking at 100 m/min, 5% incline) followed by two hours rest in a climatic chamber at -20 C. Each subject served as his own control, participating in experiments using both types of experimental garments. Under these conditions no significant difference could be detected between the two types of garments in terms of thermal insulation, nor in the ability of the two types of fabric to allow free escape of moisture produced by sweating during physical activity. Author

N74-33541 Oslo Univ. (Norway). Human Adaptability Section.
VIBRATION INJURIES AND COLD EXPOSURE
Bjorn Hellstrom *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 59-67 refs (For availability see N74-33534 23-04)

The connection between cold exposure and traumatic vasospastic desease is studied on forest workers who experience vasodilation of the fingers even in a very cold climate environment. Experimental results indicate that these workers achieve an acclimatization to cold manifesting itself by a lowered central temperature threshold for cutaneous vasodilation during exercise. Cold is the main trigger of vasospastic attacks. G.G.

N74-33542 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
COLD PHYSIOLOGIC STUDIES
James H. Veghte *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 69-76 refs (For availability see N74-33534 23-04)

A number of research studies are discussed in which human physiological responses to cold have been monitored in evaluation of insulating clothing and protective sheltering. Cold, as a stressor, can be overcome if aircrew members are educated that there is usually sufficient time in a survival situation to meet any cold stress. The importance of extremity protection, danger of CO2 or CO poisoning in snow shelters, and loss of insulation because of moisture accumulation are paramount. Author

N74-33643 Royal Naval Air Medical School, Hillhead (England).
IMMERSION HYPOTHERMIA
F. St. C. Golden *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 77-90 refs (For availability see N74-33534 23-04)

Human thermoregulation in water, and the factors affecting survival times of the immersed victim are discussed in broad detail. The physiological changes encountered in hypothermia are outlined and the associated signs and symptoms discussed. Some general advice on treatment is proposed, both from the first aid and curative standpoint. Author

N74-33644 Royal Naval Air [illegible] School, Hillhead (England).
AIRCREW SURVIVAL TRA[illegible] IN THE UNITED KINGDOM AND NORTHERN NORWAY
W. J. Blake *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 91-93 (For availability see N74-33534 23-04)

Details of the basic survival training given to Royal Naval Aircrew in the United Kingdom are reported. The further training given in northern Norway is also covered. Author

N74-33645 Royal Norwegian Air Force, Oslo.
SNOW AVALANCHES
R. A. Grimsrud *In* AGARD The Physiol. of Cold Weather Survival Jun. 1974 p 95-96 (For availability see N74-33534 23-04)

Causes and effects of snow slides are described and human survival measures in an avalanche situation are outlined. G.G.

N75-32047# Advisory Group for Aerospace Research and Development, Paris (France).
A SURVEY OF MODERN AIR TRAFFIC CONTROL. VOLUME 1
Andre Benoit, ed. Jul. 1975 400 p refs 2 Vol.
(AGARD-AG-209-Vol-1; AGARDograph-209-Vol-1) Avail: NTIS HC $10.25

Papers presented at the symposium are reported. Topics discussed include: general organization of ATC, human factors in ATC, and automation of control procedures. For individual titles, see N75-32048 through N75-32055.

N75-32048 Royal Radar Establishment, Malvern (England).
PRINCIPLES OF AIR TRAFFIC CONTROL
S. Ratcliffe *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 5-20 refs (For availability see N75-32047 23-04)

Air traffic control techniques are discussed along with the principles of traffic flow. Other topics discussed include: flight operations, terminal control, and organizational problems in an ATC sector. F.O.S.

N75-32049 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
ATC CONCEPTS
Horst A. Neumann *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 23-28 refs (For availability see N75-32047 23-04)

Ground based ATC procedures are discussed in terms of manual, electronic and structural air traffic control. F.O.S.

N75-32050 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
PRINCIPAL ATC COMPONENTS
Hans-George Friedrich *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 31-40 refs (For availability see N75-32047 23-04)

Functional descriptions are presented of ATC components. The systems described include navigation, surveillance, communications, and control centers. Author

N75-32051 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE CONTROLLER VERSUS AUTOMATION
V. David Hopkin *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 45-60 refs (For availability see N75-32047 23-04)

The relation of the controller to automation in air traffic control is discussed in terms of human factors engineering. Concepts discussed include: task changes and automation, workload, quality of navigation aid, training, potentially incompatible aims, effects of automation on task design, and automation and communication. F.O.S.

N75-32052 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
THE FUTURE POSITION OF THE CONTROLLER
Klaus Brauser and Ruediger Seifert *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 63-74 refs (For availability see N75-32047 23-04)

The problem of automation of ATC systems was shown to be a very complex task, concerning three different control loops with different characteristics but using the same data source. The different control loops were defined as executive (radar) control with the tasks of tactical intervention; planning control, with the tasks of procedural planning; and flow control. It was found that the human responsibility for air traffic safety cannot be delegated, but that there are many human activities which can be defined as black box actions performed more efficiently by computers. The resulting system is characterized as a highly effective human control system with an optimum amount of automatic devices to perform routine tasks as well as an effective decision aid with good on-line characteristics. Author

N75-32053 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE PSYCHOLOGIST'S VIEW
V. David Hopkin *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 77-102 refs (For availability see N75-32047 23-04)

The role of human factors in air traffic control depends on the stage at which it is first applied. The psychologist's contribution is most effective early in the system evolution, when he can forestall problems as well as cure them. In studying air traffic control systems, ideally the psychologist uses system and job analysis, which he can both conduct and interpret. Aspects of the man-machine interface, such as displays, controls and communications, are optimized in relation to the efficiency and well-being of the men. His knowledge of differences between men is applied to recruitment, selection, training and screening. The effects of ageing and of experience are predicted from known progressive changes within each individual. Knowledge of the capabilities and tolerances of the man is used to solve problems of work-rest cycles, stress and workload. To solve these problems, the psychologist uses orthodox methods and specially devised techniques for assessing and measuring the man at work.
Author

N75-32054 Eurocontrol Agency, Brussels (Belgium).
MEDICAL PROBLEMS RELATING TO AIR TRAFFIC CONTROL PERSONNEL
E. Evrard *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 105-124 refs (For availability see N75-32047 23-04)

The protection of air traffic control personnel was studied. The following points were examined: (1) working conditions in the air traffic control services, flight information services and alerting services; (2) psychophysiological factors determining the efficiency of air traffic control systems; (3) occupational pathology of air traffic controllers, covering the problem of the danger of emission of X-rays by the cathode-ray tubes in the display screens, visual pathology, auditory pathology, and pathology caused by nervous tension; and (4) protection of air traffic control personnel. Author

N75-32055 International Federation of Air Traffic Controllers Associations, Brussels (Belgium).
THE INTERNATIONAL FEDERATION OF AIR TRAFFIC CONTROLLERS ASSOCIATIONS (IFATCA)
T. H. Harrison *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 127-134 (For availability see N75-32047 23-04)

The IFATCA history is presented. The aims of the federation are discussed along with the annual conferences, and standing committees. F.O.S.

N75-32056 Royal Radar Establishment, Malvern (England).
PRINCIPLES OF AUTOMATION IN AIR TRAFFIC CONTROL
S. Ratcliffe *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 141-156 refs (For availability see N75-32047 23-04)

The automation of ATC by reducing the data for processing by digital computer techniques was studied. Hardware and software reliability are discussed along with men and machines in ATC. Data sources for automated systems, and the use of computers in decision making are also discussed. F.O.S

N75-32057 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
DATA PROCESSING FOR ATC
Horst A. Naumann *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 159-172 refs (For availability see N75-32047 23-04)

There are two main objectives of data processing for air traffic control: first, support of tactical control by the provision of a sophisticated display of the air traffic situation and by the application of procedures of real-time conflict detection and solution; second, avoidance of air traffic congestion as well as reduction and balancing of the load of both the planning and the executive controller by automatic filtering of conflicts and by hierarchical structuring of planning and control functions. Features and criteria of functions termed flow planning, flow control and flight progress planning and control to achieve the second objective with the application of electronic data processing are considered. Author

N75-32058 Sperry Rand Corp., St. Paul, Minn. Univac Defense Systems Div.
AUTOMATION IN AIR TRAFFIC CONTROL SYSTEMS
Adi J. Khambata *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 175-198 refs (For availability see N75-32047 23-04)

Controlling the ever-increasing number of aircraft movements in an orderly and safe manner in the nation's airspace is becoming a problem. The historical evolution is traced of Air Traffic Control (ATC) since before World War II. It also discusses the current ATC problems. The National Airspace System (NAS) design concept is presented, and the progress made in implementing it in the enroute area is described. The progress of automation in the terminal areas include systems such as the unique Common IFR Room at New York, one of the world's most congested metropolitan terminal areas, and the recently installed ARTS III System at O'Hare Field in Chicago, which is considered the world's busiest air terminal. Several other areas of automation, such as collision avoidance, which impact the ATC system, are also discussed. Author

N75-32059 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
CONFLICT AND COLLISION AVOIDANCE SYSTEMS
Roland Moreau *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 203-238 refs (For availability see N75-32047 23-04)

Greater flight safety dispite the growth in traffic by improved air traffic control was investigated. The means of ensuring greater safety for successive phases of a flight from takeoff to landing, airborne collision avoidance systems (CAS), and ATC/CAS compatibility are discussed. F.O.S.

N75-32060 Mitre Corp., McLean, Va.
CONFLICT ALERT AND INTERMITTENT POSITIVE CONTROL
Lawrence G. Culhane and Barry M. Horowitz *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 241-250 refs (For availability see N75-32047 23-04)

Analytical, simulation and experimental results are presented which were obtained in the process of designing and progressing toward the implementation of ground-based collision avoidance systems for air traffic control. Selective subsystem performance criteria established as part of the design process are also presented. Different, but compatible system concepts are discussed. For situations involving IFR aircraft, a conflict alert capability will provide the controller with a displayed alert of impending situations of separation being less than minimums. An Intermittent Positive Control (IPC) function, utilizing data link and improved surveillance, provides an automated collision avoidance capability for VFR/VFR and VFR/IFR aircraft pairs, and provides an independent backup to the ATC system for IFR aircraft pairs. In addition, IPC includes pilot warning indications (PWI) for informing pilots of the location of proximate aircraft. Author

N75-32061 Federal Aviation Administration, Washington, D.C.
AIR TRAFFIC FLOW CONTROL
Michael E. Perle, Juan F. Bellantoni, and Ian G. Wolf *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 261-278 refs (For availability see N75-32047 23-04)

The major operational problems in controlling the general flow of the nation's air traffic from a central facility are described, and some of the approaches that may be taken to help automate their solutions are outlined. The discussions are based on operational experience at the FAA's Air Traffic Control Systems Command Center and on the present prototype computer programs, developed by the Transportation Systems Center, that provide data processing support to the controllers at that facility. The operational problems, giving the history, present procedural techniques and constraints, data sources, and control strategies available are described. Some of the pitfalls in solving the operational problem. Various approaches to automating flow control such as quantifying the objectives and developing algorithms to assist the controllers are discussed Author

N75-32062 Stanford Research Inst., Menlo Park, Calif.
LOCAL AND REGIONAL FLOW METERING AND CONTROL
Robert S. Ratner, David K. Schmidt (Purdue Univ.), and Peter J. Wong *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 281-294 refs (For availability see N75-32047 23-04)

The safety and efficiency requirements for improving air traffic control were studied. Current sequencing and spacing operations in terminal areas are described along with local flow operations. F.O.S.

N75-32063 Massachusetts Inst. of Tech., Cambridge. Electronic Systems Lab.
APPLICATION OF MODERN CONTROL THEORY TO SCHEDULING AND PATH-STRETCHING MANEUVERS OF AIRCRAFT IN THE NEAR TERMINAL AREA
Michael Athans *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 287-322 refs (For availability see N75-32047 23-04)

A design concept is presented for the dynamic control of aircraft in the near terminal area. An arbitrary set of nominal air routes, with possible multiple merging points, all leading to a single runway is considered. The system allows for the automated determination of acceleration/deceleration of aircraft along the nominal air routes, as well as for the automated determination of path-stretching delay maneuvers. In addition to normal operating conditions the system accomodates variable commanded separations over the outer marker (to allow for takeoffs between successive landings); and emergency conditions (in the sense that an aircraft is given partial or complete priority for landing). The system design is based upon the combination of three distinct optimal control problems: (1) a standard linear-quadratic problem, (2) a parameter optimization problem, and (3) a minimum-time rendezvous problem. Simulation results involving twelve aircraft under both normal and emergency conditions are presented. Author

N75-32064 Eurocontrol Agency, Brussels (Belgium).
AIRCRAFT TRAJECTORY PREDICTION DATA FOR ATC PURPOSES
Andre Benoit and Eileen Evers (SCICON, Ltd., London) *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 327-367 refs (For availability see N75-32047 23-04)

A method is presented for assembling the aircraft trajectory data in a compact form which indicates the quality of the aircraft characteristic data produced. The main aspects are outlined of an EROCOA aircraft performance handbook which is being prepared. The method covers all phases of the flight with the exception of the takeoff and initial acceleration, final deceleration and landing. Climb, acceleration and deceleration at cruising level, cruise and descent are considered equally and data are assembled in order to compute the trajectory components during any of these phases. The data produced cover a fleet of over one hundred aircraft versions including sixty different aircraft types, namely most of the current commercial aircraft operating in Western Europe and manufactured in Europe of North America and a sample of aircraft specifically designed for military purposes. Author

N75-32065 Mitre Corp., McLean, Va.
NAVIGATION PERFORMANCE REQUIREMENTS FOR REDUCING ROUTE CENTERLINE SPACING
Ronald Braff *In* AGARD A Survey of Modern Air Traffic Control, Vol. 1 Jul. 1975 p 373-389 refs (For availability see N75-32047 23-04)

Several different studies have looked into the question of what can be done in the ATC system to enable the current route centerline spacing standard to be safely reduced. These studies include that of Boeing, The Royal Aircraft Establishment (RAE), Autonetics and MITRE. These four approaches to the problem of reducing route centerline spacing are summarized, and the results derived from each are compared. Author

N75-32066# Advisory Group for Aerospace Research and Development, Paris (France).
A SURVEY OF MODERN AIR TRAFFIC CONTROL, VOLUME 2
Andre Benoit, ed. Jul. 1975 336 p refs 2 Vol.
(AGARD-AG-209-Vol-2; AGARDograph-209-Vol-2) Avail: NTIS HC $8.50

Technical aids to air traffic control and operational air traffic control systems are discussed. Other topics discussed include principles of radiolocation, distance measuring methods, inertial navigation, landing guidance systems, digital radar data processing, computer use in air traffic control, satellite as an aid, TACAN, and omnidirectional radio beacons. For individual titles, see N75-32067 through N75-32082.

N75-32067 Standard Electrik Lorenz A.G., Stuttgart (West Germany).
PRINCIPLES OF RADIOLOCATION
W. Crone and G. Peuker *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 397-405 refs (For availability see N75-32066 23-04)

The basic principles of radio location are reviewed from the physical point of view; these include travel time, propagation time difference, phase difference, and amplitude. Properties of electromagnetic waves are summarized, and methods for error reduction are described with reference to errors generated by multipath propagation and reflection by obstacles. M.J.S.

N75-32068 Standard Electrik Lorenz A.G., Stuttgart (West Germany).
LONG DISTANCE AIDS (OMEGA, LORAN)
Walter Stanner *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 411-422 refs (For availability see N75-32066 23-04)

The ground-based long distance aids Omega and LORAN provide the user with position data by using the hyperbolic principle. Characteristics and equipment for the Omega, LORAN-A and LORAN-C systems are discussed. Author

N75-32069 Standard Electrik Lorenz A.G., Stuttgart (West Germany).
MEDIUM DISTANCE AIDS (VHF OMNIDIRECTIONAL RADIO BEACONS)
Guenter Hoefgen *In* AGARD A Survey of Modern Air Traffic Control, Vol 2 Jul. 1975 p 425-433 refs (For availability see N75-32066 23-04)

VHF omnidirectional radio range (VOR) is a radio aid for aircraft guidance; it is an omnidirectional radio beacon, providing the angle between aircraft and North, seen from the ground station. The VOR ground station radiates an azimuth-dependent signal which is analyzed as the bearing information by the aircraft receiver. The pilot guides the aircraft along the course selected with the aid of constant azimuth indication. The range is of the order of 100 to 150 nm. Author

N75-32070 Standard Electrik Lorenz A.G., Stuttgart (West Germany).
DISTANCE MEASURING METHODS
Manfred Boehm *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 437-448 (For availability see N75-32066 23-04)

The distance-measuring methods employing electromagnetic waves make use of the velocity of light; the path covered by a light or radio signal can be determined, if the transit time is known, from a formula. Round-trip and one-way distance measuring systems are described; the round-trip systems operate with responding transmitters (or with passive reflectors as in the case of radar or radio altimeters), and the responding transmitter will retransmit the received signal with an exactly defined delay. In the case of one-way distance-measuring systems, identical and extremely accurate time standards are used in both the transmitter and the receiver locations. Airborne and ground station equipment is discussed. Author

N75-32071 Standard Electrik Lorenz A.G., Stuttgart (West Germany).
TACAN
M. Boehm *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 449-455 refs (For availability see N75-32066 23-04)

Tactical air navigation (TACAN), a radio position-fixing method for military short and medium range aviation, is described. Each ground station currently provides azimuth or 'theta' values to any number of aircraft and distance or 'rho' values to maximum 120 aircraft at the same time. Both types of values are either directly displayed or are inputs for a navigation computer. Operational principles, airborne equipment, and TACAN ground stations are described in detail. Author

N75-32072 Ferranti, Ltd., Edinburgh (Scotland). Inertial Systems Dept.
INERTIAL NAVIGATION AND AIR TRAFFIC CONTROL
W. H. McKinlay *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 461-488 refs (For availability see N75-32066 23-04)

The history of the development of navigation within air traffic control systems is traced briefly, and the requirements for effective navigation and flight path control are discussed. They are related to the adoption of inertial navigation and to the possible future extention of its use. Typical airborne system configurations are described together with the facilities provided by them. Reference is made to systems for both civil and military aircraft. The principles of inertial navigation are described with a review of the standards of accuracy and reliability being achieved, and the technology involved. Author

N75-32073 Advisory Group for Aerospace Research and Development, Paris (France).
LANDING GUIDANCE SYSTEMS
Frank B. Brady *In its* A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 495-557 refs (For availability see N75-32066 23-04)

The evolution of aircraft landing guidance technology is reviewed, from rudimentary nondirectional beacons and markers in the 1920's through the development and installation of the current standard instrument landing system (ILS) and the microwave landing systems (MLS) proposed for future world standardization. The major milestones in landing guidance system development are depicted. Design considerations for MLS are discussed in detail. Author

N75-32074 Mitre Corp., Atlantic City, N.J.
DIGITAL RADAR DATA PROCESSING FOR ENROUTE AIR TRAFFIC CONTROL
John A. Varela *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 563-571 refs (For availability see N75-32066 23-04)

Digital radar data processing (RDP) in operation in twenty air route traffic control centers (ARTCCs) in the contiguous states are discussed. The system was extensively tested, its performance measured, and standards established for system performance. The functions of primary and secondary surveillance radar target detection, and the processing of target data in the central computer at the ARTCC are described. The latter includes filtering the data, conversion to common coordinates, correlation with automatic tracks, track smoothing and prediction in several modes, and measurement of data quality in real time. Data on measured system performance are given, and a short description of current efforts to improve system performance is included. Author

N75-32075 Eurocontrol Agency, Brussels (Belgium).
DISPLAY TECHNIQUES FOR AIR TRAFFIC CONTROL SYSTEMS
Richard Jenyns *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 577-604 refs (For availability see N75-32066 23-04)

The cathode ray tube is discussed which fulfills requirements for dynamic data displays in air traffic control systems. The basic principles of the cathode ray tube are described together with some recent developments which help to keep it in the forefront of display technology. Advanced techniques which emerged

from research and development laboratories offer advantages not found with the cathode ray tube. The most promising of these techniques, which may find applications in air traffic control systems, are discussed together with their characteristics and relative merits. Author

N76-32076 Eurocontrol Agency, Brussels (Belgium).
USE OF COMPUTER IN AIR TRAFFIC CONTROL
B. Kirstetter, G. Maignan, and V. Vachiery *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 609-636 refs (For availability see N76-32066 23-04)

The characteristics and applications of computers in air traffic control, are discussed, mainly based on experience in the upper airspace. After a short summary of the different applications, the general characteristics of hardware and software architecture are discussed. This includes a description of multiprocessor and multicomputer systems with their specific ATC oriented peripherals, real-time operating systems, programming techniques, data base, and reliability aspects and the associated problems of recovery management. The principles of data transmission in air traffic control systems are included. Radar data processing deals mainly with mono- and multi-radar tracking aspects. A summary of the different functions is given which can presently be provided by a flight data processing system. Author

N76-32077 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
GENERAL ASPECTS OF DATA FLOW
Horst A. Neumann *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 639-645 refs (For availability see N76-32066 23-04)

Regarding complex systems such as air traffic control, data acquisition and data processing are performed through cooperation of man with machine. Indispensable dialog usually is accomplished by output of machine's results via teletypes, lineprinters, plotters, or luminous data displays and by input of man's acquired data, results, and decisions via functional keys, keyboards, and touch displays. A block diagram of data flow in air traffic control is presented. Manual data input is combined with data acquisition; data output is differentiated with respect to the receiver (pilot and controller). The diagram, as seen from a general point of view, represents implicitly all possible concepts of air traffic control executed on-ground, including even the concept of manual control, which leaves time-consuming tasks of data acquisition and preprocessing as well as all crucial tasks of intrinsic data processing to controllers. Author

N76-32078 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
SOME TRENDS IN HARDWARE CONCEPTS FOR ATC COMPUTER
Wolfgang Nittner *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 649-656 refs (For availability see N76-32066 23-04)

Four main requirements are discussed for hardware-structures resulting from applications such as radar data tracking, conflict detection and resolution, long-term flight plan coordination and flow control, flight progress adjustment, recording, and statistics application programs: reliability and safety, storage capacity and processing power, time behavior, and hardware-software-integration and software related features. Technologies and important features of computer structures are outlined. Author

N76-32079 Federal Aviation Administration, Washington, D.C. Aeronautical Satellite Div.
THE SATELLITE AS AN AID TO AIR TRAFFIC CONTROL
Keith D. McDonald *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 661-697 refs (For availability see N76-32066 23-04)

The capabilities and potential are discussed of satellite-based systems for navigation and air traffic control (ATC). The utility of satellite systems was extended from communications, surface navigation, and geodetic applications into air and space, and to other functional areas such as position surveillance for air traffic control, precise time and time transfer, international maritime and aeronautical position location and reporting services, and collision avoidance. A summary is presented of the basic principles upon which the satellite systems operate, along with an indication of their advantages and potential, a brief review of the historical developments, and a description of the system concepts and characteristics of selected satellite-based ATC systems Author

N76-32080 Eurocontrol Agency, Brussels (Belgium).
EUROCONTROL DATA PROCESSING SYSTEMS
B. Kirstetter, G. Maignan, and V. Vachiery *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 703-724 (For availability see N76-32066 23-04)

The air traffic control data processing systems MADAP and KARLDAP, are designed for combined flight data and radar data processing. A description is given of the functions and hardware and software structure of the systems with special consideration to reliability, programming, and implementation aspects. The radar data processing system SHANDAP is also described. Author

N76-32081 Rijksluchtvaartdienst, The Hague (Netherlands).
THE NETHERLANDS ATC AUTOMATION PROGRAM
J. S. Smit *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 727-734 (For availability see N76-32066 23-04)

A historical summary is presented of air traffic control radar data processing systems in use in the Netherlands. Operational characteristics and specifications are included. M.J.S.

N76-32082 Mitre Corp., McLean, Va.
OVERVIEW OF US AIR TRAFFIC CONTROL SYSTEM
Howard J. Kirshner *In* AGARD A Survey of Modern Air Traffic Control, Vol. 2 Jul. 1975 p 737-744 refs (For availability see N76-32066 23-04)

A brief overview is presented of the technical features of the systems used in U.S. air traffic control centers. Emphasis is placed on the recently modernized en route and terminal control systems. Author

N76-23191# Advisory Group for Aerospace Research and Development, Paris (France).
PLANS AND DEVELOPMENTS FOR AIR TRAFFIC SYSTEMS
A. Benoit, ed. and D. R. Israel, ed. Feb. 1976 562 p refs Conf. held at Cambridge, Mass., 20-23 May 1975
(AGARD-CP-188) Avail: NTIS HC $13.50

Technological forecasting and automation of air traffic control systems are described. For individual titles, see N76-23192 through N76-23229.

N76-23192 Royal Aircraft Establishment, Bedford (England)
STUDIES OF AUTOMATIC NAVIGATION SYSTEMS TO IMPROVE UTILIZATION OF CONTROLLED AIRSPACE
K. Watling and R. C. Rawlings *In* AGARD Plans and Develop for Air Traffic Systems Feb. 1976 15 p refs (For availability see N76-23191 14-04)

It is shown that the use of improved navigation in controlled airspace in the future could produce useful savings in time and money within a short time. This conclusion is based on the optimum use of VOR/DME and will rely, from the start, on allowing reduced lateral and longitudinal separations by the provision of accurate statistically predictable performances. Certain en-route applications are possible which provide the means of assessing, at an early stage, the effectiveness of the improved systems and which provide the means of assessing, at an early stage, the effectiveness of the improved systems and which allow the development of more ambitious systems for the busy TMAs in the future. Author

N76-23193 Ecole Nationale Superieure de l'Aeronautique, Toulouse (France).
FOUR-D NAVIGATION IN TERMINAL ZONES: AN AUTOMATIC CONTROL PROBLEM
Marc J. Pelegrin *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 25 p refs In ENGLISH and FRENCH (For availability see N76-23191 14-04)

It is shown that, if a velocity profile is imposed upon the plane and controlled along a selected approach path, it is possible to limit the deviation from the computed arrival time of the plane at the ILS entry gate. Two simulation programs, a fast time one and one in real time, determine and control the optimum 4-D trajectory. The first results show that the accuracy of the simulation need not be very great; thus, the extra computing ground capacity is fairly limited. It can also be shown that an accurate descent trajectory is no problem for an aircraft equipped with an automatic throttle command. Moreover, a head-up display

that gives the optimum glide slope angle allows a very accurate control of the plane along its longitudinal axis. Author

N76-23194 Boeing Commercial Airplane Co., Seattle, Wash.
STRATEGIC CONTROL OF TERMINAL AREA TRAFFIC
Ralph L. Erwin, Jr. *In* AGARD Plans and Develop. for Air Traffic Systems Feb 1976 13 p refs (For availability see N76-23191 14-04)

An advanced method of controlling air traffic in high density terminal areas is reported. In this concept the air traffic control system defines four dimensional tracks for all arrivals that will derandomize and space the traffic for landing on the runway. The aircraft use four dimensional navigation and guidance equipment to fly the assigned paths. The advantages that result from a strategic control system using airborne four dimensional navigation and guidance equipment are presented; the resulting benefits of increased capacity and reduced fuel consumption are discussed. The logic used by the air traffic control authority to strategically control arrivals is described. This logic determines the sequence for handling the aircraft, establishes the time schedule for use of the runway by each flight, and calculates the four dimensional path to be assigned to each aircraft, recognizing the aeroperformance capabilities of the individual flight. The performance of the algorithm is demonstrated by the results of a fast time simulation of strategic control as applied to arriving traffic for Los Angeles International (LAX) Airport. Author

N76-23195 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
ATC CONCEPTS WITH EXTENSIVE UTILIZATION OF AUTOMATIC DATA PROCESSING
Horst Newmann *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 9 p (For availability see N76-23191 14-04)

Alternative concepts of electronic data processing supported ATC are outlined and technical and procedural problems are specified in each case. Emphasis is on conceivable planning functions and logical relations with air traffic control functions leading to semi-automatic air traffic control. There are two main effects of such an ATC concept utilizing automatic data processing extensively: (1) expedition of the air traffic flow and reduction of the load of both the planning and the radar controller, because automatic filtering of conflicts will be achieved; and (2) optimum balancing of the load, because automatic allocation of flights to controllers will permit more continuous control and guidance within joint control sectors. Author

N76-23196 Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
OMEGA: A SYSTEM WHOSE TIME HAS COME
John F. Beran and John E. Bortz, Sr. (Analytic Sciences Corp., Reading, Mass.) *In* AGARD Plans and Develop. for Air Traffic Systems Feb 1976 10 p refs (For availability see N76-23191 14-04)

The United States Air Force program to equip approximately 700 airlift aircraft with Omega navigation equipment is described. The program structure emphasizes obtaining low cost automatic equipment satisfying enroute air navigation performance requirements. Required equipment characteristics are identified and the structure of the equipment acquisition program is outlined. Several important Omega technology issues are discussed from a user's perspective. The paper concludes with a summary of the results of an Air Force flight test program designed to evaluate the important technology options now available in Omega navigation equipment. Author

N76-23197 Plessey Radar Ltd. Havant (England).
A SURVEY OF PRIMARY RADARS FOR AIR TRAFFIC SYSTEMS
K. Milne *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 10 p refs (For availability see N76-23191 14-04)

Application areas for primary radars in air traffic systems are reviewed. Problems facing the designers of such radars are outlined. Minimization of ground clutter, precipitation clutter and angle echoes figure high on the list of desiderata, combined with the needs for adequate data rate and high equipment reliability. Approaches to the solutions of these problems are surveyed and examples given of current practice. Future trends in primary radars are discussed in the light of recent advances in automation and in signal processing techniques. Improvements in the immediate future are likely to be evolutionary in nature, aimed at making the performance of today's radars compatible with more automated control systems. Author

N76-23198 Federal Aviation Agency, Washington, D.C. Systems Research and Development Service.
ATCRBS IMPROVEMENT PROGRAM
Martin Natchipolsky *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 10 p (For availability see N76-23191 14-04)
(ARD-241)

The Air Traffic Control Radar Beacon System (ATCRBS) experiences a number of problems such as false, broken, fading, missed and garbled targets. Although many factors contribute to the degradation of ATCRBS performance, most problems can be attributed to poor interrogator/receiver antennas, the difficulty of interrogator management, inadequate reply target detection and processing criteria or airborne transponder performance. A major development effort has been directed at improved interrogator antenna designs because the present FAA ATCRBS antenna is responsible for many of the system problems. Planned development efforts for improved ATCRBS reply processing and target detection are based on utilization of the improved antenna performance and sum difference pattern capability for monopulse processing. Author

N76-23199 Royal Radar Establishment, Malvern (England).
ADSEL/DABS: A SELECTIVE ADDRESS SECONDARY SURVEILLANCE RADAR
R. C. Bowes, P. R. Drouilhet (Lincoln Lab., MIT, Lexington), H. G. Weiss (Lincoln Lab., MIT, Lexington), and M. C. Stevens (Cossor Electronics Ltd., Harlow, Engl.) *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 13 p refs Sponsored in part by FAA (For availability see N76-23191 14-04)

ADSEL/DABS (Address Selection/Discrete Address Beacon System) is a selectively addressed secondary radar system which is an extension of present day ATCRBS/SSR. The system provides the usual surveillance data, identity, height and position and in addition a data link communication facility is available on both the ground to air and air to ground channels. The system is entirely compatible with present day ATCRBS/SSR and introduction can take place over an extended period. A modified transponder is required in the aircraft which operates on both normal ATCRBS/SSR and ADSEL/DABS. The new ground stations can provide surveillance of aircraft fitted with existing ATCRBS/SSR transponders as well as handling those with selective address transponders on board. An overall description of the system is given together with details of the message formats and modulation techniques adopted. Author

N76-23200 Elettronica S.R.L., Rome (Italy).
LEA MICROWAVE APPROACH AND LANDING SYSTEM
Roberto Nicoli *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 5 p (For availability see N76-23191 14-04)

The system operates in time sharing for terminal area navigation and landing or runway taxiing aids. In addition to the over 100 aircrafts that the system is capable of assisting in the landing phase, it can provide TMA navigation aid to several hundreds aircrafts inside a 30 n.m. radius area. The system utilizes a simple airborne equipment, while the ground equipment can be implemented at various degrees of sophistication, according to the airport size and traffic. Aircraft position data and identification are simultaneously available onboard and on the ground so that TMA and ATC are simplified. On the ground, ATC personnel have available data of all aircraft in TMA, landing or taxiing in the runways, complete with the aircraft indentification codes. The pilot has available onboard-- on standard cockpit instruments--the accurate position data of the aircraft in relation to the airport for TMA and to runway for landing. The ATC operator who monitors the aircraft situation on a scope gives ground-to-air instructions for TMA to the pilots and emergency communications for landing. Author

N76-23201 Naval Electronic Systems Command, Washington, D.C.
MATCALS: EXPANSION OF CAPACITY FOR EXPEDITIONARY AIRFIELDS
Richard R. Wilz (Marine Corps., Washington, D. C.) *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 18 p (For availability see N76-23191 14-04)

The Marine Air Traffic Control and Landing System (MATCALS) is being implemented to upgrade and automate the ATC and all weather landing control capabilities of Marine Air Traffic Control Units (MATCU). The overall role of Marine Corps

aviation is reviewed, and the crucial role and operational functions of the MATCU as a supporting element are described. An overview is presented of the MATCALS implementation program, the system as a whole, and the advanced capabilities which MATCALS will provide. Specific functional capabilities for air traffic management and control are indicated, and the technical approach toward implementing these functions is described. The MATCALS landing control capabilities and functions are then described, with emphasis on the operational advantages realized with an automated ground derived system. Finally, the impact of MATCALS on overall Marine aviation effectiveness is summarized. This summary emphasizes the quantitative factors by which MATCALS will increase the maximum rate of air firepower delivery through increased traffic handling capacity at expeditionary airfields. Author

N76-23202 Mitre Corp., McLean, Va.
ADVANCED ATC AUTOMATION: THE ROLE OF THE HUMAN IN A FULLY AUTOMATED SYSTEM
Richard A. Rucker *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 10 p refs (For availability see N76-23191 14-04)

An overview is presented of one approach to formulating and evaluating an experimental model which automates routine en route sector traffic control. Basic design concepts are identified, and the automated control tasks performed by the Front Royal sector model, a digital computer simulation, are discussed. The paper then focuses on the anticipated roles and responsibilities of the journeyman air traffic controller in such an environment and how en route sector position designs may further evolve as a result. The purpose is to explore some long range implications and potentials from the perspective of the air traffic controller. Author

N76-23203 Royal Air Force, Farnborough (England). Inst. of Aviation Medicine.
THE PROVISION AND USE OF INFORMATION ON AIR TRAFFIC CONTROL DISPLAYS
V. David Hopkin *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 12 p refs (For availability see N76-23191 14-04)

Several kinds of mismatch can occur at the man machine interface in air traffic control systems. One, often overlooked, concerns the provision of certain essential information in a form which is unusable. The traditional reliance on the man's strengths of adaptability and flexibility in order to match man and machine in the system is thwarted if he cannot use the information presented to him. Changes from qualitative to quantitative information, incomplete automation, and the apparent retention of decision making roles which in fact have been greatly modified, all pose problems of ensuring that the displayed information has been adapted successfully. Author

N76-23204 Stanford Research Inst., Menlo Park, Calif. Transportation Engineering and Control Group.
AUTOMATION OF LOCAL FLOW CONTROL AND METERING OPERATIONS IN THE ENROUTE/TRANSITION ENVIRONMENT
Robert S. Ratner *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 7 p (For availability see N76-23191 14-04)

Local flow control procedures are described that are used when a sector of the enroute/transition airspace becomes saturated, in terms of the workload or control capacity of the sector control team. The procedures are generally implemented according to prespecified plans, and take the form of restrictions on the permissible in-trail inter-aircraft separation for traffic flows upstream of the impacted sector. The desirability of enhancing this process of local flow control is discussed. A concept, termed planning control, for enhancing local flow control operations through automation, is described. The concept is based on prediction of prospective traffic levels on routes and in sectors within an air route traffic control center, using the on-line traffic data base of the NAS Enroute Stage A system. Appropriate flow control restrictions, are instituted whenever control workload in a sector exceeds a standard level. Author

N76-23205 Royal Air Force, Farnborough (England). Mathematics Dept.
THE OPTIMISATION OF TRAFFIC FLOW AROUND A NETWORK
V. W. Attwooll *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 6 p (For availability see N76-23191 14-04)

The use of flow control is considered for air routes subject to saturation. Alterations to intended flight times at the planning stage penalize the operator, but so do the delays from congestion which occur if such alterations are not made. Hence there is an optimum balance which can be expressed as a planning target flow rate on a given route. For a network of routes subject to constraints, similar considerations lead to an optimum planned distribution of traffic flow around the system. The assessment of this optimum can become complex and is best handled by computer optimization techniques. The use of such techniques may become inevitable when the increasing complexity of route systems and constraints makes it impracticable for the unaided human brain to approach an optimum traffic distribution. Our study is illustrated by examples of traffic conditions at the England/France boundary. Author

N76-23206 Eurocontrol Agency, Brussels (Belgium).
THE INTRODUCTION OF ACCURATE AIRCRAFT TRAJECTORY PREDICTIONS IN AIR TRAFFIC CONTROL
A. Benoit, J. Storey, and S. Swierstra *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 28 p refs (For availability see N76-23191 14-04)

A family of methods is proposed for predicting the trajectory of an aircraft of which a limited past history is known from radar observations at the time the prediction is produced as well as the intentions available from flight plan data. The approach is particularly designed to accommodate climbing and descending traffic and, in consequence, the paper concentrates on the vertical component of the trajectory prediction. Author

N76-23207 Royal Radar Establishment, Malvern (England)
INTERACTIVE CONFLICT RESOLUTION IN AIR TRAFFIC CONTROL
R. G. Ball, R. B. Lloyd, and G. Ord *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 14 p refs (For availability see N76-23191 14-04)

Aircraft of the major operators are becoming more and more capable of flying trajectories well defined in space and time. Such trajectories offer distinct advantages to operators and could also offer advantages to controllers for planning conflict free situations in the tactical phase of control. However, in order to use them, it is necessary for controllers to be able to visualize the trajectories further into the future, and in greater detail, than they can at present. A technique is outlined for improving the controller's visualization ability by using computer assistance to provide a predictive display. The technique is capable of being extended to help the controller with conflict detection and resolution. An important feature of the extension is that it allows the controller to conduct a dialogue with the computer enabling him to try out various options, the outcome of each of these being displayed so that he can assess the consequences of any action. The paper also discusses how the computer can assist with monitoring that aircraft remain on trajectories which are conflict free. Author

N76-23208 Federal Aviation Agency, Washington, D.C.
INTERMITTENT POSITIVE CONTROL: A GROUND-BASED COLLISION AVOIDANCE SYSTEM
Michael E. Perle, B. M. Horowitz (MITRE Corp.), A. L. McFarland (MITRE Corp.), J. U. Beuisch (Lincoln Lab., MIT), and K. D. Senne (Lincoln Lab., MIT) *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 17 p refs (For availability see N76-23191 14-04)

Intermittent Positive Control (IPC) is a totally automated ground based collision avoidance system. It functions by taking positive control of Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) aircraft on an as needed basis to avoid hazardous encounters. By also providing pilots with continuous information on the location of nearby aircraft, it results in safety in controlled, mixed, and uncontrolled airspace, among all users (air carrier, general aviation and military) in both IFR and VFR flight, while maintaining the freedom of action associated with VFR flight. To receive IPC service an aircraft must carry a Discrete Address Beacon System (DABS) transponder and an IPC display. The transponder, in addition to its beacon function, receives digital messages from the ground and presents them on the IPC display. The ground portion of the IPC system consists of the DABS sensor and an IPC computer. Author

N76-23209 Thomson-CSF, Bagneux (France).
INTEGRATED NAVIGATION SYSTEM: MULTIFUNCTION
Ljubimko Milosavic *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 43 p In ENGLISH and FRENCH (For availability see N76-23191 14-04)

The multifunction integrated navigation system is designed in an homogeneous manner for radio navigation aid functions. It carries out navigation, surveillance with identification, anticollision, data transmission and voice communications functions. It is compatible with either direct ground to air transmission links or indirect satellite transmission links. It significantly simplifies aircraft equipment. It features modular extensible design and it is practically a non-saturable system. Two overall views of the system utilization are either with enroute T/R ground stations or using satellites to cover the enroute space. Author

N76-23210 Mitre Corp., McLean, Va. Air Transportation Systems Div.
FUTURE ATC TECHNOLOGY IMPROVEMENTS AND THE IMPACT ON AIRPORT CAPACITY
Richard M. Harris *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 14 p refs (For availability see N76-23191 14-04)
(Contract DOT-FA70WA-2448)

The United States is presently in its third generation of air traffic control systems and technology. This third generation system is the first nationwide application of modern computer based technology to the management of traffic in the national airspace system. Twenty NAS Stage A enroute installations are now in place at the domestic air route traffic control centers. In addition, 61 automated radar terminal systems are now installed and operational in the major terminal areas. Linkages between these enroute and terminal facilities are presently being established and verified. Upon completion of the installation and testing the U.S.A. will have operational a large scale, semi-automated capability to provide highly improved ATC services for domestic medium, high altitude, and terminal airspace. Author

N76-23211 Royal Radar Establishment, Malvern (England).
SECONDARY RADAR FOR GROUND MOVEMENT CONTROL
Hugh N. Griffiths *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 9 p (For availability see N76-23191 14-04)

A method of using secondary radar for ground movement identification is outlined which could have sufficient positioned accuracy to label a high definition primary radar display of airfield ground movements. An experimental ground movement secondary radar installation at an airfield site is described and the results of trials are discussed. Methods for improving the performance of the basic system are indicated and possible future developments are suggested. Author

N76-23212 Transportation Systems Center, Cambridge, Mass.
ATCRBS TRILATERATION, THE ADVANCED AIRPORT SURFACE TRAFFIC CONTROL SENSOR
J. W. Ogrady, M. J. Moroney, and R. E. Hagerott *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 20 p refs (For availability see N76-23191 14-04)

The requirements of an advanced Airport Surface Traffic Control (ASTC) system have been developed and the technology identified for the sensor part of the system. Employing Air Traffic Control Radar Beacon System (ATCRBS) replies from aircraft transponders and trilateration receivers for accurate position location and vehicle identification, the sensor system satisfies the performance and readiness requirements of intermediate (1980) goal systems. The advanced ATCRBS trilateration sensor for ASTC has been analytically established and a brassboard system is being fabricated to provide empirical validation. Author

N76-23213 Service Technique de la Navigation Aerienne, Paris (France).
THE CORAIL SURVEILLANCE SYSTEM FOR AIRPORT RUNWAYS [SYSTEME CORAIL DE SURVEILLANCE DE PISTES D'AEROPORT]
Jean Marc Faysse and Guy Georges Plottin (Laboratoire Central de Telecommunications) *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 18 p In FRENCH and ENGLISH (For availability see N76-23191 14-04)

The prototype CORAIL radar installed on the Paris Orly airport runway and originally intended only for automatic runway surveillance under conditions of poor visibility has proven itself to be a powerful facility for controlling runway and approach corridor movements in real time, making it possible to increase the frequency of aircraft landings and takeoffs, even in clear water, whilst maintaining a high level of safety. Author

N76-23214 Transportation Systems Center, Cambridge, Mass.
PREDICTIVE TECHNIQUES FOR WAKE VORTEX AVOIDANCE
J. N. Hallock, W. D. Wood, and E. A. Spitzer *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 11 p refs (For availability see N76-23191 14-04)

Aircraft wake vortices represent a major impediment to increasing runway capacity. Separation criteria are conservative most of the time and thus traffic unnecessarily delayed by always adhering to the present inflexible regulations. Systems which employ vortex tracking sensors and/or meteorological sensors to determine safe reduced spacings are being designed. Any wake vortex avoidance strategy relies upon the ability to predict vortex transport and decay. The paper discusses vortex behavior, preliminary predictive models based upon the tracking of vortices from over 24,000 landing aircraft, and systems and their implementation to provide the capability of using adaptive separations. Author

N76-23215 Transportation Systems Center, Cambridge, Mass.
US/UK VORTEX MONITORING PROGRAM AT HEATHROW AIRPORT
J. N. Hallock and L. Goldstone (Civil Aviation Authority, London) *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 9 p (For availability see N76-23191 14-04)

Vortices shed from aircraft landing are being recorded and analyzed and their motion correlated with ambient meteorological conditions. It is shown that if the crosswind component measured near the runway threshold exceeds five knots, vortices linger near the extended runway centerline for a time in excess of one minute for less than 0.5 percent of the landings. This small percentage is almost entirely due to vortices from the heavy wide body jets -- the B747, DC-10 and L-1011. Author

N76-23216 Linde A.G., Munich (West Germany).
FOG DISPERSAL AT AIRPORTS, THE STATE OF THE ART AND FUTURE TRENDS
W. Baldus, F. V. Melewicz (DOT, Washington, D. C.), A. Poernja, K. Ruppert, J. F. Sowar (DOT, Washington, D. C.), and H. Wenzel *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 6 p refs (For availability see N76-23191 14-04)

Cold fog is being dispersed routinely by airborne seeding with dry ice and results show a favorable benefit to cost ratio. Also ground based systems of liquid propane dispensers are used operationally for cold fog dispersal. Warm fog dispersal being more difficult has become operational at two airports of Paris. Improved prospects of economic warm fog dissipation are offered by a new heat pump system with favorable thermodynamic properties which result in an essentially lowered requirement. The artificial visibility improvement by fog dispersal systems is considered a valuable aid for safe aircraft operation under all weather conditions. Author

N76-23217 Federal Aviation Administration, Washington, D.C.
UNITED STATES PROGRAM TO ICAO FOR A NEW NON-VISUAL APPROACH AND LANDING SYSTEM
Joseph M. DelBalzo and Stanley R. Jones (Mitre Corp., McLean, Va.) *In* AGARD Plans and Develop. for Air Traffic Systems Feb 1976 20 p (For availability see N76-23191 14-04)

The microwave landing system is a precision approach and landing guidance system designed to meet the needs of all types of aircraft, civil and military, throughout the world through at least the balance of this century. It is an air derived data system, i.e., ground stations will generate coded signals which will enable an airborne receiver/processor unit to derive precise azimuth angle, elevation angle, and range data, which are suitable for display to the pilot or for use by an automatic flight control system. Inherent in the MLS design is the incorporation of a ground-to-air data link which will provide runway identification, condition of runway, operational status of the MLS, and weather information. An important element in the concept is that of performance modularity wherein a range of equipment configurations, both ground based and airborne, would be responsive to the operational requirements and economic considerations of each category of user. Author

N76-23218 Transportation Systems Center, Cambridge, Mass.
INSTRUMENT LANDING SYSTEM PERFORMANCE PREDICTION
Gerald Chin, Lawrence Jordan, David Kahn, and Stephen Morin *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 14 p refs (For availability see N76-23191 14-04)

A physics model based on electromagnetic scattering theory has been developed for predicting comparative Instrument Landing System (ILS) localizer and glide slope antennas array performance and course structure degradation resulting from a change to an airport environment. The theoretical predictions of the localizer model were compared with flight test data from Syracuse-Hancock airport. The agreement was good. The glide slope model has been used to predict and compare the perfromance of three image type antennas: The null reference sideband reference and capture effect antennas for non flat terrain configurations. It was found that acceptable course results often could be found with only one type of glide slope antenna without performing a major terrain regrading. Author

N76-23219 Marconi Radar Systems Ltd., Leicester (England). Airfield Instrumentation.
MEASUREMENTS OF RUNWAY VISUAL RANGE
I. A. C. Stage *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 11 p refs (For availability see N76-23191 14-04)

This review of the measurement of runway visual range returns to the basic recommendation of the International Civil Aviation Organization as the basis of a fundamental appraisal of the instrumentation and system requirements. The definition of the operational requirement contains an assessment of the instrumentation task and stresses the need for representativeness in the measurement. The processes of selecting and developing the instrumentation techniques using supporting data processing are shown to provide superior system performance. Results from evaluation trails demonstrate the superior performance of an automated runway visual range system over the observer in providing operationally useful data. In conclusion, the paper discusses future requirements and instrumentation techniques for supplementary visibility assessment. Author

N76-23220 Federal Aviation Administration, Washington, D.C.
INDEPENDENT LANDING MONITORS/SURVEY REPORT
Guice Tinsley *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 2 p refs (For availability see N76-23191 14-04)

Continued interest over a number of years in independent landing monitor systems has resulted in proposals for widely varying techniques and devices to give the pilot a check on the primary instrument landing system and an assurance that the approach and landing is proceeding safely. An independent assessment that an approach is progressing safely may be essential for operator acceptance of approach guidance based on a single electronic signal. Current related developments are summarized to include concept, technical characteristics, and development status. For programs presently undergoing testing, a brief summary of test results is included. Author

N76-23221 Royal Radar Establishment, Malvern (England).
COMPUTER ASSISTED APPROACH SEQUENCING
J. M. Bonny *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1967 7 p (For availability see N76-23191 14-04)

An experimental prototype system is described that is being developed on behalf of the civil aviation authority, to investigate the feasibility of providing computer assistance in the approach sequencing task at Heathrow airport. Author

N76-23222 Transportation Systems Center, Cambridge, Mass.
ADVANCED AIR TRAFFIC AMANGEMENT SYSTEM STUDY
Robert H. Reck *In* Agard Plans and Develop. for Air Traffic Systems Feb. 1976 11 p refs (For availability see N76-23191 14-04)

Plans for the advanced air traffic management system for the late 1980's and beyond are summarized. The plans are presented in the framework of an evolutionary system concept of traffic management building upon the upgraded third generation air traffic control system, and designed to meet the projected demands for service, safety, and flexibility in a cost effective manner. The advanced air traffic management system concept is characterized by the use of satellite to supplement ground equipment for aircraft surveillance, navigation, and communication over the United States and nearby oceanic regions; strategic flight planning and control for flight in dense traffic regions; centralization of the control system; and a high level of automation. A program of research and development is described to provide the information needed for planning future system developments. Author

N76-23223 Advisory Group for Aerospace Research and Development, Paris (France).
FUTURE AIR TRAFFIC CONTROL SYSTEMS, A PRELIMINARY STUDY
In its Plans and Develop. for Air Traffic Systems Feb. 1976 19 p (For availability see N76-23191 14-04)

The results of this study particularly emphasize the vital importance both of the place of man in the system, and of the environmental factors affecting the efficiency of the air traffic controller and the pilot, especially in the context of increasing automation. It is firmly believed that future planning will not be successful unless these two user professions are closely involved in it. A predominantly directive method of air traffic control rather than a totally permissive one is evisioned for the future. Furthermore, predictable penalties associated with a pre-planned traffic flow are to be preferred to the chance penalties associated with a random distribution of traffic. At the same time it is imperative to reduce all possible penalties associated with the system to an acceptable minimum. Author

N76-23224 Massachusetts Inst. of Tech., Cambridge. Electronic Systems Lab.
APPLICATIONS OF THE AIRBORNE TRAFFIC SITUATION DISPLAY IN AIR TRAFFIC CONTROL
Mark E. Connelly *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 12 p refs (For availability see N76-23191 14-04)

The potential usefulness of displaying traffic and map information in an aircraft cockpit and the effects that the availability of such information would have on ATC procedures and capacities are evaluated. These tests indicate that the ATSD is a valuable aid to the pilot in executing the following basic functions: conflict detection and resolution, conforming to airspace structures, precise spacing in trail, merging, sequencing, monitoring runway occupancy, backup procedures after an ATC failure, approach to one of two closely spaced parallel runways operating independently, and taxiing on the airport surface. A simulation study of a terminal area metering and spacing system in which computer generated commands were transmitted directly to the pilots showed that the introduction of the ATSD eliminated all violations of spacing minimums and cut the dispersion of arrival times at the runway threshold in half. When the ATC generated metering and spacing schedule was made available to the pilots and their flight instruments modified to assist them in executing a 4DRNAV approach corresponding to the schedule, the dispersion of arrival time errors at the runway threshold was reduced to less than three seconds. Author

N76-23225 Raytheon Co., Wayland, Mass. Equipment Div.
A NEW SYSTEM ARCHITECTURE FOR ATC AUTOMATION
Paul E. Hamburger *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 13 p refs (For availability see N76-23191 14-04)

Automation of the National Airspace System (NAS) is well underway with both enroute and terminal control centers successfully converted to atuomation. These systems are based on interfacing radar outputs to high resolution displays through one or more large scale computers which provide a variety of automation functions, the most important of which are tracking controlled aircraft and formating alphanumeric data blocks for the associated aircraft. Recent studies for air traffic control systems outside the United States have shown that for applications with less concentrated traffic, a system architecture in which numerous minicomputers share the processing task, has significant advantages in cost, reliability and modularity. By being modular, the number of minicomputers required can be tailored to the size of the air traffic control center, and the computer program size can be tailored to the functional complexity warranted by the country's size, traffic level, and sophistication desired. In designing such systems, minicomputers are assigned to functions in one of two ways: either functions are subdivided and minicomputers are assinged to each subfunction, or a function performed in a similar way many times is subdivided so that several minicomputers perform the function once, or at most a few times. Author

N76-23226 Lincoln Lab., Mass. Inst. of Tech., Lexington.
CONUS AERONAUTICAL RADIONAVIGATION BY SATELLITE
Irvin G. Stiglitz *In* AGARD Plans and Develop. for Air Traffic Systems Feb 1976 5 p refs Sponsored by DOT (For availability see N76-23191 14-04)

A variety of satellite system concepts have been promulgated as solutions to the CONUS ATC problems. By categorizing these, it is possible to draw some generally valid observations about the characteristics of each of them. By selecting system architectures, representative of each category, key technical aspect of systems within each category can be explored. Critical aspects illuminated include avionics complexity, required number of satellites, system vulnerability, capacity, required ground processing, and accuracy. Author

N76-23227 Department of Transport, Ottawa (Ontario).
AERONAUTICAL SATELLITE SYSTEM (AEROSAT)
J. Ruden and J. Thomas *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 10 p (For availability see N76-23191 14-04)

An experimental aeronautical satellite program is being undertaken on an international basis to provide a satellite system and to evaluate the ability of such a system to meet future air traffic control requirements over oceanic regions. The reasons for undertaking such a program are outlined. The system itself is described and the principal parameters, which will be evaluated to assess performance and establish standards for any future satellite system, are discussed. Author

N76-23228 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Human Engineering Group.
MEASUREMENTS OF THE CONTROL CAPACITY OF ATC SYSTEM
Klaus Joachim Brauser *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 13 p refs (For availability see N76-23191 14-04)

Three methods of measuring the executive control load and control capacity have been developed and applied: (1) the measurement of the total time consumption of all executive control tasks generated by all a/c movements occurring in the area of jurisdiction of the executive controller; The time saturation condition indicates that the executive control load is approximating the saturation, i.e. the control capacity; (2) the measurement of a well defined partial work load which has been proved to be average constant part of the total workload, this partial work load being the R.T. channel load; and (3) controller questionnaires on estimates of their control capacity. Author

N76-23229 Royal Radar Establishment, Malvern (England).
A MEASURING ROD FOR ATC SYSTEMS, THE INDEX OF ORDERLINESS
H. Gent *In* AGARD Plans and Develop. for Air Traffic Systems Feb. 1976 8 p refs (For availability see N76-23191 14-04)

The index of orderliness is considered as a measuring rod for ATC systems which gives a numerical estimate of system performance at any moment of time. Its calculation requires a basis for conflict prediction and a threat weighting formula. The index is then defined as a weighted count of future conflicts. The index of orderliness/time curves produced by a collision avoidance system simulation is discussed. It is shown that such curves contain valuable information on the response time of the system. This time structure is displayed via calculation of the autocorrelation function of an index of orderliness graph. The relation of the index to a complete ATC system viewed as a hierarchy of control loops is presented and shown to be close. Finally it is suggested that indices of orderliness can be used to give a quantitative measure of the style of an ATC system, as well as of its performance. Author

N76-24200# Advisory Group for Aerospace Research and Development, Paris (France).
PRACTICAL ASPECTS OF KALMAN FILTERING IMPLEMENTATION
Mar. 1976 186 p refs
(AGARD-LS-82) Avail: NTIS HC $7.50

Application of Kalman filtering to guidance and control is investigated. Emphasis is placed on inertial navigation systems for aircraft. For individual titles, see N76-24201 through N76-24207.

N76-24201 Analytical Mechanics Associates, Inc., Mountain View, Calif.
EXPERIENCES IN THE DEVELOPMENT OF AIDED INS FOR AIRCRAFT
Stanley F. Schmidt *In its* Pract. Aspects of Kalman Filtering Implementation Mar. 1976 21 p refs (For availability see N76-24200 15-04)

Experiences in the development and test evaluation of Kalman filters in aided navigation systems for aircraft are presented. Designs for two operational systems for enroute-navigation uses and two experimental systems for terminal area and landing uses are described. The primary emphasis is on the developmental approach used with examples from the actual designs. Practical considerations are stressed rather than the mathematical formulations and theory. Details are presented on the square-root implementation of the Kalman filter which is used in three of the actual systems. Problems encountered in actual designs and the solutions selected for these problems are discussed. A brief overview of the possible future trends in aircraft navigation systems is also given. Author

N76-24202 Rockwell International Corp., Anaheim, Calif. Autonetics Group.
PRACTICAL CONSIDERATIONS IN IMPLEMENTING KALMAN FILTERS
John C. Wauer *In its* Pract. Aspects of Kalman Filtering Implementation Mar. 1976 11 p ref (For availability see N76-24200 15-04)

Techniques that are used to implement the Kalman filter for aircraft inertial navigation applications are presented. The applications include AMSA advanced development task flight test, FB-111 and F-111D aircraft avionics, at-sea alignment aboard aircraft carriers, and stationary alignment of electrostatic gyro-strapdown navigation system. Techniques used to simplify the filter model are discussed. The use of random walk and white noise error sources is described. State vector transformations are performed to simplify the filter model. Detection of failures is accomplished by testing the measurements for reasonableness. Computational techniques used in computers with fixed-point arithmetic are discussed. A flexible covariance matrix scaling technique is essential to maintain adequate resolution in a fixed-point computer. Efficient algorithms for covariance matrix and state vector extrapolation and reset are described. Author

N76-24203 Boeing Co., Seattle, Wash.
EXPERIENCES WITH THE B-1 NAVIGATION FILTER
John E. Bergeson *In its* Pract. Aspects of Kalman Filtering Implementation Mar. 1976 20 p refs (For availability see N76-24200 15-04)

Practical aspects of Kalman filter design are discussed. Topics presented include error model definition, software-implementation considerations and flight test verification. Although B-1 navigation filter experiences are emphasized, the discussion is applicable to Kalman filter design for any long-range, high-speed cruise vehicle with similar navigation sensors. Inertial-platform flow-induced phenomena and their implication for filter design are emphasized. Author

N76-24204 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
EXPERIENCES IN FLIGHT TESTING HYBRID NAVIGATION SYSTEMS
Heinz Winter *In its* Pract. Aspects of Kalman Filtering Implementation Mar. 1976 29 p refs (For availability see N76-24200 15-04)

Experiences gained in error modeling for navigation sensors, designing filters for hybrid navigation systems; sensitivity analysis of these filters; building up high precision reference systems for the flight tests; flight testing hybrid navigation systems; and evaluating the flight test results are described. The navigation accuracies of Doppler-inertial and baro-inertial systems, derived from theoretical analysis and flight tests, are given. Author

N76-24205 Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France).
DESIGN AND DEVELOPMENT OF KALMAN FILTERS NAVIGATION SYSTEMS [ETUDE ET REALISATIONS DE FILTRES DE KALMAN POUR SYSTEMES DE NAVIGATION]
Pierre Faurre and Lole Camberlein *In its* Pract. Aspects of

Kalman Filtering Implementation Mar 1976 42 p refs In FRENCH, ENGLISH summary (For availability see N76-24200 15-04)

Two systems using Kalman filtering are described. A hybrid inertial-Doppler-position reset navigator was studied and experimented from 1967 to 1972. The numerical algorithms were studied and implemented with care. The complete program was split into two computers, and the subprogram corresponding to the filter represented about 6,000 words, over 11,000 for the total. Curves are given both for theoretical performances, and for experimental flight results. Algorithms and software for optimal alignment of an inertial platform were developed and tested from 1972 to 1974. The inertial system used for the experiment is an MGC 30. The mathematical model is quite simple, and the complete alignment program uses 1,800 words. The improvement in alignment time is quite impressive: 450 seconds for optimal alignment, to be compared to 1,031 seconds for classical alignment. Author

N76-24206 Le Petit Montheion, Acigne (France)
A SHIP TRACKING SYSTEM USING A KALMAN-SCHMIDT FILTER
Claude A. Darmon *In its* Pract. Aspects of Kalman Filtering Implementation Mar. 1976 24 p refs (For availability see N76-24200 15-04)

The digital processing is described of measurements at a high accuracy ship-tracking system. The errors affecting the azimuth measurement supplied by the measuring device of the ground-based station are found to be the most critical for the overall accuracy of the system. A Kalman-Schmidt filter is selected for an optimum estimation of the azimuth speed, following comparisons with a Kalman filter and an averageing filter. The estimation of the navigation parameters is described and the position and speed accuracy achieved by the system is calculated. Moreover, various effects resulting from the data processing in a computer are analyzed and optimized: for instance choice of the computation rate for the azimuth velocity, scaling of navigation parameters, etc. Finally, the programming of the data processing in a microcomputer is described and evaluated from two standpoints: memory space requirement and computation time. The results obtained confirm the efficiency of the solutions selected. Author

N76-24207 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany).
DESIGN AND ANALYSIS OF LOW-ORDER FILTERS APPLIED TO THE ALIGNMENT OF INERTIAL PLATFORMS
Willi Kortuem *In its* Pract. Aspects of Kalman Filtering Implementation Mar 1976 26 p refs (For availability see N76-24200 15-04)

The typical steps and considerations for designing low-order efficient state estimators or Kalman filters are described. The design steps are demonstrated on a platform alignment problem where Kalman filtering is used rather than conventional procedures to reduce the time necessary for the required alignment accuracy. The work reported is based on a test series for modelling gyro-drift and accelerometer errors. The selection of a design model for the filter, the filter design itself, and a complete covariance analysis are emphasized. The main goal of the filter design is to achieve a simple, i.e., low-order, insensitive design. Author

N76-32140# Advisory Group for Aerospace Research and Development, Paris (France).
MEDIUM ACCURACY LOW COST NAVIGATION
Aug. 1976 387 p refs Presented at the AGARD Avionics Panel Tech. Meeting, Sandefjord, Norway, 8-12 Sep. 1975 (AGARD-CP-176) Avail: NTIS HC $10.75

A total of 29 papers were presented dealing with medium accuracy low cost navigation systems for aircraft and other vehicles, by considering all the options available, so as to determine, if possible, the optimum cost/accuracy mix. These papers were divided into the following five areas: requirements and specifications, radio techniques, non-radio techniques, appropriate navigation system components, and total system considerations. For individual titles, see N76-32149 through N76-32176. Author

N76-32149 Advisory Group for Aerospace Research and Development, Paris (France)
HIGHLIGHTS OF KEY CHARACTERISTICS CONSIDERED FUNDAMENTAL TO ANY NAVIGATION SYSTEM THAT MIGHT BE INTRODUCED INTO BRITISH ARMY AIRCRAFT
A. C. D. Watts (Brit. Army Air Corps) *In its* Medium Accuracy Low Cost Navigation Aug. 1976 5 p (For availability see N76-32148 23-04)

Operational factors influencing the requirement for army battlefield helicopter navigation systems are discussed and the needs of the operating crew are outlined. These considerations lead to the conclusion that a low cost, light weight, accurate, self-contained navigation system is required. Author

N76-32150 Royal Navy, London (England).
A SURVEY OF LOW COST SELF CONTAINED NAVIGATION SYSTEMS AND THEIR ACCURACIES
J. A. Tayler *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 5 p (For availability see N76-32148 23-04)

A definition of medium accuracy and low cost is first attempted, and it is noted that air-data systems do not achieve medium accuracy and inertial systems do not yet fall within the definition of low cost. Some simple truths about self contained systems are highlighted. The level of assurance at which navigation accuracies are quoted should be standardized. Doppler/compass accuracy is dictated by heading accuracy overland and by surface effects over water. The basic navigation information required by the pilot is whether he should steer left or right. Investigation is required on how best to integrate navigation systems with low light sensors. Author

N76-32151 Ferranti Ltd., Edinburgh (Scotland).
THE CONCEPTION OF LOW COST NAVIGATION SYSTEMS: ART OR SCIENCE?
W. H. McKinlay *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 7 p (For availability see N76-32148 23-04)

Some of the factors involved in arriving at the requirement for low cost navigation systems were pointed out. It turns out that while improvements in technology tend to reduce the costs of conventional systems, a true low cost system is probably one which is capable of extending the facilities offered by it to applications in which earlier solutions would have been declared uneconomic. The initial adoption of many of today's navigation techniques has been a result of the pressures to apply a new technology. It is suggested that in the low cost area, the corresponding pressures exerted by the market are much more significant. Most of today's devices meet traditional requirements and there may be alternative solutions if the sources of information and the techniques available to handle them are related to the minimum requirements of the operator. The closest and fastest possible process of iteration between operator and system designer is necessary. Author

N76-32152 Aeroplane and Armament Experimental Establishment, Boscombe Down (England). Navigation and Radio Div.
MEDIUM ACCURACY LOW COST NAVIGATION SYSTEMS FOR HELICOPTERS
T. J. Penfold *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 7 p (For availability see N76-32148 23-04)

All the factors leading to a choice of a future navigation system for military helicopters were examined. The examination considers the past, the basic requirements for the navigation system, the helicopter environment, service requirement, possible systems, cost and standardization. It is concluded that a Doppler/compass system could meet the requirements for a medium accuracy/low cost system but that the requirement needs further definition especially in the areas of operational requirement and costs. It is hoped that in the future some measure of standardization be achieved, such an aim will need to be recognised and receive the goodwill of all interested parties. Author

N76-32153 Hawker Siddeley Aviation Ltd., Brough (England).
SOME NAVIGATIONAL CONCEPTS FOR REMOTELY PILOTED VEHICLES
J. W. Lyons, J. D. Bannister, and J. G. Brown *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 15 p refs (For availability see N76-32148 23-04)

Methods by which the navigation function for Remotely Piloted Vehicles (RPVs) can be achieved without the need for complex specialized navigation equipment were discussed. The objective is to make use of equipment normally carried for RPV operation to supplement a simple dead reckoning navigation system. The additional processing is carried out at the control center where restrictions on equipment size and cost are not so prohibitive.

Techniques varying from the use of the data link to provide range-bearing navigation to map matching using reconnaissance sensors or a forward looking sensor picture were discussed. Use can also be made of an on-board laser to provide range-to-terrain measurements which, when correlated with a computer stored map, enables the RPV position to be continuously updated. Results of simulation studies carried out to validate the techniques and provide an estimate of the accuracies are presented. Author

N76-32154 Rockwell International Corp., Anaheim, Calif.
MICRO-NAVIGATOR (MICRON)
Jerry A. Schwarz *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 14 p refs Sponsored by the AF (For availability see N76-32148 23-04)

The Micron strapdown inertial navigation system, developed to be a low cost medium accuracy (one nautical mile per hour radial position error CEP rate) navigation system for future aircraft/missiles requiring medium accuracy, was described. The heart of the Micron system is the micro-electrostatic gyro, which consists of a one centimeter diameter spherical rotor suspended electrostatically by eight capacitor plates. The rotor is untorqued, thus avoiding the accuracy degradation and reliability degradation from gyro torquing electronics. The gyro is used in a strapdown mechanization and utilizes a unique mass-unbalance modulation technique for obtaining whole angle readout over all attitude angles. Two breadboard Micron systems have been fabricated and tested. The test results indicate better performance than the one nautical mile/hr performance goal under all environments tested (laboratory, vibration, shock, cold soak, scorsby, van, and flight test). The prototype Micron system is currently being designed, and a full evaluation test program is planned. Author

N76-32155 Draper (Charles Stark) Lab., Inc., Cambridge, Mass.
DIGITAL PHASE PROCESSING FOR LOW-COST OMEGA RECEIVERS
Duncan B. Cox, Jr., William H. Lee, William M. Stonestreet, and Edwin V. Harrington, Jr. (AFAL) *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 16 p refs (For availability see N76-32148 23-04)
(Contract F33615-72-C-1335)

The application of the serial digital phase filter (SDPF) to Omega receivers is explored. It is shown that the internal functions of an Omega receiver can be organized to take advantage of one or more SDPF's used in combination with an LSI microprocessor. The SDPF's can also be used to reduce the load on the microprocessor by reducing the bandwidth of the phase data being presented to it. The SDPF's can also accomplish demodulation and analog-to-digital conversion, thereby eliminating the need for special circuitry to perform these functions. Because of the reduction in data bandwidth, there is an increase in efficiency and productivity of the microprocessor. The processing efficiency of the entire receiver is then more closely maximized with respect to hardware and software cost. The design approach is applicable to a bare-bones receiver, which would incorporate the most elementary and inexpensive micoprocessor or no microprocessor at all. Author

N76-32156 ITT Avionics, Nutley, N.J.
LOW COST NAVIGATION PROCESSING FOR LORAN-C AND OMEGA
James F. DeLorme and Arthur R. Tuppen *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 17 p (For availability see N76-32148 23-04)

A technology feasibility demonstration was performed to determine the impact of advances in MOS/LSI semiconductor developments on performance and cost of radio navigation equipment, in particular, Loran C performance and cost objectives were demonstrated. This demonstration has clearly shown that the performance requirements for both austere and sophisticated users can be satisfied. Advancement in semiconductor technology has provided MOS/LSI and Schottky Bi-Polar/LSI chip sets, central processor units and compatible semiconductor memories, whose architecture is compatible with the requirements for navigation processing. This technology has been applied to a Loran C sensor processor and a low cost airborne Omega Navigator. The digital processing, micro-computer configuration, resultant performance and cost projections for Loran C applications are described. The results of the mechanization for these systems are used to configure a combined Loran C or Omega Navigator, including an assessment of performance parameters, physical characteristics and costs projections. Author

N76-32157 Naval Electronics Lab. Center, San Diego, Calif.
A NAVIGATION MONITOR FOR VLF SIGNALS
E. R. Swanson *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 7 p refs (For availability see N76-32148 23-04)

An overview of the need for and the design of a VLF navigation monitor is presented. Fundamental associated with various VLF navigational techniques are discussed briefly. 2-n.mile accuracy or better is assumed typical. Safe operation within existing airways is normally possible, but protection against propagationally induced blunders should be provided by a navigation monitor. The monitor can be designed so as to provide not only disturbance warning but also disturbance prediction. The monitor can also assist in preflight. Author

N76-32158 Standard Electrik Lorenz A.G., Stuttgart (West Germany)
SOME CONSIDERATIONS ON POSSIBLE NEW VHF LOW COST RADIO NAVIGATION AIDS
M. Bruhm *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 16 p refs (For availability see N76-32148 23-04)

New possibilities for low cost navigation aids for use in allocated VHF communication frequency bands are described. Conventional VHF radio sets are to be useable also for navigation by adding a simple attachment. Three system proposals are presented. (1) The ship navigation system SNS is to use shore stations employing either amplitude or frequency modulation. It would provide 0.1 deg error azimuth within a sector of e.g. 10 deg and 3.5 deg error omnirange azimuth. (2) The ship identification and location system SILOS is to employ a chain of shore based VHF DF stations which determine positions of ships by triangulating their communications transmissions. (3) The hyperbolic navigation system HNS for tactical applications is to use a chain of VHF stations transmitting synchronized modulation frequencies used for navigation. The coordinates of the highly mobile stations can be transmitted to the users continously in a coded form. Expected accuracy is 50 m CEP. Author

N76-32159 Messerschmidt-Boelkow G.m.b.H., Munich (West Germany).
CONTINUOUS NAVIGATION UPDATING METHOD BY MEANS OF AREA CORRELATION
A. Hessal and W. Eckl *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 18 p refs (For availability see N76-32148 23-04)

An autonomous automatic updating method is considered for the improvement of navigation accuracy. This is based upon the correlation between an instantaneously taken picture and a stored scene of the area of interest. The displacement between the actual position and the indicated position (taken from the simple basic system) is derived from the maximum crosscorrelation of the two pictures. Results of different correlation-algorithms applied to microwave images of different sizes and scene complexity (grey values) are shown. Topics for further research work necessary before flight testing such a system are outlined. Author

N76-32160 Wansbrough-White and Co. Ltd., London (England).
GRAPHIC AREA NAVIGATION WITH VOR/VOR, AND VOR/DME INPUTS
G. Wansbrough-White *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 17 p (For availability see N76-32148 23-04)

The following conclusions relative to some aspects of graphic area navigation were given and discussed. (1) area navigation offers advantages of safety and economy to both airlines and general aviation, with advantages to air traffic control. (2) area navigation must depend on conventional DR methods, with and without radio, in the low cost area of general aviation. There are pilot/navigator problems, and one development has been the airborne course line computer ('ghost VOR'). (3) another development is Graphic Area Navigation (GRNav), which uses standard VOR, DME (and other inputs), and is a computer based cartesian system that is self checking and geographically oriented. (4) GRNav has airways and marine applications. (5) GRNav has been shown to be a practical, simple and cheap navigation system, and is now subject to scientific evaluation in the UK and the USA. Author

N76-32161 Office National d'Etudes et de Recherches Aerospatiales, Paris (France)
INEXPENSIVE SYSTEM OF MULTIPLE BEACON LOCALIZATION FOR HELICOPTERS

Jacques Dorey *In* AGARD Medium Accuracy Low Cost Navigation Aug 1976 9 p refs In FRENCH, ENGLISH summary (For availability see N76-32148 23-04)

Two systems of angular (elevation and azimuth) localization of multiple beacons, for application to helicopters, are presented: 2 system making use of the helicopter blades as receiving dipole support, in association with UHF emitting beacons. a system making use of an independent rotating arm as dipole support, placed under the helicopter fuselage, in association with microwave emitting beacons. The first system is analyzed in detail, limitations of various kinds are emphasized, in particular those concerning the working wavelength. The data processing devices leading to the electromagnetic imagery of the beacon angular distribution are described. The second system, less applicable to helicopter, is presented and compared to the first one as regards its performance. Author

N76-32162 Naval Weapons Center, China Lake, Calif.
THE APPLICATION OF RING LASER GYRO TECHNOLOGY TO LOW-COST INERTIAL NAVIGATION
William F Ball *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 16 p (For availability see N76-32148 23-04)

The Advanced Tactical Inertial Guidance System (ATIGS), a strapdown system using Ring Laser Gyros (RLGs), low-cost accelerometers, and large-scale integrated circuitry computer technology, was described. Although primarily developed for a long-range tactical missile application, the system mechanization that has evolved is directly applicable to aircraft inertial navigation. The first ATIGS unit entered captive flight evaluations in a pod on a A-7E aircraft on 20 June 1974. Results achieved during this first series of tests showed approximately 4 nmi/hr radial error. In March 1975, ATIGS was flight-tested as an aircraft navigator, with ground self-alignment and with flight times of 3 to 4 hours. In these tests an average circular error probable radial error of 2.16 nmi/hr was obtained. The Ring Laser Gyro RLG appears to offer a truly low-cost alternative for future aircraft inertial navigation based on the results of the ATIGS program. Further ATIGS results have indicated that excellent long-term stability can be expected from these unconventional instruments. These factors indicate that, if properly integrated with low-cost accelerometers and appropriate low-cost digital computers, a medium-accuracy, low cost inertial navigator is possible. Author

N76-32163 Singer Co., Little Falls, N.J. Aerospace and Marine Systems Div.
INERTIAL NAVIGATOR FOR COMMERCIAL AIRLINES
Julius Weiss *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 11 p refs (For availability see N76-32148 23-04)

The GAMMA Advanced Inertial Navigation System is an outgrowth of the SKN-2400 family of military inertial navigation equipment, and hence represents the present state of the art in advanced electronic packaging. The development of the GAMMA Advanced Inertial Navigation System, its physical and functional description and its impact, specifically on smaller general aviation aircraft, are described. The development of the system was completed after many months of qualification and flight testing under the aegis of the Federal Aviation Administration (FAA). The details of these tests and their results are provided. Author

N76-32164 Teledyne Ryan Aeronautical Co., San Diego, Calif.
LIGHTWEIGHT DOPPLER NAVIGATION SYSTEM
Robert E. Chapman *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 22 p (For availability see N76-32148 23-04)

A self contained, low cost, lightweight, accurate, and reliable navigation system for military helicopters was designed. The system consists of a Doppler Radar Velocity Sensor (DRVS) and a Computer Display Unit (CDU) with a combined mean time difference between failures of more than a 1000 hours, and a .38 percent circular error probability. The capability of the system to be integrated with radio-aided navigation systems such as LORAN and OMEGA is described. An important feature of the system is the capability of rapidly isolating failures to a replaceable module, and ease of replacement of the 'failed' module. The use of a special modulation form in the DRVS to develop a coherent local oscillator is described. Also described is an IMPATT solid state transmitter, time duplexed travelling wave array antenna, and digital frequency tracker. Use of a single chip microprocessor in the CDU is described; emphasis on the human factors engineering aspects of the man-machine interface. Results indicate that system meets the requirements that it was designed for. J.R.T

N76-32165 Singer Co., Wayne, N.J.
DOPPLER RADARS FOR LOW-COST, MEDIUM ACCURACY NAVIGATION
Heinz Buell *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 10 p (For availability see N76-32148 23-04)

A lightweight Doppler Navigation System (LDNS) was designed which weighs under 30 pounds and has a predicted mean time difference between failures of over 1400 hours and a predicted navigation accuracy of 1.3% of distance travelled with 1% (1 sigma) heading reference. The system is designed for use in military helicopters. The LDNS consists of four units: (1) Doppler radar velocity sensor, consisting of a receiver transmitter antenna unit and signal data converter unit, (2) control display unit, and (3) steering hover indicator unit. Diagrams illustrating each unit are shown. Author

N76-32166 Ferranti Ltd., Edinburgh (Scotland)
TWO NEW SENSORS AND THEIR POSSIBILITIES IN LOW COST HEADING REFERENCE SYSTEMS
W. H. McKinlay, A. Lisbing, and K. R. Brown *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 7 p (For availability see N76-32148 23-04)

The requirement for heading in a navigation system, both as primary data and for the pointing of certain sensors is discussed. The airborne applications of heading for fixed and rotating wing aircraft are examined. It is pointed out that developments in gyroscopes, resulting from inertial technology, now make it possible to provide a heading memory with a very low drift. But this is not usable unless the device can first be referenced to true North, which introduces the desirability of gyro-compassing. This, in turn, leads to certain instrument requirements. Two new sensors suitable for use on gimballed platforms but essentially of simple construction and relatively low cost. They are Double Integrating Angular Accelerometer and a Free Rotor Gyroscope, the Oscillogyro. Possible system configurations are indicated, and conclusions are drawn as to areas in which these techniques can most profitably be applied. Author

N76-32167 Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (West Germany)
THE FNA 615: A SELF CONTAINED LOW-COST NAVIGATION SYSTEM FOR GROUND-VEHICLES
U. K. Krogmann *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 18 p refs (For availability see N76-32148 23-04)

The Fahrzeug-Navigations-Anlage system's application to a German artillery observation tank is examined. Required performance data and general requirements were met utilizing proven hardware. To meet the required very short initialization time a Meridian-Gyro was used for aligning the heading reference unit of the system. Built-in test hardware and software were incorporated to achieve high error detection and localization probability without the need for external test-equipment. Because the system is selfcontained it is thus insensitive regarding jamming. In its basic configuration it is essentially a low cost system and because of its modular design it can be modified and augmented easily. Author

N76-32168 Marconi-Elliott Avionic Systems Ltd., Rochester (England). Airport Works
HELICOPTER AIR DATA MEASUREMENT
C. J. Frost *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 13 p (For availability see N76-32148 23-04)

A helicopter air data sensor system was developed which can provide accurate air data including forward, aftward, sideways and vertical airspeed information for flight control and navigation purposes. The helicopter air data system consists of the following equipment: (1) a multi-axis swivelling pitot static probe, (2) a digital air data computer, and (3) optional displays of altitude, altitude rate, calibrated airspeed, sideslip angle, combined torque and maximum torque, payload margin, and air temperature. Present helicopter air data sensors suffer from gross errors at flight velocities below 40 knots. The causes of these errors are the inability of airborne sensors to detect low air velocities or dynamic pressures, and the corruption of the pressure-flow field around the helicopter by the rotor induced flow. Photographs of the installed air data sensor system in a helicopter are provided. Author

N76-32169 Sperry Gyroscope Co. Ltd., Bracknell (England).
LOW COST SELF CONTAINED SOLUTIONS TO THE NAVIGATION PROBLEM IN ROTARY AND FIXED WING AIRCRAFT

E Brewin (Decca Co., London), T S Kitching (Decca Co., London), and D L Wright *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 11 p (For availability see N76-32148 23-04)

Defense budget limitations often make it necessary for the operational staff of many air forces to review their avionics system requirements. Only limited reliance can be placed on the use of ground based radio aids while the high cost pure inertial solution far from satisfies the multiplicity of military aircraft roles with which the operational staffs have to contend. A Modular Building Block Concept for self contained systems is proposed which can be tailored to provide the required facilities and performance to meet a specific role while retaining a high degree of logistic commonality between differing aircraft types, and at a low cost. The proposed modular solution, already a fact with hardware in production and going into service is based upon the use of the following hardware elements: (1) a two/three axis velocity sensor, (2) a two/three axis heading/attitude sensor, and (3) a digital navigation computer. The possibility of coupling of these systems to a range of weapon delivery equipment is suggested. Author

N76-32170 Rockwell International Corp., Anaheim, Calif.
HAND HELD CALCULATOR TECHNOLOGY APPLIED TO AN ADVANCED LOW COST OMEGA RECEIVER
Bernard N. Gaon *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 9 p refs (For availability see N76-32148 23-04)

Recent technological advances in metal oxide semiconductor circuitry have resulted in mass production of commercial calculators and with it the availability of low cost microprocessors. These devices, although limited in computational capability, can be successfully applied to the development of a low cost Omega navigation set. The basic desirable features of an airborne Omega receiver were studied, and the required functions identified. A simplified technique to achieve better accuracy was identified. The ways in which microprocessors can be utilized to arrive at a low cost, fully automatic composite airborne system are outlined. The receiver and processor portions of the Omega set are detailed. Prototype hardware that has been flight tested is described, and performance data are presented. The basic function of the Omega set is to determine and keep track of present position by receiving and processing the Omega very low frequency transmissions. Photographs of the control and display units of the Omega set are provided. Author

N76-32171 Marconi-Elliot Avionic Systems Ltd., Basildon (England).
THE APPLICATION OF MINI-PROCESSORS TO NAVIGATION EQUIPMENT
M. R. Hopper *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 11 p (For availability see N76-32148 23-04)

Modern technology has allowed the production of a very small miniature processor using integrated circuit techniques. Because of it's simplicity and size, the same processor can be used variously, to process information from a variety of different inputs, to provide information to drive various output peripherals, or to process information within a dedicated equipment. The design requirements for, and the operation of such a mini-processor are considered. It's uses are illustrated by it's inclusion in a piece of dedicated navigation equipment (TACAN), where it is used to solve a particular set of data. Also it is considered in a family of area navigation systems, where it's flexibility is illustrated by the varying requirements of such systems. Photographs of display devices, digital computers and other components used are shown. Author

N76-32172 National Aerospace Lab., Amsterdam (Netherlands).
A MATHEMATICAL MODEL FOR THE ANALYSIS OF NAVIGATION SYSTEM ERRORS OF MODERN FIGHTER AIRCRAFT
F. J. Abbink and N. VanDriel *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 11 p refs (For availability see N76-32148 23-04)

An error analysis of an inertial navigation system by computerized simulation is presented. In order to compute the standard deviations of the navigation system errors, the matrix equation representing the set of linearized differential equations for the navigation system error behavior was transformed into an evolution equation for the covariance matrix. The navigation system error model took into account, alignment, navigation along a specific flight profile and updating. Position error distributions were calculated and analyzed for different flight profiles, with and without updating for a specific type of inertial navigation system. Author

N76-32173 ITT Avionics, Nutley, N.J.
MEDIUM ACCURACY, LOW COST NAVIGATION: LORAN-C VERSUS THE ALTERNATIVES
J. P. VanEtten *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 24 p refs (For availability see N76-32148 23-04)

The fundamentals of the Loran C system are compared with the fundamentals of alternative navigation systems (Omega, Decca, Loran D). The operational merit, the universal applicability, and the economy of Loran C are discussed. The use of Loran C as a low cost navigation system on a national and international level is examined. The use of Loran C in military, nonmilitary, and commercial air service is also considered. Radio frequencies and bandwidth used by Loran C and other navigation systems are cited. Also provided are block diagrams of a generalized radio navigation receiver. Author

N76-32174 Air Force Avionics Lab., Wright-Patterson AFB, Ohio.
SYSTEM APPROACH TO PRACTICAL NAVIGATION
Jin W. Chin and Russell E. Weaver, Jr. (Northrop Electronics Div.) *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 14 p refs (For availability see N76-32148 23-04)

A background introduction is presented of various navigation sensors discussing their characteristics and limitations. The forthcoming satellite navigation system, NAVSTAR Global Positioning System (GPS), will be exploited as an ultimate capability of providing L Band signals from which position, velocity, and time can be determined. This dual capability will simplify the implementation of integrated systems. A typical medium accuracy system is described. The widely accepted inclusion of an inertial subsystem will be emphasized on the merit of a multifunctional capability beyond that for navigation. Roles in flight control, instrumentation, and augmentation of mission avionics are recognized. The strapdown mechanization and associated instruments are introduced to discuss a potential alternative to the conventional all attitude, gimballed platform. These advances provide the attributes to accomplish low cost designs of medium accuracy navigation systems. Integration of available sensor data to provide the required navigation performance is considered the most effective method of attaining low cost equipment. Modularity expressed in the design will provide flexibility and adaptability to a broad class of users. A total performance, costs of ownership, approach is used to verify system design and selection. Author

N76-32175 Decca Navigator Co. Ltd., Chessington (England). SSM Div.
INTEGRATED DOPPLER/HEADING REFERENCE/RADIO NAVIGATION
D. Halliwell *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 9 p (For availability see N76-32148 23-04)

Medium accuracy low cost navigation systems provide flexibility of operation with the minimum of limitations, while retaining the major benefits of simplicity of concept and of design. A simple system concept based on currently available equipments is outlined. A DR system based on a currently available gyromagnetic heading reference and a fixed-aerial Doppler radar is assessed as capable of two sigma accuracy in the range 1% to 3% of distance flown. For operations requiring consistent accuracy over long periods of flight or accurate relative navigation the DR system is supplemented by a simple Omega receiver front-end, the signals being processed in the DR system computer. The system is capable of providing medium to high accuracy navigation at low total cost for a wide range of helicopter and aircraft operational requirements. Author

N76-32176 Computing Devices of Canada, Ltd., Ottawa (Ontario).
AN OPTIMALLY INTEGRATED PROJECTED MAP NAVIGATION SYSTEM
D. B. Reid, R. K. Harman, and D. J. Frame *In* AGARD Medium Accuracy Low Cost Navigation Aug. 1976 31 p refs (For availability see N76-32148 23-04)

A unique integrated tactical navigation system (ITNS) concept for helicopter applications is described. This concept, which could be extended for application in high performance tactical aircraft, is based on the projected map system, PMS 5-6, currently in production. The primary navigation unit of the ITNS is the Doppler dead reckoning (DR) subsystem which uses simple directional

and vertical gyros as heading and attitude sensors. Auxiliary navigation data are supplied by a projected map display (PMD) and a triad of magnetometers strapped to the airframe. The PMD displays aircraft position, track and bearing to destination pictorially, providing excellent pilot orientation and position fixing capability. The magnetic sensor measures three components of the earth's field, from which additional heading and attitude information are derived. A digital Kalman filtering algorithm is implemented to estimate system errors from DR, PMD and strapdown magnetic data. The error estimates are fed back to correct DR position and null sensor errors, resulting in a fully integrated system which provides excellent performance at low cost. Simulation results indicate that system accuracy without position fixes will be better than 2 per cent of distance travelled (95 per cent confidence). Author

X75-70673 Advisory Group for Aeronautical Research and Development, Paris (France).
TECHNICAL EVALUATION REPORT ON THE GUIDANCE AND CONTROL PANEL SYMPOSIUM ON PRECISION WEAPON DELIVERY SYSTEMS EMS
C. Tom Money Dec. 1973 1 p Conf. held at Eglin AFB, Fla., Jun. 1973
(AGARD-AR-74) NATO Classified report

NOTICE: Available to U.S. Government Agencies and Their Contractors.

A technical evaluation of the conference is presented. Symposia papers and discussion are synthesized in order to identify the critical issues as well as establish a conference consensus. Author

X75-70674 Advisory Group for Aeronautical Research and Development, Paris (France)
PRECISION WEAPON DELIVERY SYSTEMS
Sep. 1973 1 p
(AGARD-CP-142) NATO--Classified report

NOTICE: Available to U.S. Government Agencies and Their Contractors

A symposium was held at Eglin AFB, Florida which covered the following main topics: (1) system development techniques, (2) navigation and control technology, (3) terminal phase technology, (4) precision weapon concepts, and (5) system evaluation, and research and development program needs. Author

X77-72036 Advisory Group for Aerospace Research and Development, Paris (France).
USE OF PRECISION POSITIONING SYSTEMS BY NATO, VOLUME 1
Jul. 1976 48 p
(AGARD-AR-88-Vol-1) Avail: Advisory Group for Aerospace Research and Development, Paris, France NATO-Classified report

NOTICE: Available to U.S. Government Agencies.

An evaluation of the potential applications within NATO of a precision positioning system (PPS) - as exemplified by the U.S. NAVSTAR Global Positioning System - is presented. Special emphasis is placed on a qualitative and quantitative evaluation of the impact of increased position information accuracy on the tactical air attack capability of NATO in Europe in the 1980's and beyond. The study concludes that a secure and very precise PPS is feasible. With such a system, the all-weather attack capability on quasi stationary targets is so promising that continuing operational analysis should be performed. Author

X77-72042 Advisory Group for Aerospace Research and Development, Paris (France).
NIGHT VISION DEVICES FOR FAST COMBAT AIRCRAFT
[1975] 624 p
(AGARD-R-73; AASC-Study-5) Avail: Advisory Group for Aerospace Research and Development, Paris, France
NATO-Classified report

NOTICE: Available to U.S. Government Agencies.

The application of night vision devices to fast combat aircraft operating at low altitudes is considered from the standpoint of synthesizing and analyzing overall systems for attacking typical ground targets. The effects of terrain screening, weather, human factors and display problems, target characteristics with the main emphasis on vehicles, navigation accuracy, and aircraft attack dynamics for the case of retarded bombs are examined. Shortfall in knowledge in key areas is highlighted, principally the importance of atmospheric attenuation on FLIR performance, the degradation in human operator performance in turbulent conditions at low altitudes, and the interaction of sensor/display parameters with severe search time constraints. The impact of a threat environment was deliberately excluded. Author

05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology. For related information see also *18 Spacecraft Design, Testing and Performance* and *39 Structural Mechanics*.

N74-18682# Advisory Group for Aerospace Research and Development, Paris (France).
AN OVERVIEW OF US ARMY HELICOPTER STRUCTURES RELIABILITY AND MAINTAINABILITY
Thomas L. House (Army Air Mobility R and D Lab., Fort Eustis, Va.) Jan. 1974 19 p refs Presented at 36th Meeting of the Structures and Mater. Panel (SMP), Milan, 2-5 Apr. 1973
(AGARD-R-613) Avail: NTIS HC $4.00

Approximately 25 percent of all U. S. Army helicopter failures and field maintenance man hours are related to structures. Externally induced damage is the primary cause of many failures, and it is the essential reliability and maintainability consideration in the selection of rotor blade and transparency designs. With the exception of rotor blades, most structural failures are normally considered as maintenance downtime sensitive as opposed to a cost problem. Greatly improved design and test documents coupled with lessons learned appear to be the most responsive approach to gaining significant structural improvements. Helicopter vibration reduction can produce a major reduction in secondary structural failure and maintenance rates. Author

N74-20639# Advisory Group for Aerospace Research and Development, Paris (France).
TECHNICAL EVALUATION REPORT ON AGARD FLIGHT MECHANICS PANEL SYMPOSIUM ON FLIGHT IN TURBULENCE
W. S. Aiken, Jr. (NASA), Washington) and D. Lean (Roy. Aircraft Estab., Redford, Engl.) Feb. 1974 10 p Conf. held at Woburn Abbey, Engl., 14-16 May 1973
(AGARD-AR-57) Avail: NTIS HC $4.00

The proceedings of a conference on the effects of atmospheric turbulence on flight characteristics are presented. The subjects discussed include the following: (1) turbulent environment, (2) operational problems, (3) design criteria, and (4) artificial aids for flight improvement. One conclusion is that there is a critical need for cross correlation measurements between various low atmosphere turbulence components. Additional discussion were held concerning wake vortex research for wake vortex detection and avoidance. Author

N74-26445# Advisory Group for Aerospace Research and Development, Paris (France).
PREDICTION METHODS FOR AIRCRAFT AERODYNAMIC CHARACTERISTICS
May 1974 349 p refs
(AGARD-LS-67) Avail: NTIS HC $20.50

The proceedings of a conference on methods of predicting aircraft performance are presented. Emphasis was placed on predicting aircraft range and radius, airfield and maneuver performance, and aerodynamic characteristics. Combat and transport aircraft were considered over conditions ranging from extremely low speeds through subsonic/transonic to supersonic speeds. Aircraft lift and drag estimation methods were analyzed along with related aerodynamic optimization techniques. Practical methods for wing/body aerodynamic design and boundary layer flow treatments were considered. The prediction and implications of special aerodynamic characteristics associated with engine installation and external store effects are examined, relevant stability/control needs are reviewed, and some aircraft noise restraints on aerodynamic design are investigated. For individual titles, see N74-26446 through N74-26455.

N74-26446 Royal Aircraft Establishment, Farnborough (England).
GENERAL TECHNICAL INFORMATION
John Williams *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 5 p (For availability see N74-26445 16-02)

Prediction and optimization methods for determining aircraft performance are discussed. The major deficiencies in the state of knowledge on aerodynamic characteristics are assessed. Recommendations for improvement in theoretical treatments, ground based testing facilities, and flight testing techniques are submitted. The overall technical constraints on aircraft performance prediction are defined. Specific technical lectures on the subjects of aircraft performance, wing aerodynamic design, engine installation aerodynamics, external store aerodynamics, and stability and control implications are identified. Author

N74-26447 McDonnell-Douglas Corp., Long Beach, Calif. Aerodynamics Subdivision.
AERODYNAMIC PREDICTION METHODS FOR AIRCRAFT AT LOW SPEEDS WITH MECHANICAL HIGH LIFT DEVICES
J. G. Callaghan *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 52 p refs (For availability see N74-26445 16-02)

A survey of present methodology used for the estimation of low speed aerodynamic characteristics of aircraft with mechanical high lift systems is presented. While this methodology is applicable to a large variety of aircraft with unpowered high lift systems, the emphasis is on transport type aircraft. Prediction methods empirically derived from experimental data, as well as more sophisticated theoretical methods are discussed. Correlations of calculated results with both wind tunnel and flight measurements are presented. To place the current state of the art of methodology into proper perspective, a critical review of areas of both strength and weakness is presented, with emphasis on future requirements. Within this context, the particular need for methods to estimate the high lift characteristics of aircraft with thin, highly swept, low aspect ratio wings, such as supersonic transport configurations are reviewed. Author

N74-26448 Royal Aircraft Establishment, Bedford (England).
A REVIEW OF THE LOW SPEED AERODYNAMIC CHARACTERISTICS OF AIRCRAFT WITH POWERED LIFT SYSTEMS
D. N. Foster *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 43 p refs (For availability see N74-26445 16-02)

The aerodynamic characteristics of a number of different configurations of fixed-wing aircraft with powered lift systems are discussed. Methods for predicting the aerodynamic characteristics are developed. Consideration is given to aircraft employing boundary layer control, based on jet flaps with internal blowing, external blowing from underwing and overwing engines, and augmentor systems. Spanwise blowing and other specialized techniques are examined. Aerodynamic characteristics in ground effect, as well as in free air, are reported. Some aspects of the noise problems which are directly related to the particular lowered lift system under discussion are considered. Author

N74-26449 Boeing Commerical Airplane Co., Renton, Wash.
AIRCRAFT LIFT AND DRAG PREDICTION AND MEASUREMENT
G. M. Bowes *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 44 p refs (For availability see N74-26445 16-02)

Techniques for predicting and measuring lift and drag relationships for subsonic cruise flight are described. The status of this drag methodology is reviewed. Recent presentations on the subject are referenced and incorporated into an overall summary describing current capabilities for developing the basis of aircraft performance predictions. The role of the wind tunnel in airplane design and development is discussed, and the importance of flight test measurements of specific range and engine parameters is emphasized. Theoretical developments for three-dimensional design and lift/drag predictions are described. The accuracy with which the drag levels of a new design can be determined is examined. Examples of specialized wind tunnel and flight investigations into the airflow and pressures on localized portions of an airplane are presented. Author

N74-26450 British Aircraft Corp., Filton (England).
PREDICTION OF SUPERSONIC AIRCRAFT AERODYNAMIC CHARACTERISTICS
C. S. Leyman and T. Markham *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 52 p refs (For availability see N74-26445 16-02)

The methods currently available for the prediction of the aerodynamic characteristics of supersonic aircraft as they effect performance are reviewed. The problems of supersonic aircraft

design are illustrated by consideration of hypothetical transport and flighter aircraft. The methods used to predict the performance of the Concorde aircraft are stressed. The aerodynamic principles which make supersonic aircraft different from subsonic designs are analyzed. The accuracy and suitability of design methods for various stages of design are examined. The state of the art for estimating parisitic drag and thrust loss due to air leakage is described. Problems of estimating the installed powerplant performance are included. Author

N74-26451 National Aerospace Lab., Amsterdam (Netherlands).
APPRAISAL OF WING AERODYNAMIC DESIGN METHODS FOR SUBSONIC FLIGHT SPEED
W. Loeve *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 41 p refs (For availability see N74-26445 16-02)

For a number of direct calculation methods for the prediction of flows around wings at subsonic speed, the basic assumptions are discussed. This forms the basis for the applicability of the methods. Comparison of calculated pressure distributions with results from wind-tunnel tests serve to illustrate this for three-dimensional wings and for the limiting case of plane flows around airfoils. Attention is paid to the use of inverse methods. In this context the use of hodograph methods for the design of aerofoils with transonic shockfree flow is discussed. Author

N74-26452 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Aerodynamik.
BOUNDARY LAYER CALCULATION METHODS AND APPLICATION TO AERODYNAMIC PROBLEMS
J. Steinheuer *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 48 p refs (For availability see N74-26445 16-02)

Methods for analyzing boundary layer flow characteristics and application to predicting aircraft performance are discussed. Mathematical models for a steady two-dimensional incompressible boundary layer are developed. The structures of the various types of boundary layers are analyzed. Tables of data are included to show the numerical solution of partial differential equations for different flow conditions. Examples of boundary layer calculations are included for cases of compressible boundary layers, three dimensional boundary layers, and turbulent boundary layers. Airfoils are examined for conditions of attached flow over a single airfoil, attached flow over an airfoil with a slotted flap, and airfoil flow with separation. Methods for predicting buffet boundaries for a wing in transonic flow are reported. Author

N74-26453 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
ENGINE INSTALLATION AERODYNAMICS
J. Laynaert *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 22 p refs (For availability see N74-26445 16-02)

Aspects of engine installation aerodynamics are considered to include theoretical design, optimization of the engine installation, and experimental study. Air intake, afterbody, and engine/aircraft integration problems are analyzed for high subsonic and supersonic aircraft. High speed and low speed performance are discussed. Comments are made on variable geometry devices. Special attention is given to the significance of the various propulsion and drag balance terms. Author

N74-26454 Aircraft Research Association, Ltd., Bedford (England).
EXTERNAL STORE AERODYNAMICS FOR AIRCRAFT PERFORMANCE PREDICTION
J. B. Berry *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 34 p refs (For availability see N74-26445 16-02)

Some effects of external stores on the aerodynamic characteristics of aircraft and in particular the incremental drag due to various types of store installation are described. Examples of drag increments for single and multiple store assemblies installed underwing and underfuselage and the effects of C sub L and Mach number up to high subsonic speeds, illustrate some of the interference features in the aircraft-store flow field which contribute to high or low drag. The prospects for incremental drag prediction, the possible use of calculated or measured flow field data, empirical methods and flight-tunnel comparisons are discussed. Approximate empirical estimation procedures for simple underwing and underfuselage store installations are described. It is suggested that for multiple store assemblies, opportunities for drag reduction offer considerably more promise than attempts to predict the drag increment. Significant drag savings are demonstrated not only for new types of installation but also by relatively simple modifications to existing designs. Author

N74-26455 Royal Aircraft Establishment, Farnborough (England).
SUPPLEMENTARY CONTRIBUTION ON AIRCRAFT PERFORMANCE CONSIDERATIONS FOR NOISE REDUCTION
John Williams *In* AGARD Prediction Methods for Aircraft Aerodyn. Characteristics May 1974 1 p (For availability see N74-26445 16-02)

The problem of achieving much lower noise levels outside airport boundaries, while at the same time predicting and guaranteeing the noise field from future aircraft with greater accuracy, is examined. Methods for obtaining reductions in aircraft noise levels are identified. The integration of aircraft performance characteristics, airframe design, and airframe-engine aero-acoustic interaference parameters to produce reduced noise levels is emphasized. Author

N74-31458# Advisory Group for Aerospace Research and Development, Paris (France).
AIRCRAFT DESIGN INTEGRATION AND OPTIMIZATION, VOLUME 1
Jun. 1974 347 p refs In ENGLISH; partly in FRENCH Conf. held at Florence, Italy, 1-4 Oct. 1973
(AGARD-CP-147-Vol-1), Avail: NTIS HC $20.50

The proceedings of a conference on aircraft design integration and optimization are presented. The subjects discussed include the following: (1) the preliminary design process and its impact on cost, (2) methods and approaches for balancing requirements, capabilities, and costs in aircraft design, (3) analysis, optimization, and validation testing techniques, and (4) the integration of subsystems and application of new technology. For individual titles, see N74-31459 through N74-31464.

N74-31459 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
THE ROLE OF PRELIMINARY DESIGN IN REDUCING DEVELOPMENT, PRODUCTION AND OPERATIONAL COSTS OF AIRCRAFT SYSTEMS
William E. Lamar *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 7 p (For availability see N74-31458 21-02)

Methods for reducing the development, production, and operational costs of aircraft systems through preliminary design procedures are discussed. The manner in which the preliminary design process is conducted is analyzed. The critical program decisions which are made on the basis of the preliminary design process are identified. The preliminary process is further defined to show the application for assessing the payoff of technical innovations and emerging technologies on system capabilities. Diagrams are provided to show the preliminary design flow chart, system program phases, preliminary design process uses, and cost reduction methodologies. Author

N74-31460 General Dynamics/Fort Worth, Tex.
PRELIMINARY DESIGN ASPECTS OF DESIGN-TO-COST FOR THE YF-16 PROTOTYPE FIGHTER
William C. Dietz *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 16 p (For availability see N74-31458 21-02)

Methods for reducing the development costs of the YF-16 aircraft are discussed. The YF-16 prototype aircraft was conceived and is being developed as a low-cost, exceptionally high-maneuvering-performance fighter aircraft. To meet the cost/performance objectives, a number of advanced technology features, including vortex lift, variable wing camber, wing/body blending, relaxed static stability/fly-by-wire, and high-performance normal-shock inlet, were optimized and integrated during the preliminary design phase. The basic design concept was to apply these advanced technologies in a way, first, to produce a small-size aircraft and, second to achieve simplicity - both of these design objectives having a direct beneficial effect on the development, acquisition, and life-cycle cost. The resulting configuration is predicted to meet all program cost/performance objectives. Author

N74-31461 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
ECONOMIC ASPECTS OF PROTOTYPING
Erich Rutzen *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 5 p refs (For availability see N74-31458 21-02)

The cost aspects and schedule implications involved in a prototype development concept are compared with standardized development philosophies. The time scales of the total system development program and the time scales of the prototype development program are illustrated. The procedures involved in conducting a comparative cost analysis are reported. Diagrams are included to show the budget requirements, accumulated costs at program milestones, specifications uncertainties, and the confidence factor. Organizational charts for the total system development concept and the prototype development concept are also compared. Author

N74-31462 Douglas Aircraft Co., Inc., Long Beach, Calif.
CREATIVE ADVANCED DESIGN: A KEY TO REDUCED LIFE-CYCLE COSTS
Richard E. Black and John A. Stern *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 13 p refs (For availability see N74-31458 21-02)

Advanced design decisions with an impact upon the life cycle costs of aircraft systems are discussed. The impact of advanced design decisions commences during the detail design and development phases, continues into the production phase and becomes a dominant factor during the operational life of the aircraft system. Even for a well defined mission there are many factors bearing on costs that must be considered during the advanced design phase. Several of these have been selected for examination: (1) the number of engines to be used, (2) selection of equipment and systems, (3) the simplification of design, (4) the materials to be used, and (5) the level of avionics sophistication. These advanced design decisions cannot be made solely from a technical or cost standpoint, but must consider the operational environment in which the aircraft system will function as well as the demands of the market place. There are strong indications that the more intense the advanced design effort the lower will be the detailed design, manufacturing and development costs as well as life cycle costs. During the advanced design phase, it is extremely important that the critical wind-tunnel tests be performed to avoid costly redesign after the detailed design drawings have been released. The contribution that creative Advanced Design makes to the development of effective aircraft systems has greatly increased as the result of rising costs. Errors in judgement are now more costly than ever before. Author

N74-31463 Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
CRITICAL ANALYSES AND LABORATORY RESEARCH WORK AT THE STAGE OF AIRCRAFT PRELIMINARY DESIGN
Claude Lievens and Philippe Poisson-Quinton *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 26 p ref In FRENCH; ENGLISH summary (For availability see N74-31458 21-02)

The requirements to be met by a research laboratory in preparation for the preliminary design phase of sophisticated aircraft development are analyzed. It is stated that the research center must forecast the main trends of aeronautical techniques in order to provide the government services and the constructors with a maximum of information. The required actions of the government technical services are defined to include: (1) generation of preliminary studies for contractor use, (2) to begin basic research studies, (3) to identify technical risks, and (4) to monitor the progress of works under development and reorient the effort where required. Author

N74-31464* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
COMPUTERIZED PRELIMINARY DESIGN AT THE EARLY STAGES OF VEHICLE DEFINITION
Thomas J. Gregory *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 8 p refs (For availability see N74-31458 21-02)
CSCL 01B

The conceptual and preliminary design processes are used to provide information regarding the feasibility and selection of various approaches to aircraft mission requirements. Decisions influenced by this information often have enormous cost implications at the later stages of the development process and during vehicle operation, yet the resources expended during the early phases are usually relatively small and distributed over several alternate approaches. The information provided during these early conceptual and preliminary design phases needs to be credible and complete, even though it must be generated with limited resources. Criteria for acceptance of early design information, modern methods of providing it and suggestions for defining adequate levels of resources to accomplish the objectives of the activity are described. Specific examples of the most difficult type of early design studies, which are those requiring significant undeveloped technology, are used to discuss these points. The examples include design studies and cost estimates of liquid hydrogen fueled aircraft, oblique winged aircraft, and remotely piloted vehicles. Author

N74-31465 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany).
PRELIMINARY DESIGN TECHNIQUES FOR UNMANNED, REMOTE PILOTED VEHICLES
R. Staufenbiel and H. Schmidtlein *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 14 p (For availability see N74-31458 21-02)

The steps involved in the design of remotely piloted vehicles are discussed. Specific areas of concern are: (1) combat tactics, (2) weaponry, (3) sensors, (4) payload and range, (5) guidance and control, and (6) maintainability, storability, and vulnerability. The characteristics of a typical RPV are analyzed to provide an example of the important factors which are involved in the design procedure. Author

N74-31466 Hawker Siddeley Aviation, Ltd., Hatfield (England).
AN APPROACH TO DESIGN INTEGRATION
Anthony W. Bishop and Alan N. Page *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 16 p refs (For availability see N74-31458 21-02)

The nature of an aircraft design team and the techniques to be integrated into the organization to improve design efficiency are discussed. The structure and implementation of new techniques which have been applied to the preliminary stages of design in Hawker Siddeley Aviation are stressed. Block diagrams are developed to show the data base mechanism, the interaction between applications programs and the data base, and the flow of typical project study activities. The costs and benefits of the system of design are analyzed. Author

N74-31467 Boeing Commercial Airplane Co., Seattle, Wash.
DESIGN EVOLUTION OF THE BOEING 2707-300 SUPERSONIC TRANSPORT. PART 1: CONFIGURATION DEVELOPMENT, AERODYNAMICS, PROPULSION, AND STRUCTURES
W. C. Swan *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 18 p (For availability see N74-31458 21-02)

The design activities involved in developing the Boeing 2707 supersonic transport aircraft are discussed. The history of the design activity is presented to show areas where failure and/or misconception occurred due to insufficient knowledge and to show how the shortcomings were corrected or avoided in subsequent configuration evaluations. Emphasis is placed on selected areas where preliminary design tools could be improved. The various design configurations are illustrated and their technical features are analyzed. The structural design features of various components are described and illustrated. The operational objectives on which the preliminary planning was based are defined. The functions of specific segments of the organization are reported. Author

N74-31468 Boeing Commercial Airplane Co., Seattle, Wash.
DESIGN EVOLUTION OF THE BOEING 2707-300 SUPERSONIC TRANSPORT. PART 2: DESIGN IMPACT OF HANDLING QUALITIES CRITERIA, FLIGHT CONTROL SYSTEM CONCEPTS, AND AEROELASTIC EFFECTS ON STABILITY AND CONTROL
W. T. Kehrer *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 10 p refs (For availability see N74-31458 21-02)

The intensive efforts undertaken to develop an economically competitive SST are discussed. New design approaches in the areas of airplane longitudinal control and stability and flight control systems design were developed. Extensive research work was

conducted to push the state of the art as hard as possible in the development of handling qualities criteria and in the design evolution of the stability augmentation system. The end product was a control-configured vehicle employing multiple redundant electronic stability augmentation systems to meet design requirements for both normal handling qualities and minimum-safe handling qualities. This design approach contributed substantial gains in range/payload capability over that attainable through the conventional approach that inhibits airplane design through the requirement to provide inherent aerodynamic stability. Throughout all of the design development work the effects of structural aeroelastics on aircraft stability and control played a major role in configuration design decisions. The complex engineering work involved in the aeroelastic analyses paced the configuration development design cycles and contributed substantially to the total engineering costs. The experience gained in these areas has identified the need for improved quality, automated aeroelastic analysis methods to speed the design development work and reduce the engineering costs and design risks. Author

N74-31468 British Aircraft Corp., Preston (England). Military Aircraft Div.
RECENT EXPERIENCE FROM BAC AIRCRAFT FOR NATO
P. J. Midgley *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 10 p ref (For availability see N74-31458 21-02)

An analysis of trends in total cost of ownership of combat aircraft was developed. The life cycle cost analysis is related to the Air Force budget and ways are considered in which the rising costs of Air Force operations may be alleviated. The subjects discussed include the following: (1) Air Force budget trends, (2) the procurement process, (3) life cycle costs, (4) launch and acquisition costs, (5) development philosophy, (6) operating costs, and (7) training costs. Charts, graphs, and diagrams are included to illustrate the contents of the text. Author

N74-31470 Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
THE F-15 DESIGN CONSIDERATIONS
Harry E. Rifenbark and Richard D. Highet *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 11 p (For availability see N74-31458 21-02)

The major design considerations of the F-15 air superiority aircraft are traced from the initial requirements, through the design, and into the flight testing. Selection of the overall configuration is discussed with particular emphasis on the wing, inlet, and secondary power design. The ground and flight test programs are briefly reviewed. Author

N74-31471 Dornier-System G.m.b.H., Friedrichshafen (West Germany)
SYSTEM ANALYSIS FOR A BATTLE-FIELD AIR SUPERIORITY FIGHTER PROJECT WITH RESPECT TO MINIMUM COST
Johannes Spintzyk *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 14 p refs (For availability see N74-31458 21-02)

The battle-field air superiority fighter is an air defense aircraft with the function to gain and to hold air superiority over the combat area for limited time and limited operational area. For given budget the fleet effectiveness can be optimized by reducing the price of the aircraft thus allowing for a higher number of aircraft. Mainly a low cost design can be achieved by minimizing the take-off weight. Design philosophy is to adjust range, payload and equipment to absolute necessary requirements thus arriving to a simple design, but not to compromise air combat capability. For the evaluation of different solutions a method is discussed which shows the role of aircraft characteristics with respect to air combat and which can be used in the preliminary design phases. In the present paper, the influence of mission and design parameters of range, combat time, wing loading and thrust/weight ratio on take-off weight, system cost and air combat effectiveness for the battle-field air superiority fighter is shown. Different versions of a battle-field air superiority fighter are presented and comparative results shown. Author

N74-31472 Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
THE B-1 BOMBER: CONCEPT TO HARDWARE
Robert J. Patton *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 10 p (For availability see N74-31458 21-02)

The development of the B-1 bomber aircraft is traced from the initial conceptual studies to the hardware production. The interaction of the B-1 requirements and advanced technology is emphasized. The preliminary design process is examined and the hardware product is compared with earlier designs. The lessons learned from the analysis are summarized. The mission of the B-1 aircraft is defined and specific operational requirements are considered to show the rationale of design decisions. Author

N74-31473 Boeing Aerospace Co., Seattle, Wash. Aeronautical and Information Systems Div.
DESIGN OF VERY LARGE AIRPLANES FOR LEAST SYSTEM COST
Robert B. Brown *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 6 p (For availability see N74-31458 21-02)

An analysis was conducted to determine the design and development techniques for large aircraft which would result in the least system cost. The effects of program and total life cycle costs are examined to show the effects on starting new aircraft development. Methods for designing an aircraft to maintain low cost are described and illustrated. Specific examples of aircraft designed for various missions are investigated to show the various approaches which were taken to keep down development costs. Author

N74-31474* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
INTEGRATED, COMPUTER AIDED DESIGN OF AIRCRAFT
R. R. Heldenfels *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 12 p refs (For availability see N74-31458 21-02)
CSCL 01B

The design process for conceptual, preliminary, and detailed design of aircraft is discussed with emphasis on structural design. Problems with current procedures are identified and improvements possible with an optimum man-computer team using integrated, disciplinary computer programs are indicated. Progress toward this goal in aerospace and other industries is reviewed, including NASA investigations of the potential development of Integrated Programs for Aerospace-Vehicle Design (IPAD). The benefits expected from IPAD lead to the conclusion that increased use of the computer by a man-computer team that integrates all pertinent disciplines can create aircraft designs better, faster, and cheaper. Author

N74-31475 Vereinigte Flugtechnische Werke G.m.b.H., Bremen (West Germany).
PROJECT WEIGHT PREDICTION BASED ON ADVANCED STATISTICAL METHODS
Wolfgang Schneider *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 20 p refs (For availability see N74-31458 21-02)

A survey of the possibilities of mathematical statistics for engineering evaluation of reliable data sets for design weight estimates of first level accuracy was conducted. Based on a form of regression analysis, several statements which are adapted for finding weight prediction formulas are described. The two principle statements are: (1) constraint regression for development formulas which give physically interpretable weight trends, using methods of quadratic optimization and (2) nonlinear regression statements which are solved by using iterative computer routines. Practical examples to show the possibilities of applying statistical evaluations are included. Author

N74-31476 Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
POTENTIAL PAYOFF OF NEW AERODYNAMIC PREDICTION METHODS
Richard H. Klopinger and Robert Weissman *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 17 p refs (For availability see N74-31458 21-02)

The trade studies and design compromises to optimize the aircraft configuration for specific purposes are discussed. Typical problems involved in the aircraft design process are examined. Illustrations are provided to show the performance improvement which resulted from design modifications to various aircraft. Methods for accurately predicting the performance of an aircraft prior to flight test are reported. Design criteria based on lateral-directional static stability have been developed to reveal possible problems relative to departure characteristics and spin susceptibility. It is stated that the application of three dimensional

aerodynamic analysis methods and spin prevention criteria early in the development of a new aircraft may be the key to better design optimization and improved integration of the components. Author

N74-31477 Royal Aircraft Establishment, Farnborough (England).
INITIAL-DESIGN OPTIMISATION ON CIVIL AND MILITARY AIRCRAFT
D. L. I. Kirkpatrick and M. J. Larcombe *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 18 p refs (For availability see N74-31458 21-02)

The development of a computer program which can optimize the preliminary design of a subsonic, swept-wing, jet transport aircraft is discussed. The program can be used to assess rapidly the effects on the optimum design of changes in the specified performance or of advances in aerodynamic, structural, or engine technology. Compound optimization functions, including several of the aircraft characteristics, with different weighting factors can be used to produce designs in which large improvements in some characteristics have been obtained with small penalties in others. Author

N74-31478 Societe Nationale Industrielle Aerospatiale, Paris (France).
NEW TECHNOLOGIES AND MAINTENANCE OF HELICOPTERS
Jacques Andres *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 13 p In FRENCH (For availability see N74-31458 21-02)

Two fundamental criteria are proposed to study helicopter maintenance: specific costs which constitute the reference for the purchase price of the helicopter and the specific operational price which constitutes the reference cost in helicopter utilization. Data are also given on the problem of cost of performance, security, and comfort in helicopter design. The contribution of new technologies to actual helicopter cost effectiveness was evaluated. Transl. by E.H.W.

N74-31479 Vereinigte Flugtechnische Werke G.m.b.H., Bremen (West Germany).
DESIGN OPTIMIZATION OF THE VAK 1918 AND ITS EVALUATION BASED ON RESULTS FROM THE HARDWARE REALISATION AND TEST DATA
Rolf Riccius and Bernhard Woll *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 19 p refs (For availability see N74-31458 21-02)

The design optimization procedure for the VAK 1918 fighter aircraft is discussed. The procedure of design optimization is evaluated based on the results obtained from ground and flight tests. The emphasis in the original planning was placed on aircraft performance. The results of the tradeoff studies in combination with point design studies are reported. The different approaches to the power plant selection are defined. The rationale behind the final selection of the aerodynamic configuration is explained. Author

N74-31480 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
CONCEPT CCV AND SPECIFICATIONS
Jean-Claude Wanner *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 6 p In FRENCH; ENGLISH summary (For availability see N74-31458 21-02)

The application of the control configured vehicle (CCV) concept to the design stage of new aircraft is discussed. The systems considered under the CCV concept are (1) static stability compensation, (2) maneuver load control, (3) active ride control, and (4) active flutter control. The overall goal of the CCV concept is to take advantage of the most recent technological progress in electronics and to make use of new types of control actuators in order to satisfy the compromise between performance, handling qualities, lifetime, and cost. Author

N74-31481 Boeing Co., Wichita, Kans.
INTRODUCTION OF CCV TECHNOLOGY INTO AIRPLANE DESIGN
Richard B. Holloway *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 16 p refs (For availability see N74-31458 21-02)

The control configured vehicle (CCV) aircraft design process is compared with conventional design procedures. The CCV procedure capitalizes on the potential of considering advanced flight control concepts during the initial parametric studies and trades. Formulation of the parametric aircraft can also be altered by the CCV approach, since traditional empirical design procedures no longer necessarily apply. CCV studies indicate that the most significant performance improvements are achieved in the following functions: (1) augmented stability, (2) gust load alleviation, (3) maneuver load control, (4) fatigue reduction, (5) ride control, and (6) flutter mode control. Author

N74-31482 Lockheed-Georgia Co., Marietta.
AVIONIC FLIGHT CONTROL SUBSYSTEM DESIGN AND INTEGRATION IN THE C-5 AIRPLANE c03
W. Elton Adams *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 12 p refs (For availability see N74-31458 21-02)

The preliminary design process influence on the C-5 avionic flight control system development, production, and operational cost is discussed. The design decisions made during the preliminary design phase relative to the stability augmentation systems illustrate the extent of the impact on the design, test, manufacture, and installation of the avionic systems. These decisions lie acquisition costs, (5) development philosophy, (6) operating costs, and (7) training costs. Charts, graphs, and diagrams are included to illustrate the contents of the text. Author

N74-31483 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
ADVANCEMENTS IN FUTURE FIGHTER AIRCRAFT
Wolfgang Herbst *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 7 p refs (For availability see N74-31458 21-02)

An analysis of advanced design technology as applied to future fighter aircraft was conducted. The following conclusions were reached: (1) a new aircraft development can be justified if the performance of the new aircraft exceeds that of the old by 15 to 20 percent, (2) foreseeable technological air frame advances, such as CCV and composites, do not justify the development of new weapon systems, per se, (3) refent engine technology advances allows a performance improvement which will justify new aircraft design, and (4) foreseeable air frame advances will pay off if applied to new aircraft development. Author

N74-31484 Ministry of Defence, London (England).
ESTIMATION OF PROGRAMMES AND COSTS FOR MILITARY AIRCRAFT c34
J. C. Morrall *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 14 p (For availability see N74-31458 21-02)

The purposes, history and methods of budgetary estimation for military aircraft development programs conducted by the United Kingdom are discussed. The derivation of the methods are analyzed using the airframe as the main example. The use of the timescale, resources, and cost estimating techniques to provide cost trade-offs for different aircraft operational capabilities is demonstrated. The main purposes served by the budgetary estimate are: (1) planning and funding, (2) project selection, appraisal, and approval, and (3) assessment of future loading on the aircraft industry for aerospace policy decisions. Author

N74-32420# Advisory Group for Aerospace Research and Development, Paris (France).
PRELIMINARY AIRCRAFT DESIGN
Clem C. Weissman Jun. 1974 189 p refs Partly in ENGLISH and partly in FRENCH Lecture series presented at Brunswick, West Germany, 6-7 May 1974, Breda, Netherlands, 9-10 May 1974, and Cranfield, England, 13-14 May 1974
(AGARD-LS-65) Avail: NTIS HC $12.50

An analysis of preliminary aircraft design procedures was conducted to show the response to a proposed military requirement with the first estimate of a complete aircraft configuration. The decision rationale and the initial estimation of size, weights, lift and drag, performance, and cost is presented with respect to the payload for various aircraft types and classes and the proposed mission. Emphasis is placed on how this small preliminary design team must make the first decisions regarding technical feasibility and operational desirability. An experienced design team can predict with sufficient accuracy the overall weight, configuration, performance, and cost to permit confident decision to proceed with advanced development of the project. For individual titles, see N74-32421 through N74-32426.

N74-32421 Advisory Group for Aerospace Research and Development, Paris (France).
INTRODUCTION TO PRELIMINARY AIRCRAFT DESIGN

Clem C. Weissman *In its* Prelim. Aircraft Design Jun. 1974 2 p (For availability see N74-32420 22-02)

The satisfaction of military aircraft requirements as it affects the size and performance of aircraft is discussed. The basic boundaries for the new aircraft design are defined as: (1) the operational concept for the dominating mission and physical boundaries, (2) the aircraft performance desired with respect to aircraft speed, range, altitude ceiling, acceleration, and payloads, and (3) physical constraints as determined by ground support facilities. The procedures to be followed in arriving at a three view drawing and a weight and balance statement are briefly explained. Some of the compromises which must be met in aircraft design are explained. Author

N74-32422 Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).

PRELIMINARY DESIGN OF CIVIL AND MILITARY AIRCRAFT AT AVIONS MARCEL DASSAULT-BREGUET AVIATION

J. Czinczenheim *In* AGARD Prelim. Aircraft Design Jun. 1974 66 p refs In FRENCH and ENGLISH (For availability see N74-32420 22-02)

The procedures followed by a French aircraft manufacturing company in the design and production of military and civilian aircraft are discussed. The subjects considered include the following: (1) the organization of the preliminary project staff, (2) the responsibilities of the project engineer or program manager, and (3) iterative steps to be followed in arriving at the preliminary aircraft configuration. The design procedures which followed in the development of specific military and civilian aircraft are analyzed. The steps which are taken to predict the performance of the preliminary design configuration are explained. The evaluation of lift and drag characteristics at the preliminary design stage is emphasized. The functions of a weapon system department with respect to the preliminary project phase, the detailed definition phase, integration tests, and the integration of production equipment are outlined. Author

N74-32423 British Aircraft Corp., Preston (England).

PROPULSION/AIRCRAFT DESIGN MATCHING EXPERIENCE

Raymond F. Creasey *In* AGARD Prelim. Aircraft Design Jun. 1974 72 p (For availability see N74-32420 22-02)

The procedures for matching propulsion systems and airframes to obtain specific performance standards are described. The actual experiences of aircraft development for a reconnaissance aircraft, a fighter aircraft, a supersonic transport, and a subsonic transport are reported. Data are presented in the form of graphs to show aircraft performance in terms of speed versus altitude, fuel consumption versus range, and thrust and drag characteristics. The various formulas and mathematical models which are used to obtain the desired match of power plant and airframe for various mission requirements are included. The application of computer techniques for the optimization of aerodynamic configurations is discussed. Author

N74-32424 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).

DESIGNING FOR MANEUVERABILITY: REQUIREMENTS AND LIMITATIONS

Helmut Langfelder *In* AGARD Prelim. Aircraft Design Jun. 1974 18 p (For availability see N74-32420 22-02)

Based in the technology expected to be operationally available in the 1970 time period, the design requirements and relevant design trades to ensure adequate maneuverability of military aircraft are discussed. The basic contradiction of range versus payload and maneuverability requirements are treated from the point of view of preliminary design. Maximum lift and buffet penetration as well as maneuver devices are presented. Reference is made to cost implications. A point design for extreme maneuverability is analyzed with respect to the characteristics of balanced design for fighter aircraft. Author

N74-32425 LTV Aerospace Corp., Dallas, Tex.

MODERN ENGINEERING METHODS IN AIRCRAFT PRELIMINARY DESIGN

W. W. Huff, Jr. *In* AGARD Prelim. Aircraft Design Jun. 1974 16 p refs (For availability see N74-32420 22-02)

The impact of computer technology on modern engineering methods for the preliminary design of aircraft is discussed. Large capacity digital computer systems and their peripheral equipments provide the opportunity to bring all significant technical and managerial disciplines together in an integrated program. Most design synthesis computer programs are constructed in a modular fashion, which are controlled by the technical disciplines responsible for the state-of-the-art in each particular area. In general, these disciplines will apply the input data at a level of detail consistent with the phase of the preliminary design process. The phases of preliminary design which are considered are: (1) program definition, (2) concept formulation, and (3) contract definition. Author

N74-32426 General Dynamics/Fort Worth, Tex. Convair Aerospace Div.

THE TEAM LEADER'S ROLE IN DESIGN TO COST PRELIMINARY DESIGN

Lyman C. Josephs, III *In* AGARD Prelim. Aircraft Design Jun. 1974 9 p (For availability see N74-32420 22-02)

The organization and functions of a typical Air Force weapon systems office involved in aircraft development are discussed. Emphasis is placed on the YF-16 aircraft program. The management approach of the office is described. The contract requirements to accomplish the objectives for the prototype program are defined. Charts are developed to show the schedule for the YF-16 prototype program and the total budget cost versus actual expenditures are shown. The configuration changes which occurred since approval of the contract are discussed to show the effects on expenses and weapon system development. Author

N74-33449# Advisory Group for Aerospace Research and Development, Paris (France).

HELICOPTER OPERATIONAL LOADS SPECTRUM AND DESIGN CRITERIA

A. J. Gustafson, Jr. (Army Mobility R and D Lab., Fort Eustis, Va.) Jul. 1974 11 p refs

(AGARD-R-622) Avail: NTIS HC $4.00

The USAAMRDL helicopter loads programs have proceeded along three complementary lines: (1) loads prediction techniques (2) mission spectrum development, and (3) loads measurement. The loads measurement programs involved the measurement of several flight parameters on helicopters performing actual missions in SEA and CONUS. The flight parameters were airspeed, altitude, vertical, lateral, and longitudinal acceleration at the helicopter's center of gravity, outside air temperature; main rotor speed, engine torque, and longitudinal, lateral, and collective stick positions versus time. Five basic types of aircraft were instrumented: cargo, crane, utility, observation, and gunship. The operational profiles deduced from the field data were compared to the profiles used in the design of the aircraft. The results of this effort are currently being used to construct mission profiles for the next generation designs for these types of aircraft. Author

N74-34488# Advisory Group for Aerospace Research and Development, Paris (France).

TECHNICAL EVALUATION REPORT ON THE AGARD SPECIALISTS MEETING ON DESIGN AGAINST FATIGUE

J. B. DeJong (Natl. Aerospace Lab., Amsterdam) Aug. 1974 18 p

(AGARD-AR-71) Avail: NTIS HC $4.00

Properties and performance data on fighter aircraft fatigue are examined. Damage tolerance associated with structural safety and inspectability is considered, along with flight load monitoring J.A.M.

N75-10053# Advisory Group for Aerospace Research and Development, Paris (France).

CRITICAL REVIEW OF METHODS TO PREDICT THE BUFFET CAPABILITY OF AIRCRAFT

Helmut John (Messerschmitt-Boelkow Blohm G.m.b.H., Munich) Sep 1974 33 p refs

(AGARD-R-623) Avail: NTIS HC $3.75

A general survey of methods for predicting the buffet penetration capability of aircraft of various configurations is presented. The influence that limiting factors may have on the performance of a fighter aircraft is analyzed. The sensitivity of turn rates at subsonic, transonic, and supersonic speeds are examined. The effects on structural aspects to include fatigue

life of the airframe and weapon system performance are explained. Graphs of typical buffeting conditions are included. Author

N75-10054*# Advisory Group for Aerospace Research and Development, Paris (France)

TRANSONIC BUFFET BEHAVIOR OF NORTHROP F-5A AIRCRAFT

Chintsun Hwang (Northrop Corp., Hawthorne, Calif.) and W. S. Pi (Northrop Corp., Hawthorne, Calif.) Sep. 1974 33 p refs (Contract NAS2-6475)

(NASA-CR-140939; AGARD-R-624) Avail: NTIS HC $3.75 CSCL 01C

Flight tests were performed on an F-5A aircraft to investigate the dynamic buffet pressure distribution on the wing surfaces and the responses during a series of transonic maneuvers called wind up turns. The conditions under which the tests were conducted are defined. The fluctuating buffet pressure data on the right wing of the aircraft were acquired by miniaturized semiconductor-type pressure transducers flush mounted on the wing. Processing of the fluctuating pressures and responses included the generation of the auto- and cross-power spectra, and of the spatial correlation functions. An analytical correlation procedure was introduced to compute the aircraft response spectra based on the measured buffet pressures. Author

N75-15641# Advisory Group for Aerospace Research and Development, Paris (France).

EFFECTS OF SURFACE WINDS AND GUSTS ON AIRCRAFT DESIGN AND OPERATION

Nov. 1974 95 p refs

(AGARD-R-626) Avail: NTIS HC $4.75

An analysis of the effects of surface winds and gusts on aircraft stability and control is presented. The analysis is applied to the development of airframes, improvement of basic airworthiness, better flight characteristics through gust load alleviation, and methods for avoiding atmospheric turbulence. The subjects discussed are as follows: (1) the wind characteristics in the planetary boundary layer, (2) research on aeronautical effects of surface winds and gusts, and (3) the use of radiosonde data to derive atmospheric wind shears for small shear increments. Graphs and tables of wind characteristics, wind speed dispersion, and statistical analyses of gust load conditions. For individual titles, see N75-15642 through N75-15644

N75-15642 Atmospheric Sciences Lab., White Sands Missile Range, N.Mex.

WIND CHARACTERISTICS IN THE PLANETARY BOUNDARY LAYER

Henry Racheie and Manuel Armendariz *In* AGARD Effects of Surface Winds and Gusts on Aircraft Design and Operation Nov. 1974 p 1-98 refs (For availability see N75-15641 07-05)

Equations, graphs, correlation coefficients, and tabulated results describing wind shear, gust factors, wind variability, and the turbulent characteristics of the atmosphere are presented. Data were collected in the planetary boundary layer at White Sands Missile Range (WMSR), New Mexico. When possible, results were compared with those obtained by other investigators in other parts of the country. In most cases, it was found that simple mathematical models could be used to describe the meteorological parameter as a function of stability. Author

N75-15643 Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.

UK RESEARCH ON AERONAUTICAL EFFECTS OF SURFACE WINDS AND GUSTS

J. G. Jones *In* AGARD Effects of Surface Winds and Gusts on Aircraft Design and Operation Nov. 1974 p 59-78 refs (For availability see N75-15641 07-05)

An outline of topics concerning aeronautical effects of surface winds and gusts currently under investigation in the UK or planned for future research is presented. Emphasis is upon effects on aircraft handling and ride qualities, although attention is drawn to the influence of handling performance upon loads experienced in turbulence. Particular areas discussed include turbulence models and related procedures for aircraft airworthiness requirements, turbulence models for ground-based simulation, criteria for aircraft ride quality, the representation of the human pilot in analytical studies of flight in turbulence, and the use of active controls for gust alleviation. Author

N75-15644 Army Missile Research, Development and Engineering Lab., Redstone Arsenal, Ala.

USE OF RADIOSONDE DATA TO DERIVE ATMOSPHERIC WIND SHEARS FOR SMALL SHEAR INCREMENTS

Oskar M. Essenwanger *In* AGARD Effects of Surface Winds and Gusts on Aircraft Design and Operation Nov. 1974 p 79-88 refs (For availability see N75-15641 07-05)

The wind vector shear in the lowest 6000 feet for the 90, 95 and 99 percent threshold of the annual cumulative distribution and the maximum shear from 14 stations of the climatological ringbook and 27 stations of unpublished vector shear distributions are derived. All data were normalized to a 100 m shear interval by a formula. The outcome of the analysis confirms that the vector shear decreases from the surface to a minimum at around 2 km. A definite latitudinal dependence can be discovered with the mid-latitudes exposing the strongest shear while the polar or tropical zones display significantly lower values. Tables for 100 m and 50 m shear intervals are given for the average 90, 95 and 99 percent threshold and the maximum shear within three typical geographic zones (polar, mid-latitude and tropical), and for the station with the strongest shears within that zone. Author

N75-32096# Advisory Group for Aerospace Research and Development, Paris (France).

FLUTTER SUPPRESSION AND STRUCTURAL LOAD ALLEVIATION

Jul. 1975 94 p refs In ENGLISH and partly in FRENCH Presented at the 40th meeting of the Struct. and Mater. Panel, Brussels, 13-18 Apr. 1975

(AGARD-CP-175) Avail: NTIS HC $4.75

Conference data on advances made in the area of flutter suppression and structrual load alleviation are summarized. Particular attention was given to system design, behavior, reliability, safety and redundancy, as found by analyses, model and flight tests. The use of active controls to suppress flutter was the dominant subject. The general problem was explored and specific examples and experiences were also presented. Flutter control of the wing/store combination, of the empennage and of a straight wing were studied, wind tunnel tests were discussed, automatic pilotage in turbulent air was examined and the mechanization of active controls was reviewed. For individual titles, see N75-32097 through N75-32104.

N75-32097 McDonnell Aircraft Co., St. Louis, Mo.

DESIGN CONSIDERATIONS FOR AN ACTIVE SUPPRESSION SYSTEM FOR FIGHTER WING/STORE FLUTTER

C. H. Perisho, W. E. Triplett, and W. J. Mykytow (AFFDL) *In* AGARD Flutter Suppression and Structural Load Alleviation Jul. 1975 19 p refs (For availability see N75-32096 23-05)

Results from a previous study on wing/store flutter are extended in a preliminary system design to determine realistic system integration features, and to provide a feasibility evaluation of a completely automatic, pilot-out-of-the-loop, adaptive active flutter control system which automatically adjusts a system gain and compensation for different stores on the aircraft. Information obtained included a definition of details involving hydraulic and structural modifications, hardware and software components, flight safety features, expected performance benefits and limitations, and program plans for a wind tunnel verification effort and subsequent flight test demonstrations. Author

N75-32098 British Aircraft Corp., Filton (England). Commercial Aircraft Div.

ACTIVE FLUTTER SUPPRESSION

M. R. Turner *In* AGARD Flutter Suppression and Structural Load Alleviation Jul. 1975 14 p refs (For availability see N75-32096 23-05)

The use of Root-locus, Nyquist plots and state space theory in the design of active flutter suppression feedback laws is discussed. The concept of an optimum flutter suppression pole placement requirement is introduced. Description and examples are given of Dressler's and Kalman's dynamic observers for state space feedback when only one transducer is used. Examples are given of the effectiveness of feedback laws at off-design conditions for three different types of aircraft. The effect of aileron power control unit rate limit on the aileron control of hard flutter of a high aspect ratio wing in the presence of discrete and random gusts was shown. For a capability of 160 deg/sec., a 20 percent increase of flutter speed can be achieved with very large weight savings. The cutoff frequency usually quoted for the transfer function of power control units is shown to underestimate its flutter control capabilities. The possible need for feedback laws based upon flight test measurements is discussed. Author

N75-32099 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).

ACTIVE CONTROL OF EMPENNAGE FLUTTER
O. Sensburg, H. Hoenlinger, and M. Kuehn *In* AGARD Flutter Suppression and Structural Load Alleviation Jul. 1975 11 p refs (For availability see N75-32096 23-05)

After a successful application of the active flutter control technology on a wingstore flutter problem, an extension of this technology to an empennage flutter problem was considered. The task was to develop, build and test a control system which actively suppresses a total airplane model flutter problem by counteracting with a hydraulically driven rudder. The flutter phenomenon described is characterized by large contributions of fuselage torsional movement therefore producing high inertial forces in comparison with unsteady aerodynamic forces. These properties lead to a mild onset of flutter. For the same reason no rapid phase changes of the flutter mode near the flutter point are occurring. Author

N75-32100 Boeing Co., Wichita, Kans.
WIND TUNNEL INVESTIGATION OF CONTROL CONFIGURED VEHICLE SYSTEMS
G. O. Thompson and F. D. Sevart *In* AGARD Flutter Suppression and Structural Load Alleviation Jul. 1975 8 p refs (For availability see N75-32096 23-05)

Research studies was conducted to demonstrate active flutter mode control and forward body ride control systems on a one-thirtieth scale B-52E aeroelastic model. The NASA model, originally designed and constructed for low speed gust response testing, was modified to represent the airplane used in the B-52 control configured vehicle (CCV) flight test program. The CCV program flutter mode control and vertical ride control systems were scaled to model frequency and tested in the transonic dynamics tunnel at conditions equivalent to airplane flight test conditions. Wind tunnel test results were compared with model analytical and airplane flight test results. The good correlation demonstrates wind tunnel test models can be employed to verify CCV system analysis and synthesis results, thus reducing risks involved in a new airplane development. Author

N75-32101 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
CLOSED FORM EXPRESSION OF THE OPTIMAL CONTROL OF A RIGID AIRPLANE TO TURBULENCE
Gabriel Coupry *In* AGARD Flutter Suppression and Structural Load Alleviation Jul. 1975 8 p refs In FRENCH; ENGLISH summary (For availability see N75-32096 23-05)

An explanation is given as to how Wiener's theory makes it possible to derive in closed form, the transfer function of the filter used for control. It shows that this transfer function can be expressed in autoadaptative form, the poles being proportional to the velocity of the aircraft. The influence of parameters like mass, scale of turbulence, is discussed. Finally, a comparison is given between results of flight test and prediction. Author

N75-32102 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
WIND TUNNEL TEST OF A FLUTTER SUPPRESSOR ON A STRAIGHT WING
Roger Destuynder *In* AGARD Flutter Suppression and Structural Load Alleviation Jul. 1975 3 p In FRENCH; ENGLISH summary (For availability see N75-32096 23-05)

A study was made of flutter due to a load hung under the wing of an aircraft. Special attention was given to aerodynamic and natural structural modes. Using an aerodynamically uncoupled control surface made it possible to simplify the transfer function of the servo-system. The control obtained this way is not optimal, but it does not require a precise knowledge of the aerodynamic forces and the wing dynamic characteristics, and provides an increased damping ratio in the whole velocity range. Author

N75-32103 Sperry Rand Corp., Phoenix, Ariz.
MECHANIZATION OF ACTIVE CONTROL SYSTEMS
James B. Flannigan and Thomas R. Elliott *In* AGARD Flutter Suppression and Structural Load Alleviation Jul. 1975 14 p refs (For availability see N75-32096 23-05)

Characteristics and limitations of current active control systems, in their ability to satisfy the requirements of more precise control of gain/phase relationships and flight safety implications, are discussed. Solutions to the potential shortcomings of these systems were also covered. Author

N75-32104 Hydraulic Research and Mfg. Co., Valencia, Calif.
HYDRAULIC CONTROLS FOR ACTIVE FLUTTER SUPPRESSION AND LOAD ALLEVIATION
Don A. Wiggins *In* AGARD Flutter Suppression and Structural Load Alleviation Jul. 1975 12 p refs (For availability see N75-32096 23-05)

A description is given of how system requirements influence the design and redundacy mechanizations of the hydraulic actuation portion of the flight control system. Some of the redundant hydraulic actuation concepts being used on advanced vehicles such as the NASA F-8 digital fly-by-wire aircraft and the space shuttle are discussed by examples. A summary is given of the present technology available in the field of redundant electrohydraulic actuation systems. Author

N76-15146# Advisory Group for Aerospace Research and Development, Paris (France).
HANDLING QUALITIES SPECIFICATION DEFICIENCIES
A. G. Barnes Nov. 1975 23 p refs
(AGARD-AR-89) Avail: NTIS HC $3.50

A summary is presented on the contributions received from NATO nations on the deficiencies of six different handling qualities specifications. They are: Mil-H-8501, Mil-F-8785-B, TSS-3, Mil-F-83300, AR 577, AvP 970. The purpose was to determine those portions of the various handling qualities specifications which were inadequate or overly restrictive. The result shows that there were not a great many severe deficiencies, and those that were found were not entirely unexpected. The collected comments illustrate the difficulty of collecting information from design or certification authorities which quantifies flying qualities. Difficulties arise because the information needed to compare an early aircraft design with a current specification is often not available; also there is a reluctance to publicize information which might show a particular aircraft in a bad light. The need for further research is shown. Author

N76-17092# Advisory Group for Aerospace Research and Development, Paris (France).
SPECIALISTS MEETING ON STRUCTURAL DESIGN TECHNOLOGY
Nov. 1975 183 p refs partly in ENGLISH and FRENCH Presented at the 40th Meeting of the Struct. and Mater. Panel, Brussels, 13-16 Apr. 1975
(AGARD-CP-184) Avail: NTIS HC $6.75

The many problems of dynamics, aerodynamics and stress, which are involved in aircraft structural design, are discussed. For individual titles, see N76-17093 through N76-17100.

N76-17093 Hawker Siddeley Aviation Ltd., Woodford (England).
THE SIGNIFICANCE OF VARIOUS MANAGEMENT AND TECHNICAL TECHNIQUES ON AIRCRAFT STRUCTURAL DESIGN
Alan James Troughton *In* AGARD Specialists Meeting on Structural Design Technology Nov. 1975 16 p refs (For availability see N76-17092 08-05)

Techniques are summarized which are used in aircraft structural design. The in-service performance of aircraft as regards structural accidents and incidents is given together with typical costs for R&D structural activities. All aircraft structural design techniques are reviewed including stressing, detail design, computer aided design and alternative methods of testing. The use of value engineering in obtaining optimum cost aircraft is discussed. Author

N76-17094 Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
EVOLUTION OF THE ROLE PLAYED BY THE STRESS ANALYSIS OFFICE IN THE DESIGN OF A PROTOTYPE [EVOLUTION DU ROLE DU BUREAU DES STRUCTURES DANS LA REALISATION D'UN PROTOTYPE]
Marcel Peyrony *In* AGARD Specialists Meeting on Structural Design Technology Nov. 1975 8 p In FRENCH (For availability see N76-17092 08-05)

Changes that have taken place in the work organization of the stress analysis and aircraft structures design office during the last few years due to the introduction of computer techniques were reviewed. The relative advantages and disadvantages of plotters and interactive graphics terminals were summarized. A number of computer programs used in the design of representative aircraft structures and elements were mentioned. Problems related to computer running time and the inputting and retrieval of data into and from computers were described. Applications to the Mercure and Falcon 50 aircraft were mentioned and illustrated. Transl. by Y.J.A.

N76-17095 Westland Helicopters, Ltd., Yeovil (England).
THE STRUCTURAL DESIGN PROCESS FOR HELICOPTERS WITH EMPHASIS ON THE ROTOR
D. A. S. Howell *In* AGARD Specialists Meeting on Structural Design Technology Nov. 1975 18 p ref (For availability see N76-17092 08-05)

The helicopter structural designer must develop an awareness of many potential design problems not encountered in the fixed wing field. The solution of these problems invariably involves the three disciplines of dynamics, aerodynamics and stress, and is further complicated by the increasingly stringent demands of the overall performance requirements. These particular aspects of helicopter design as well as the design process are introduced by the paper, which also considers the role of the structural designer during the development phase of the helicopter. The development of new analytical and experimental techniques, the application of new materials, and some structural design objectives are also presented with a view to enhancing further the capabilities of the helicopter. Author

N76-17096 Technische Hogeschool, Delft (Netherlands)
THE PROBLEMS ASSOCIATED WITH INTERNATIONAL DESIGN TEAMS AND THEIR SOLUTIONS
E. J. VanBeek *In* AGARD Specialists Meeting on Structural Design Technology Nov. 1975 4 p (For availability see N76-17092 08-05)

Some problems relating to international cooperation in design of aircraft and possible solutions for these problems are discussed. The strong identity of experienced design organizations, based on tradition and a long history, initially results in many difficulties and differences of opinion, before a smoothly running cooperation has been achieved. Other important factors are variations in the drawing numbering systems, affecting the modification system used during the design phase and thereafter. There are the problems related to normalization and standardization of standard parts, and there is still a large variation in national material specifications for basically the same material. Variations in the national airworthiness requirements resulting in special conditions are an important feature in multi-national design cooperation. Author

N76-17097 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
THE INTRODUCTION OF NEW MATERIALS
V. V. Tein and P. Selvaggi (Aeritalia, Turin) *In* AGARD Specialists Meeting on Structural Design Technology Nov. 1975 21 p refs (For availability see N76-17092 08-05)

Besides a discussion of the state of the art concerning materials, a summary is presented about work with new materials at AERITALIA and Messerschmitt-Boelkow-Blohm. Special attention is given to materials for fighter aircraft structures. Author

N76-17098 General Dynamics/Fort Worth, Tex
THE ROLES OF ANALYSIS IN RELATION TO STRUCTURAL TESTING
William C. Dietz and Lawrence C. Seth *In* AGARD Specialists Meeting on Structural Design Technology Nov. 1975 14 p (For availability see N76-17092 08-05)

The relationship between analysis and test is explained for a typical modern fighter aircraft. The role each plays as a part of the total structural certification program is emphasized for each element of the structural design process. These include the efforts involved in development of basic allowable stresses for design, wind tunnel testing, loads and stress analysis, full scale test, and flight test. Currently used methods and procedures for solution of recent problems in achieving economically durable airframe structure and the approach to the application of composites are reviewed. Author

N76-17099 British Aircraft Corp., Preston (England). Military Aircraft Div.
THE USE OF COMPUTERS TO DEFINE MILITARY AIRCRAFT STRUCTURES
I. C. Taig *In* AGARD Specialists Meeting on Structural Design Technology Nov. 1975 32 p refs (For availability see N76-17092 08-05)

The use of the computer as a tool to aid structural design has become firmly established during the last twenty years. In particular, it is probably true that in no other area of computer operation has greater progress been made than in structural analysis. The present state of the art in the related use of computers is surveyed and benefits and penalties which result therefrom are discussed. Author

N76-17100 McDonnell Aircraft Co., St. Louis, Mo
WEIGHT CONTROL AND THE INFLUENCE OF MANUFACTURING ON STRUCTURAL DESIGN
R. C. Goran *In* AGARD Specialists Meeting on Structural Design Technology Nov. 1975 16 p (For availability see N76-17092 08-05)

Practices of weight control and the influence of manufacturing on structural design are discussed for the F-4 series of aircraft, the F-15 air superiority aircraft, and the DC-10 wing for commercial aircraft. Many of the problems are a result of the constant need to design efficient lighter weight structures by the introduction of new materials, configurations, and joining methods, together with closer tolerances. To some extent, optimum design and minimum manufacturing cost appear divergent in nature. Much of the interaction between design and manufacturing is to compromise or seek acceptance for seemingly conflicting requirements. Author

N76-18108# Advisory Group for Aerospace Research and Development, Paris (France).
CURRENT STANDARDS OF FATIGUE TEST ON STRIKE AIRCRAFT
R. D. J. Maxwell (RAE, Farnborough, Engl.) Jan 1976 13 p refs
(AGARD-AR-92; ISBN-92-835-1205-7) Avail: NTIS HC $3.50

The major fatigue test constitutes one of the most important aspects in almost all modern tactical aircraft designs. Within NATO, where numerous different tactical aircraft are employed, and where several user nations may operate an aircraft built by a different nation, it is important that the major fatigue test be performed in such a manner that the results can be interpreted and used by the various countries concerned. This Advisory Report, therefore, presents a statement of the objectives of a fatigue test, a list of essential steps needed to achieve the objectives, a summary of recommendations of the way the steps should be carried out and a review of the background philosophy behind the recommendations. Author

N76-30207# Advisory Group for Aerospace Research and Development, Paris (France).
HELICOPTER DESIGN MISSION LOAD SPECTRA
Aug. 1976 71 p refs In ENGLISH; partly in FRENCH Presented at 42d Meeting of the Structures and Mater. Panel, Ottawa, Canada, 8 Apr., 1976
(AGARD-CP-208) Avail: NTIS HC $4.50

Mission related load spectra are applied to component fatigue life predictions for helicopter design criteria. For individual titles, see N76-30208 through N76-30213.

N76-30208 Advisory Group for Aerospace Research and Development, Paris (France).
MISSION SPECTRA FOR THE COMPUTATION OF LIFE EXPECTANCIES [SPECTRES DE MISSION POUR LE CALCUL DES DUREES DE VIE]
F. Liard *In its* Helicopter Design Mission Load Spectra Aug. 1976 10 p In FRENCH (For availability see N76-30207 21-05)

The computation of the life expectancies for helicopter parts was shown to be strongly affected by the assumptions made in the type of missions to be performed. It appears preferable to restrict oneself to the most important flight characteristics, such as speed and load factor, instead of including more elaborate data (such as constraints) which cannot be carried over to the design of new helicopters. The choice of helicopters selected should be based on a statistical sampling of the air fleet considered to give reliable information on the average mission spectra of these helicopters, rather than to focus the attention on the single helicopter with the most severe utilization; the reason for this is that it is extremely unlikely that the weakest part would be found on the most highly stressed machine. Transl. by Y.J.A.

N76-30209 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
THE IMPACT OF HELICOPTER MISSION SPECTRA ON FATIGUE
G. Reichert *In* AGARD Helicopter Design Mission Load Spectra Aug. 1976 17 p refs (For availability see N76-30207 21-05)

Helicopter components are requested to have long service lives, coming close to unlimited lifetimes. However, there are

still real problems in the accurate prediction of the resulting component lives because this requires the availability of adequate mission load spectra. The nature of the typical fatigue loading situation, in combination with the requested long lifetimes raises the question of the sensitivity to variations in mission requirements and load spectra. For a light helicopter with a hingeless rotor system using fiberglass rotor blades - in commercial as well as in military application - the influence of different mission requirements on load spectra and fatigue is discussed. Normally, only a small portion of the complete mission is of importance for fatigue. Therefore, the impact of modified mission spectra on fatigue is assessed. Author

N76-30210 Westland Helicopters Ltd., Yeovil (England)
HELICOPTER DESIGN MISSION LOAD SPECTRA
A. D. Hall *In* AGARD Helicopter Design Mission Load Spectra Aug. 1976 5 p (For availability see N76-30207 21-05)

The various stages of helicopter design are related to projected flight mission fatigue load magnitudes and occurrences. The latter were expressed as a percentage of total flying time or as a number of occurrences per hour of flight. Magnitude of loading was derived for the design stage from calculation or by parametric readout from similar aircraft types. The assumed maneuver spectrum was the critical link in developing the design stage, throughout prototype development and model fatigue testing. G.G

N76-30211 Technology, Inc., Dayton, Ohio.
US AIR FORCE HELICOPTER OPERATIONAL FLIGHT SPECTRA SURVEY PROGRAM: PAST AND PRESENT
G. L. Martin and R. B. Johnson, Jr. *In* AGARD Helicopter Design Mission Load Spectrum Aug. 1976 16 p refs (For availability see N76-30207 21-05)

Development and application of the Flight Condition Recognition (FCR) technique for the processing of helicopter operational data are elaborated. The FCR technique identifies aircraft operations and transitions which are called flight conditions, and flight phases which are called mission segments. Each identification is based on the characteristic behavior of the in-flight parameters. With such identifications, the data processing consists basically of determining the occurrences and durations of the flight conditions and mission segments, of measuring the in-flight parameters, and accordingly of presenting these data so that the flight condition and mission segment time and frequency distributions are quantitatively defined by selected ranges of the flight parameters. This application of the FCR technique permits the fatigue analyst to comprehend and apply more effectively the operational usage spectrum to the calculation of the fatigue life of critical helicopter components. Author

N76-30212 Naval Air Systems Command, Washington, D.C.
US NAVY HELICOPTER OPERATIONAL FLIGHT SPECTRUM SURVEY PROGRAM: PAST AND PRESENT
R. E. Malatino *In* AGARD Helicopter Design Mission Load Spectrum Aug. 1976 13 p refs (For availability see N76-30207 21-05)

In-flight load spectra surveys have been performed on the SH-3A, CH-53A, CH-46D, UH-1E, TH-1L and RH-2D helicopters. Data from these surveys have been used to establish a more rational basis for static and fatigue structural design criteria as well as to more realistically establish the service lives of existing critically loaded structural components. In addition to these in-flight load surveys, data have been obtained during operational landing surveys performed on the HUP-1, HTL-3, HTL-4, HTL-5, HO3S, and HRS-1 helicopters. These surveys were performed during the early 1950's. In the late 1960's, data were obtained in confined area landing operations with the CH-53A and CH-46F helicopters. Recently, surveys were made during landing operations with the HH-2D and SH-2F aircraft on the landing platforms of small ships at sea. These data have been used to up-date the Navy's design and test criteria for structural strength for landing. Results and details of these surveys as well as the Navy's current plans for future surveys such as flight surveys in mine countermeasures operations with the RH-53D helicopter and at-sea hauldown landing operations with the SH-2F helicopter are discussed. Author

N76-30213 Army Air Mobility Research and Development Lab., Moffett Field, Calif.
CRITIQUE AND SUMMARY OF THE SPECIALISTS MEETING ON HELICOPTER DESIGN MISSION LOAD SPECTRA
Frederick H. Immen *In* AGARD Helicopter Design Mission Load Spectra Aug. 1976 4 p (For availability see N76-30207 21-05)

A low cost structural integrity monitoring system is reported that permits the determination of in-service fatigue damage of helicopter structural components. The parametric data recording system indicates airspeed, static pressure, outside air temperature, main rotor RPM, roll attitude, vertical acceleration, landing gear touchdown, and engine torque. In addition to measuring mission load spectra in actual service, the use of a highly truncated fatigue load spectrum during initial design is advocated that assumes aircraft operation in the worst loading regime within G load, power, vibration, performance, or stability limits 100% of the time. G.G

N76-32183# Advisory Group for Aerospace Research and Development, Paris (France)
ADVANCES IN ENGINE BURST CONTAINMENT AND FINITE ELEMENT APPLICATIONS TO BATTLE-DAMAGED STRUCTURE
Sep. 1976 22 p refs Presented at 42d Struct. and Mater. Panel Meeting, Ottawa, Apr. 1976
(AGARD-R-648) Avail: NTIS HC $3.50

Two papers dealing with protection systems for aircraft against damage arising from the impact of a variety of projectiles such as military weapons and debris from engine disintegration were presented. For individual titles, see N76-32184 through N76-32185.

N76-32184 Boeing Co., Seattle, Wash.
ADVANCES IN ENGINE BURST CONTAINMENT
R. J. Bristow, C. D. Davidson, and J. H. Gerstle *In* AGARD Advan. in Eng. Burst Containment and Finite Elem. Appl. to Battle-Damaged Struct. Sep. 1976 p 1-6 (For availability see N76-32183 23-05)

A partial review of recent research performed into the application of fragment impact studies leading to an understanding of engine burst fragment impacts and the initial development of an engine burst containment system using duPont Kevlar material were described. All test work to date has involved translational accelerators. The program has not yet resulted in a satisfactory containment system. In addition to a summary of program accomplishments, several areas where unexpected results occurred and where information was obtained that may influence future fragment containment efforts were discussed. One of these areas involves spinning fragments. None of the predicted adverse effects on Kevlar fabric was found. Another area concerns thermal effects. It was found that the efficiency of the barrier in stopping fragments was influenced by the temperature of the Kevlar. Author

N76-32185 Naval Surface Weapons Center, White Oak, Md.
FINITE ELEMENT APPLICATIONS TO BATTLE DAMAGED STRUCTURE
Pao C. Huang *In* AGARD Advan. in Eng. Burst Containment and Finite Elem. Appl. to Battle-Damaged Struct. Sep. 1976 p 7-16 refs (For availability see N76-32183 23-05)

A 'Patching Technique' for the development of a finite element model truly representing a battle damaged aircraft was introduced. The applications of the preprocessors Ping and Bing to the automatic generation of input data for NASTRAN analyses are also briefly shown. Finally, the importance of modeling technique is addressed. Author

N77-10049*# Kanner (Leo) Associates, Redwood City, Calif.
CRITICAL ANALYSIS OF COMPARISONS BETWEEN FLIGHT TEST RESULTS AND WIND TUNNEL TEST PREDICTIONS IN SUBSONIC AND SUPERSONIC TRANSPORT AIRCRAFT
C. Pelagatti, J. C. Pilon, and J. Bardaud Washington NASA Aug. 1976 56 p refs Transl. into ENGLISH of French report AGARD-CP-187, Apr. 1976 Presented at the 48th Meeting of the Flight Mech. Panel, Valloire, France, 9-13 Jun. 1975
(Contract NASw-2790)
(NASA-TT-F-17186; AGARD-CP-187) Avail: NTIS HC A04/MF A01 CSCL 01C

In relating test results obtained from wind tunnels to results from actual flight tests, corrections must be made to allow for aeroelastic effects and the effect of Reynolds' number differences. Using data from Concorde and airbus tests, an attempt is made to define what degree of accuracy may be expected from aerodynamic coefficients derived from wind tunnel measurements. Author

N77-16034# Advisory Group for Aerospace Research and Development, Paris (France).
NONLINEAR EFFECTS IN AIRCRAFT GROUND AND FLIGHT VIBRATION TESTS
G. Haidl (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich) Dec. 1976 21 p refs Presented at 43d Struct. and Mater. Panel Meeting, London, Sep. 1976
(AGARD-R-662; ISBN-92-835-1231-7) Avail: NTIS HC A02/MF A01

Examples of non linear vibration behavior in ground resonance tests of an aircraft are shown. Model tests for a simplified system with non-linear properties have been performed, to study the effects of friction and backlash with respect to ground resonance test and flight flutter test. With symmetric and asymmetric non-linear stiffness characteristics effects of amplitude dependent frequencies, mode coupling, mode asymmetries and the consequences in parameter identification in vibration tests are pointed out and discussed. In case of flutter critical modes the problems of apparent damping caused by non-linear system properties are shown, and recommendations are given to reach a representative flutter clearance with respect to this non-linear system behavior.
Author

N77-16031# Advisory Group for Aerospace Research and Development, Paris (France).
AVIONIC COOLING AND POWER SUPPLIES FOR ADVANCED AIRCRAFT
P. W. Smith, ed. Nov. 1976 226 p refs Partly in ENGLISH; partly in FRENCH Presented at Avionics Panel Specialists' Meeting, The Hague, 10-11 Jun. 1976
(AGARD-CP-196; ISBN-92-835-0182-9) Avail: NTIS HC A11/MF A01

Alternatives are discussed to improve military aircraft cooling systems. These efforts include: (1) reduction in the quantity of avionics, (2) more efficient use of primary power, (3) more efficient cooling of avionics systems, (4) increase in the acceptable ambient temperature of components, (5) reduction in critical components, and; (6) reduction in cooper conductors and more efficient distribution of generated heat. The temperature effects on aircraft equipment are investigated.
I.M.

N77-16032# British Aircraft Corp., Preston (England).
THE PROBLEMS OF COOLING HIGH PERFORMANCE MILITARY AIRCRAFT
Ian Howells *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 13 p (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

The problems imposed on the aircraft designer in disposing of rejected heat were discussed and the penalties on the aircraft of doing so were examined. The reasons why the problem is so great in today's generation of aircraft, and the probability of growth in the next generation of aircraft were discussed. Sources of heat and their cooling requirements were identified. The quantity of heat to be rejected has increased, but the mass of the aircraft has decreased. In particular, the effect of avionic cooling requirements on total aircraft heat rejection was illustrated.
Author

N77-16033# Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
AVIONICS COOLING ON USAF AIRCRAFT
George C. Letton, Jr. *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 9 p refs (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

There is a continual effort by the United States Air Force to provide improved avionics equipment on today's USAF aircraft were reviewed and approaches which will improve avionics reliability, reduce aircraft penalty and lower life cycle cost, were outlined. Greater emphasis is needed on producing compatible avionics equipment and cooling systems. A comprehensive trade study of avionics reliability versus environmental control system (ECS) cooling capability should be conducted at the start of the aircraft development program. From this trade study, the ECS cooling capability can be optimized to minimize total aircraft life cycle cost. The avionics contractor should conduct a detailed analytical thermal analysis of internal black box temperatures early in the development program. During qualification testing, a thermal verification test should be conducted to verify that all component temperatures are within the necessary limits for required reliability. Use of narrow limits on inlet coolant temperature, greater use of cold plates and liquid cooling, and use of ECS approaches similar to the Advanced Environmental Control System should be seriously considered for new aircraft design.
Author

N77-16034# Dornier-System G.m.b.H., Friedrichshafen (West Germany).
ADVANCED THERMAL COMPONENTS FOR EFFICIENT COOLING OF AVIONIC SYSTEMS
W. J. Schwarzott *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 16 p (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

Avionics cooling requirements are described and the overall design features of spacelab avionics cooling system are presented. The analytical tools for comprehensive calculations in the area of cooling systems are described. Different types of heat pipes and phase change components are presented showing the possible kinds of applications. These heat transport and storage components mainly were developed for space application.
Author

N77-16035# Federal Water Quality Administration, Chicago, Ill.
BEST CONCEPT FOR AIRCRAFT ELECTRONIC EQUIPMENT [CONCEPTION OPTIMALE DES EQUIPMENTS ELECTRONIQUES AEROPORTES]
Jean Bertrais *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 10 p refs In FRENCH (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

A method is proposed for reducing the mass of electronic equipment on aircraft and the electric power required to operate it. This optimal solution gives the values of all parameters, as well as the energy required. Factors of relative merit are given for establishing a comparison between different materials. The desired modifications are defined. Dynamic programming is used to simplify calculations. The method is general and can be used for researching the economics of materials or of energy.
Transl. by A.H.

N77-16036# Smiths Industries Ltd., Bishops Cleeve (England). Aviation Div.
THE POSSIBLE IMPACT OF DC AIRCRAFT POWER SUPPLIES ON THE DESIGN OF AVIONIC AND OTHER EQUIPMENT
N. L. Sigourney *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 5 p (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

In most cases, the use of dc for primary power in equipment will: (1) reduce weight by the order of 10 percent, (2) reduce dissipation by the order of 10 percent, (3) give more flexibility in switching power supplies, and (4) reduce electro-magnetic radiation by the elimination of power rectifiers and by removing restrictions on some filter components necessitated by 400 Hertz supplies. To achieve the maximum benefits in the aircraft, the following are necessary: (1) a range of dc circuit breakers, (2) further development of inverters for ac gyro and similar motors to give high efficiency overall, (3) development of inverters for induction motors or brushless dc motors to drive continuously running pumps and fans, and (4) development of reliable low dissipation dc to dc converters, particularly using large scale integrated circuits to reduce size and cost.
Author

N77-16037# British Aircraft Corp., Preston (England). Military Aircraft Div.
AIRCRAFT POWER SUPPLIES: THEIR PERFORMANCE AND LIMITATIONS
K. P. Gerrity and R. F. Bertolini *In* AGARD Avionic Cooling and Power Supplies for Avanced Aircraft Nov. 1976 15 p (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

The causes and rates of occurrence of such effects as abnormal or emergency limits, transients and interruptions which raise the need for power supply conditioning were examined. The contributions to the overall supply quality of each of the major generation system components and their mode of interconnection were highlighted. The basic problems of incompatibility between avionic equipments and electrical generation systems on modern military aircraft were discussed. The operation of typical generation systems were examined and the reason for deviations from the ideal supply were explained.
Author

N77-16038# Dassault-Breguet Aviation, St. Cloud (France).
ELECTRIC GENERATION AND ONBOARD NETWORKS IN MODERN AIRPLANES [GENERATIONS ELECTRIQUES ET RESEAUX DE BORD DAN LES AVIONS MODERNES]
Antoine Beau *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 11 p In FRENCH (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

National norms defining the limits of different parameters of electric supply and its utilization do not include methods for verification of compatability. An approach to such a definition is presented. Various types of electrical networks found on aircraft are reviewed. Characteristic limitations of the different sources of electrical energy which directly concern the equipment using the energy are discussed. Funcational zones (normal, rare, exceptional) and the types of charging and discharging (permanent or transitory) applicable to power supply and power utilization are examined. Transl. by A.H.

N77-16039# Marconi-Elliott Avionic Systems Ltd., Rochester (England).
AIRCRAFT POWER SUPPLIES AND COOLING PROBLEMS: A VIEWPOINT FROM THE POWER CONDITIONER DESIGNER
P. Chapman *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 16 p refs (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

The main trade-offs in a modern avionic power conditioner designed to interface between electronic units and aircraft power supplies were detailed. The ability to overcome the major limitations of these supplies was demonstrated and the advantages to be gained by improving them were discussed. It is proposed that a systems approach, rather than the consideration of power supplies and/or power conditioner alone, will produce a better solution to the thermal problems associated with avionic equipment. Author

N77-16040# British Aircraft Corp., Preston (England).
AIRCRAFT COOLING TECHNIQUES
Ian Howells *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 13 p (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

The compatibility of the major heat sources in military aircraft with the available heat sinks are examined. The techniques available for refrigeration and the methods which can be used for transporting the heat from its source to cooling medium are described. Author

N77-16041# Boeing Co., Seattle, Wash.
THERMAL MANAGEMENT OF FLIGHT DECK INSTRUMENTS
K. D. Groom and G. W Brooks *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov 1976 16 p refs (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

Screening tests, for improving avionic equipment cooling, were conducted to identify limits and deficiencies in current crew station instrument panel cooling systems and to investigate advanced cooling systems which extend or remove those limits. A test article simulating an engine instrument panel was constructed. The advanced concepts have cooling designed into the instrument panel structure; one includes a simplified retaining method for the units. Significant results for the baseline concept (current) are cascading temperature effects and thermal sensitivity to the uncontrolled airspaces behind the units which limit them to low power units Author

N77-16042# National Aerospace Lab., Amsterdam (Netherlands)
THE COOLING OF A POD-MOUNTED AVIONIC SYSTEM
I. DeBoer *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov 1976 6 p (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

During the flight testing of a pre-production reconnaissance system, unexpected cooling problems were encountered. These problems, which had not been experienced during previous prototype tests, could be shown to originate in the flush air intake. By changing to a flush air intake with parallel side walls the cooling system could be made to perform to entire satisfaction in the series. Author

N77-16043# Normalair-Garrett Ltd., Yeovil (England).
EFFICIENT SOURCES OF COOLING FOR AVIONICS
G. R. Giles and G. F Stevenson *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov 1976 19 p refs (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

The penalties and design constraints which can be applied with advantage to avionics cooling are discussed. These range from orthodox air cycle bleed air systems to those utilizing ram air only for their power supply. The emphasis is on systems designed specifically for avionics cooling with minimum overall aircraft penalty. The effect of the aircraft operational role is also discussed. Author

N77-16044# Departement Systemes Advances Aerospatiale, Toulouse (France).
THE COOLING OF AVIATION EQUIPMENT ON BOARD COMMERCIAL AIRPLANES [LE REFROIDISSEMENT DE L'EQUIPMENT AVIONIQUE A BORD DES AVIONS COMMERCIAUX]
Pierre M Desjean *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 20 p In FRENCH (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

Feasibility, cost, complexity, weight, and maintenance are factors to be compromised when considering the cooling of avionic equipment on commerical aircraft. Problems encountered in designing the cooling system for the Concorde and the Airbus are discussed. The new concepts for installation (N.I.C.) propose methods for handling the growing complexity of electronic equipment using techniques developed for spatial utilization. Cooling by conduction, by liquid, and by boiling are considered. Transl. by A.H

N77-16045# Hawker Siddeley Aviation Ltd., Kingston upon Thames (England).
PERFORMANCE ASSESSMENT OF THE CONDITIONING SYSTEM FOR THE AVIONIC EQUIPMENT BAY OF A SMALL HIGH SUBSONIC MILITARY AIRCRAFT
R. LeClaire *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 23 p (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

Engine bleed air is cooled by ducting it through a heat exchanger (in which heat is rejected to ram air) and a cold air unit, in which the work done by the air expanding through the turbines is absorbed by a fan inducing ram air through the heat exchanger. The cold bleed air is then mixed with uncooled bleed air in proportions governed by a temperature control valve which ensures that air is supplied to the equipment compartment at the lowest temperature which would prevent any risk of condensation. Author

N77-16046# General Dynamics/Fort Worth, Tex
THE EFFECT OF AVIONICS SYSTEM CHARACTERISTICS ON FIGHTER AIRCRAFT SIZE, COOLING, AND ELECTRICAL POWER SUBSYSTEMS
S. Keith Jackson, Jr. *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 13 p ref (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

The effect of avionic systems electrical power and cooling requirements on overall aircraft size and life cycle cost are considered. Power and cooling requirements typical of advanced fighter aircraft are first defined, their direct weight and cost influences are then estimated, and a simplified parametric analysis is used to determine the compounding effects on the engine and airframe characteristics brought about by the aircraft growth curve. It is shown that overall weight and cost effects are significant, particularly when considered in the context of total program life cycle cost. It is found that technology developments should emphasize system weight reductions Author

N77-16047# Royal Signals and Radar Establishment, Malvern (England).
COOLING OF ELECTRONIC EQUIPMENT IN RELATION TO COMPONENT TEMPERATURE LIMITATIONS AND RELIABILITY
G. German *In* AGARD Avionic Cooling and Power Supplies for Advanced Aircraft Nov. 1976 10 p (For primary document see N77-16031 07-05)
Avail: NTIS HC A11/MF A01

The temperature limitations of electronic components are discussed together with the influence of temperature on the reliability of the equipment and its component parts. The thermal performance of two representative avionic designs are compared and the influence of continuing solid state device developments on future equipment heat loads is considered. The limitations of air as a heat transfer medium are examined and a comparison made with liquid cooling. Author

X76-70675 Advisory Group for Aeronautical Research and Development, Paris (France).
AIRCRAFT DESIGN INTEGRATION AND OPTIMIZATION, VOLUME 2
Sep. 1973 1 p
(AGARD-CP-147-VOL-2) NATO-Classified report

NOTICE: Available to U.S. Government Agencies and Their Contractors.

Classified papers were presented at a meeting of the FMP. Technical and operational characteristics of RPV weapon systems were presented in a session on design integration; design features of air combat were also discussed. Author

X77-72040 Advisory Group for Aerospace Research and Development, Paris (France).
APPLICATION OF UNMANNED AIRCRAFT
Apr. 1975 486 p
(AGARD-R-79, AASC-Study-4) Avail: Advisory Group for Aerospace Research and Development, Paris, France
NATO-Classified report

NOTICE. Available to U S Government Agencies.

The operational concept is one of complementing tactical air forces by employing unmanned aircraft (UMA) to carry out conventional attacks against vital counter-air targets. A UMA modular design configuration was used which permits easy conversion to alternate missions and provides a step by step advancement from an attack drone to an attack remoted piloted vehicle and finally to the more sophisticated autonomous terminal attack drone. The UMA system capabilities were analyzed quantitatively by considering the subsytems, the total system, cost, weapons, delivery, survivability/vulnerability, and life cycle cost. Major technology areas requiring additional efforts in order to achieve the capability to perform the postulated missions effectively were identified Author

06 AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices, and flight instruments. For related information see also *19 Spacecraft Instrumentation* and *35 Instrumentation and Photography*

N74-18833# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD FLIGHT TEST INSTRUMENTATION SERIES, VOLUME 5: MAGNETIC RECORDING OF FLIGHT TEST DATA
G. E. Bennett, W. D. Mace, ed., and A. Pool, ed. Feb. 1974 80 p refs
(AGARDograph-160-Vol-5; AGARD-AG-160-Vol-5) Avail: NTIS HC $7.00

An assessment of the general requirement for a flight test data acquisition system is followed with a general discussion of the complete system. The more important individual functions of the system are those most intimately involved in determining the performance of the system and its efficiency in acquiring the data. In the case of the recording aspects emphasis is placed on the basic recording process, its capabilities and its problems, and on the techniques necessary to overcome its shortcomings. Basic design principles of airborne tape transports and the characteristics of write/read heads and magnetic tape are also discussed. Author

N74-25933# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD FLIGHT TEST INSTRUMENTATION SERVICES, VOLUME 1: BASIC PRINCIPLES OF FLIGHT TEST INSTRUMENTATION ENGINEERING
A. Pool, ed. and D. Bosman, ed. Apr. 1974 168 p refs
(AGARDograph-160-Vol-1; AGARD-AG-160-Vol-1) Avail. NTIS HC $11.50

Monographs on the more important aspects of flight test instrumentation are presented. The subjects discussed include: (1) in-flight temperature measurements, (2) fuel flow and engine rotation speed measurements, (3) open and closed-loop accelerometers, and (4) magnetic tape recording. The main emphasis is on large automated instrumentation systems for the initial flight testing of modern military and civil aircraft. The overall areas of consideration are the design of the instrumentation system, the characteristics of the individual measuring channel, and the integration of the individual data channels into one data collection system. For individual titles, see N74-25934 through N74-25945.

N74-25934 British Aircraft Corp., Preston (England).
THE USERS' REQUIREMENTS
M. L. Henney *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 9 p refs (For availability see N74-25933 15-14)

The process for determining the general requirements for a flight test instrumentation system is discussed. The manner in which the requirements are derived is indicated by considering the test planning process and data analysis. Specific requirements arising in various categories of tests are detailed. Explanation of the data analysis requirements is given. The application of the selection process to flight tests of uncertificated and certificated aircraft is compared. Author

N74-25935* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
AN INDUCTION INTO THE DESIGN OF FLIGHT TEST INSTRUMENTATION SYSTEMS
B. L. Dove *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 9 p refs (For availability see N74-25933 15-14)

The development of flight test instrumentation systems based on specific requirements for the flight tests is discussed. The factors which influence the instrumentation system design are described. The use of a measurements list as a device for determining flight test requirements is explained. A block diagram of a typical flight test instrumentation system is provided. The effects of factors such as cost, schedule, personnel, accuracy, environmental qualifications, and reliability are analyzed. Author

N74-25936 Centre d'Essais en Vol, Bretigny-sur-Orge (France).
METEOROLOGICAL CHARACTERISTICS OF A MEASURING CHANNEL
J. Idrac *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 11 p refs (For availability see N74-25933 15-14)

An analysis of the fundamental characteristics of a measuring process is provided. The technical aspects of designing a measuring channel are discussed. The phases in a measuring operation are explained. The errors in measurement are analyzed to show the type of errors, the shape of the distribution curve, and the effects of various degrees of error. Curves are developed to show the amplitude and response characteristics of flight instrumentation systems. Author

N74-25937* National Aeronautics and Space Administration. Flight Research Center, Edwards, Calif.
TRANSDUCERS
L. H. Weirather *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 14 p refs (For availability see N74-25933 15-14)

The use of transducers in the measuring channels of flight test instrumentation systems is discussed. Emphasis is placed on transducers with an electrical output. The physical effects used for producing the electrical outputs are defined. Diagrams of the various types of transducers are included to show the operating principles. Author

N74-25938 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
SIGNAL CONDITIONING
W. G. James *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 15 p refs (For availability see N74-25933 15-14)

The signal conditioning of transducer signals obtained during flight test data recording is discussed. The linear operations performed on the signal are defined. Signal conversion techniques based on amplitude modulation, frequency modulation, pulse duration modulation, and pulse code modulation are analyzed. Circuit diagrams of signal conditioning systems are provided. Author

N74-25939 Radiation, Inc., Melbourne, Fla.
SAMPLING AND FILTERING
L. W. Gardenhire *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 13 p refs (For availability see N74-25933 15-14)

The characteristics of data sampling and filtering systems used in flight test instrument systems are described. The different approaches of data compression, redundancy reduction, and asynchronous sampling are analyzed. The errors of commission and aliasing are analyzed to show the effects on system accuracy. Curves are developed to compare frequency against attenuation for various data recording systems. Author

N74-25940 Boeing Co., Seattle, Wash.
CALIBRATION
D. A. Tougas *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 9 p refs (For availability see N74-25933 15-14)

The various types of calibration which are used with flight test instrumentation systems are described. The conditions under which limited calibration procedures may be applied are defined. The choice of the calibration standard and the points used in system calibration are analyzed. The calibration of a test instrument or measurement system for environmental parameters is emphasized. Author

N74-25941 Boeing Co., Seattle, Wash.
TECHNICAL ASPECTS IN THE DESIGN OF MULTI-CHANNEL DATA COLLECTION SYSTEMS
H. L. Tollisen and R. L. VanDerVelde (Natl. Aerospace Lab., Amsterdam) *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 18 p refs (For availability see N74-25933 15-14)

The technical requirements to be met in the design of multichannel flight test instrument systems are defined. It is stated that reliability and accuracy are the leading considerations in the choice of the components and the design of the system and the wiring. The selection of on board recording and telemetry equipment is analyzed. The design and development of data processing equipment are explained. A block diagram of a data collection system with common signal conditioners is provided. The procedure for integrating the main components into a complete system is discussed. Author

N74-25942 Societe de Fabrication d' Instruments de Mesure SFIM, Massy (France).
ON-BOARD RECORDING
C. Roquefeuill *In* AGARD AGARD Flight Test Instrumentation Ser., Vol 1 Apr 1974 12 p refs (For availability see N74-25933 15-14)

The recording methods used in flight test evaluations are discussed. The systems in general use are identified as: (1) photo panel recorders, (2) continuous trace recorders, (3) analog magnetic tape recorders, and (4) digital magnetic tape recorders. Advantages and disadvantages of the systems are analyzed. Block diagrams of a typical airborne analog magnetic recording system and an airborne digital magnetic recording system are provided
Author

N74-25943 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
TELEMETRY
A. Becker *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr 1974 13 p refs (For availability see N74-25933 15-14)

The telemetry component of a flight test instrument system is described. A block diagram of a typical telemetry system is provided. Curves are developed to show the modulation methods used with telemetry systems. Examples of supercommutation and subcommutation are illustrated. Systems of on-line data processing using analog computing methods, digital computing methods, and hybrid computing methods are discussed. Author

N74-25944 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
GROUND-BASED EQUIPMENT a11
O. Weber *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 11 p refs (For availability see N74-25933 15-14)

The ground based equipment, often in combination with airborne telemetry equipment, is discussed from the standpoint of trajectory measurement. An important aspect of ground based equipment is time synchronization with recordings made on board the aircraft. The capabilities of a trajectory measuring system are explained. The selection of a site and the procedure for setting up the equipment are analyzed. The methods used to obtain synchronization of the recording devices are reported.
Author

N74-25945 Centre d'Essais en Vol, Bretigny-sur-Orge (France).
DATA PROCESSING
J. Perrochon and J. T. M. VanDoorn *In* AGARD AGARD Flight Test Instrumentation Ser., Vol. 1 Apr. 1974 14 p refs (For availability see N74-25933 15-14)

A functional analysis of the data processing systems used for flight test instruments is presented. The types of data input are identified. Preprocessing of data is discussed and the main functions of the procedure are reported. Medium sized and large stations with a relatively large amount of automation, are emphasized.
Author

N74-33948# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD FLIGHT TEST INSTRUMENTATION SERIES, VOLUME 6: OPEN AND CLOSED LOOP ACCELEROMETERS
I. McLaren (RAE), W. D. Mace, ed., and A. Pool, ed. Jul. 1974 46 p refs
(AGARD-AG-160-Vol-6; AGARDograph-160-Vol-6) Avail: NTIS HC $5.50

The state-of-the-art of both open and closed loop accelerometers used for aircraft flight test work, covering system and component analysis and basic hardware design is discussed. Both physical design problems and mathematical analysis are covered and special emphasis is put on those aspects likely to be relevant to aircraft flight test work. Performance details include repeatability, compensation for temperature variation, insusceptibility to cross effects, stability under vibration and frequency response. The application of accelerometers in several flight test techniques together with their performance requirements are reviewed in order to guide the flight test engineer in making his choice of instrument in any particular case. The principles of frequency response tests are discussed in association with the theoretical characteristics of various, nominally, second order systems which are modified either by the method of testing or by the inherent, practical difficulties of instrument design.
Author

N76-17107# Advisory Group for Aerospace Research and Development, Paris (France).
ELECTRONIC AIRBORNE DISPLAYS
Dec. 1975 430 p refs In ENGLISH and FRENCH Presented at the Avionics Panel Symp., Edinburgh, 7-11 Apr. 1975
(AGARD-CP-167) Avail: NTIS HC $11.75

Problems of airborne displays were considered. Reports in the following areas were presented: trends in the field of airborne displays, evaluation and assessment procedures for airborne display systems, display devices and materials, data processing, and displays for particular applications. For individual titles, see N76-17108 through N76-17140.

N76-17108 Thomson-CSF, Malakoff (France). Div. des Equipements Avioniques.
THE IMPACT OF MODERN ELECTRONIC AIRBORNE DISPLAYS IN FUTURE AVIATION
Y. Brault *In* AGARD Electron. Airborne Displays Dec. 1975 8 p In FRENCH (For availability see N76-17107 08-06)

The expected impact of modern electronic airborne display systems on future aircraft was presented, with emphasis on the need to improve man-machine interactions, especially in military aviation. The need is imposed by the following factors: (1) the setting of more and more complex operational flying missions, (2) the introduction of aircraft (interceptors, fixed and rotating wing attack models) with ever higher performance, (3) the introduction of more and more diversified weapon systems, (4) the existence of an extremely lethal and complex environment. Future applications to civil aviation were also briefly mentioned.
Transl. by Y.J.A.

N76-17109 Marconi-Elliott Avionic Systems Ltd., Rochester (England).
TRENDS IN TECHNOLOGY IN AIRBORNE ELECTRONIC DISPLAYS
P. A. Hearne *In* AGARD Electron. Airborne Displays Dec. 1975 16 p (For availability see N76-17107 08-06)

The increasing complexities and capabilities of flight instruments are discussed with emphasis on future display technology. Cathode ray tube and solid state displays are examined along with the organization of the displays for providing an integrated electronic system.
F.O.S.

N76-17110 Smiths Industries Ltd., Bishops Cleeve (England). Advanced Displays Studies Group.
PERFORMANCE REQUIREMENTS FOR AIRBORNE MULTIFUNCTION DISPLAY SYSTEMS
G. Mann *In* AGARD Electron. Airborne Displays Dec. 1975 6 p refs (For availability see N76-17107 08-06)

Any airborne multifunction display must by definition be capable of presenting information from a variety of sensors and data sources. Some of these sensors and their critical parameters are briefly considered in relation to their display requirments. The multifunction display may need to be compatible with any such sensor or source and also with computer generated symbology derived from instrumentation sensors and weapon systems. The input sources which appear to require the highest performance from airborne displays are those of the current and future image forming sensors. There is a danger that many systems using multifunction displays could be display limited unless the complex interaction between sensor, display and observer is understood.
Author

N76-17111 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).

COMPARISON OF CONVENTIONAL AND ADVANCED AIRCRAFT DISPLAYS

Ralf Beyer (Techn. Univ., Brunswick) *In* AGARD Electron. Airborne Displays Dec. 1975 7 p refs (For availability see N76-17107 08-06)

The comparison of conventional and advanced aircraft displays often requires a discrimination of two sample means of pilot's performance and workload measures for a limited sample size, a postulated minimum difference of means and a given error probability. Under these conditions significant results may be obtained only if the population variance does not exceed a certain limit. Some major sources of variability and their influence on the significance of experimental results are discussed. Furthermore two different philosophies of evaluation of displays are presented as well as some experiences with pilot's performance and workload measures employed in flight simulator and inflight investigations of displays. Author

N76-17112 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugfuehrung.

EFFICIENT ASSESSMENT AND OPTIMIZATION OF DISPLAY LAYOUT BY CONTINUOUS TACHISTOSCOPY

Josef Thomas and Ulrich Stolzke *In* AGARD Electron. Airborne Displays Dec. 1975 12 p refs (For availability see N76-17107 08-06)

The method of continuous tachistoscopy and its benefits in the design process of electronic airborne display layout are described. A typical application in the field of advanced monitor displays is presented. The results of this experiment show the suitability of the proposed investigation method for a straightforward assessment and optimization of complex display arrangements in simulator tests, herewith contributing to a considerable reduction of expensive inflight testing. Author

N76-17113 Thomson-CSF, Paris (France). Groupement Tubes Electroniques.

COLOR AND BRIGHTNESS REQUIREMENTS FOR COCKPIT DISPLAYS PROPOSAL TO EVALUATE THEIR CHARACTERISTICS

J. P. Galves and J. Brun *In* AGARD Electron. Airborne Displays Dec. 1975 8 p ref In FRENCH; ENGLISH summary (For availability see N76-17107 08-06)

Introduction of color coding for information displays added several qualities to the already existing monochromatic electronic aircraft display. The information density to be displayed is increased, and the data acquisition time and the error possibilities are reduced. These advantages are fundamental in order to display graphic and numerical informations and lighted areas for jet plane flights control (map display, hud). These informations have to be detected by the pilot for every surround illumination level. An experimental work schedule, associating brightness and chrominance measurements on one hand, and visual perception of operators on the other, permitted to separate different parameters and to formulate several definitions about brightness and color contrast, the interaction between these two parameters and their measuring conditions. 'Detection Index' and 'Discrimination Index' notions are introduced. These parameters can be measured and permit to easyly evaluate the display quality for every background and surround illumination. Minimum index values are proposed for a confortable detection and identification of standard symbols especially in the case of direct sunlight on the displaying board. Color display used is a color CRT with a penetration screen developed by THOMSON-CSF for 'Head down' and 'Head up' display. Definition and standard introduced can be applied to every color or monochromatic display such as plasma panel, liquid crystals, LED or any electromechanical devices. Author

N76-17114 Ferranti, Ltd., Edinburgh (Scotland).

INTEGRATED MULTI-FUNCTION COCKPIT DISPLAY SYSTEMS

J. M. Braid *In* AGARD Electron. Airborne Displays Dec. 1975 13 p refs (For availability see N76-17107 08-06)

The multifunction display concept and the necessity for its efficient integration to meet the more demanding future tasks are defined briefly. Attention is drawn to the potential shortcomings of past arrangements, particularly in the pilot's cockpit. The different data sources and sensors, categories of airborne display, display devices and types of drive signals are described and reference is made to their compatibility. Particular mention is made of cursive, raster and cursive-on-raster writing. An example is given of how the various elements in the system can be integrated with integrity, into a system which permits more attention to be paid to the achievement of a satisfactory man-machine interface, without compromising individual sensor performance. Diagrams and photographs demonstrate the feasibility of the concept and compatibility of the hardware within the cockpit constraints. Pitfalls facing the implementation of such a system are included and the probable areas of conflict and reward are established. Author

N76-17115 Royal Aircraft Establishment, Farnborough (England). Space Dept.

THE USE OF MODERN LIGHT EMITTING DISPLAYS IN THE HIGH ILLUMINANCE CONDITIONS OF AIRCRAFT COCKPITS

Brian Ellis and John Wharf *In* AGARD Electron. Airborne Displays Dec. 1975 11 p refs (For availability see N76-17107 08-06)

A 3 mm high LED display was tested in 80,000 lux. Further tests on the format and color of small matrix displays are also described. It was found that red displays are more legible than green in 10,000 lux. A number of other aspects of the perception of light emitting displays in high illuminance were also examined. Author

N76-17116 Transportation Systems Center, Cambridge, Mass.

AN EXPERIMENTAL EVALUATION OF VARIOUS ELECTRONIC COCKPIT DISPLAYS FOR AIR/GROUND DATA LINK COMMUNICATIONS

R. W. Wiesler, J. F. Canniff, and E. H. Hilborn *In* AGARD Electron. Airborne Displays Dec. 1975 34 p refs (For availability see N76-17107 08-06)

A series of laboratory and cockpit simulator experiments was conducted by the Department of Transportation, Transportation Systems Center in a study of the human factors aspects of a cockpit digital data link system for air traffic control (ATC) and airline company business communications. The laboratory experiments utilized photographic slides to study message formatting. The simulator experiments evaluated visual displays, computer generated synthetic speech and pilot input devices. The potential of data link for reducing pilot workload and channel congestion while providing efficient communications in a highly automated ATC system is of great interest to the Federal Aviation Administration. The experimental results to date led to the recommendation of a 16-character short message display, development of some guidelines for abbreviating and formatting messages, and the conclusion that pilots can effectively communicate using visual displays, synthetic speech, and pushbutton keysets, with an overall reduction in workload. Author

N76-17117 Thomson-CSF, Issy les Moulineaux (France). Groupe Optronique.

NEW ELECTRONIC DISPLAY SYSTEMS FOR AIRCRAFT INSTRUMENT PANELS [NOUVEAUX DISPOSITIFS DE VISUALISATION ELECTRONIQUE SUR PLANCHES DE BORD D'AVIONS]

M. Coussediere *In* AGARD Electron. Airborne Displays Dec. 1975 7 p In FRENCH (For availability see N76-17107 08-02)

Concepts for new electronic display systems for aircraft instrument panels were proposed, emphasizing the need to integrate and synthesize the information presently given by a number of different instruments. These new systems can either take the form of 'head-up' or 'head-down' display devices depending on the type and phase of each flight or mission. Such systems would present the following advantages: (1) presentation of more information in less space, (2) presentation of the information that is only required during a specific flight or mission situation, (3) greater flexibility and large information carrying capacity, (4) presentation of the instantaneous position of the aircraft and prediction of its future flight path. The hardware used in the construction of these display systems could either be based on the present state of the art and include multicolored CRT's, or could include new techniques now under study such as plasmas or liquid crystals. Transl. by Y.J.A.

N76-17118 Ferranti, Ltd., Oldham (England).

CRT'S FOR ELECTRONIC AIRBORNE DISPLAYS

M. R. Bennett *In* AGARD Electron. Airborne Displays Dec. 1975 13 p refs (For availability see N76-17107 08-06)

The two CRT display systems currently under development are described. The first is a packaged 178 x 127mm head down display (HDD) CRT. The design concept and subsequent selection of the various alternative parameters which were available at the start of the development are described. Each parameter is taken separately and the analysis and subsequent results are described. Full details are given of a final package design currently nearing completion which is intended to be fitted into a Hawker

Hunter aircraft of RAE Farnborough for flight trails to evaluate the performance under real direct sunlight and sunlit cloud conditions. The prime design consideration for this CRT was the combination of a suitable contrast enhancement technique together with the best currently available phosphor for operation at high brightness levels. The second CRT package described was again developed using a number of individual steps to optimize the design for a particular application. In this case the application was for a helmet mounted head up display (HMHUD) CRT. Reduced weight and size were necessary in order to harmonize with the current helmet display concepts. This CRT was based on a commercial tube 02B/97D2Kh and the VX1776 designs which preceded it. The individual parameters are analyzed separately. Author

N76-17119 Thomson-CSF, Paris (France). Groupement Tubes Electroniques.
COLOR HEAD DOWN AND HEAD UP CRT'S FOR COCKPIT DISPLAYS
A. Martin and J. Brun *In* AGARD Electron. Airborne Displays Dec. 1975 8 p In FRENCH; ENGLISH summary (For availability see N76-17107 08-06)

Important development work, during several years, led to the use of color CRT in cockpit displays. The characteristics of these tubes and their behavior in airplanes are discussed. A separate program allowed the measurement of illumination range found during flight, for determining visibility conditions of instrument boards from complete darkness to sunlight illuminance. A simulator was built which reconstitutes the lighting conditions. Color display, incorporating color CRT, allowing simultaneous presentation of symbols in several colors, luminance and shape were tested. Measurements of detection index, as described in another lecture, were carried on to evaluate conditions of perfectly confortable vision and conditions of 100% accuracy indication of color symbols displayed by color CRT. A 7 inch diagonal rectangular color CRT THX613-E17, meeting these specifications was developed for head down utilization. The tube incorporates a penetration screen displaying red at 10 kV, amber at 13 kV and green at 17 kV. The electron gun was designed to face beam intensity requirements at all colors and symbol luminances. An electrostatic focusing with zero current need, with focus voltage linearly dependent of screen voltage just requests single high voltage power supply for tube drive. The CRT is ruggedized and double heater gun has been adapted in order to increase reliability. Under sunlight illumination (7,000 fc), detection index over 1 were achieved, and detection index over 2 allowing very confortable vision were obtained in other less stringent conditions. Author

N76-17120 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio. Flight Deck Development Branch.
SOLID STATE FLIGHT INSTRUMENT DEVELOPMENT
Wayne R. Clements *In* AGARD Electron. Airborne Displays Dec. 1975 4 p (For availability see N76-17107 08-06)

An Air Force Advanced Development Program is investigating the applicability of dot matrix displays for flight control instrumentation. Program goals include flat panel design, digital addressability, format flexibility and multi-function operability. Validation of the technology was reported and addressed the areas of technology selection and fabrication techniques, optical contrast enhancement filtering, and dot matrix standards for legibility and design. The light emitting diode (LED) technology was selected as it fulfilled program objectives and did not require a research breakthrough prior to application. Fabrication techniques were demonstrated and are within the realm of a high volume production method. Acceptable contrast enhancement via filtering resulted from the combination of a circular polarizer, band pass element, and antireflective coatings. A contrast ratio of 6:1 under the high ambient condition, i.e., 10,000 foot candles (fc), can be achieved. Human factors studies showed little, if any, performance differences between the display of punctate and continuous symbology. Author

N76-17121 Royal Radar Establishment, Malvern (England).
LIQUID CRYSTAL DISPLAY DEVICES
E. P. Raynes *In* AGARD Electron. Airborne Displays Dec. 1975 14 p refs (For availability see N76-17107 08-06)

Liquid crystals enable low voltage (approximately 3 volt) low power (approximately 1 micro-W) displays to be made which are readable in high ambient light level and can be as large as 30 cms by 30 cms. After a brief introduction to the liquid crystalline state, the basis and the operation are described of the twisted nematic effect, which has become the most widely used liquid crystal electro-optic effect. Basic device construction is also reviewed. The origin of patches of different contrast in these devices is discussed together with methods of eliminating them to produce devices with uniform contrast. Considerable progress has been made since the invention of the cyanobiphenyls in producing stable, colorless, low viscosity liquid crystals usable over the temperature range of -10 to +60 C. This progress is reviewed. The problems encountered with the extended temperature range required for cockpit displays and the displaying of complex alpha-numeric information is examined. Author

N76-17122 Royal Radar Establishment, Malvern (England).
MULTICOLOUR DISPLAYS USING A LIQUID CRYSTAL COLOUR SWITCH
Ian A. Shanks *In* AGARD Electron. Airborne Displays Dec. 1975 11 p refs (For availability see N76-17107 08-06)

The conversion of a monochrome CRT display to a two color frame sequential display was demonstrated using a flat liquid crystal electro-optical color switch. The use of a similar device as a polarization switch permitted the production of a frame sequential stereoscopic CRT display which may be monochrome or color. Switching speeds of 1 msec at repetition rates up to 40 Hz are achieved by using an appropriate two frequency drive to the liquid crystal cell. This is sufficiently fast to meet frame sequential requirements. The construction, properties and performance of these devices are described and their advantages and limitations are discussed in relation to cockpit displays and other military applications. Author

N76-17123 Services Electronics Research Lab., Baldock (England).
ELECTRONICALLY-CONTROLLED LIQUID-CRYSTAL GRATICULES FOR USE IN OPTICAL SYSTEMS
C. H. Gooch and R. C. Bottomley *In* AGARD Electron. Airborne Displays Dec. 1975 8 p refs (For availability see N76-17107 08-06)

In a number of optical systems there is a requirement for a graticule whose position in the field of view can be controlled electronically. This may be achieved by a liquid crystal device addressed by MOS circuits built onto the display. The device described gives a graticule display of 400 x 150 lines and achieves a resolution of 10 lines/mm. Author

N76-17124 Sperry Rand Corp., Phoenix, Ariz.
RECENT HARDWARE DEVELOPMENTS FOR ELECTRONIC DISPLAY SYSTEMS FOR US MILITARY AIRCRAFT
Richard A. Wallace *In* AGARD Electron. Airborne Displays Dec. 1975 12 p (For availability see N76-17107 08-06)

The hardware design tradeoffs required to meet the varied requirements of several CRT cockpit display systems are discussed. The multimode display systems use both stroke and raster techniques to present varied formats of data from radar, TV, IR, attitude, fire control, flight director, and other aircraft systems. These display requirements are translated into CRT, phosphor-filter, high voltage, video, deflection, and symbol generator requirements. Power and thermal considerations are emphasized as a primary factor in various tradeoff studies. Digital symbol generation is examined in terms of hardware functional, speed, and memory size requirements. Author

N76-17125 Royal Radar Establishment, Malvern (England).
DIGITAL SCAN CONVERSION TECHNIQUES
T. Snowball and T. R. Berry *In* AGARD Electron. Airborne Displays Dec. 1975 19 p refs (For availability see N76-17107 08-06)

The Digital Semiconductor Scan Converter, and the factors determining the storage capacity required are discussed in terms of sensor and display CRT resolution, picture texture and observer acuity. A versatile experimental digital scan converter with a one megabit storage capacity, having various modes of store organization and display presentation is described. Author

N76-17126 Royal Radar Establishment, Malvern (England).
POLAR TO CARTESIAN AXIS-TRANSFORMING DIGITAL SCAN CONVERTERS
T. R. Berry and T. Snowball *In* AGARD Electron. Airborne Displays Dec. 1975 25 p ref (For availability see N76-17107 08-06)

Ways in which digital scan converters can improve on conventional radar display formats are examined and how a display can be extended to give presentations not previously available is shown. The major limitations of scan converters based on shift registers are discussed, in particular where such converters are required to transform polar radar formats to rectilinear TV. It is then shown how the introduction of the fast semi-conductor

random access Memory (RAM) has made the axis-transformation problem a relatively straightforward hardware implementation of conventional axis-conversion formulae. Special display and conversion problems associated with moving platform systems are outlined, and techniques for applying motional stabilization to the converter to facilitate scan to scan integration discussed. The organization of such ground stabilized converters to provide a choice of ground or platform stabilized displays are then described. Finally, the limitations of a simple system based on a single picture point update per store word access (spot at a time transfer) is considered, and a more complex organization which allows for more than one spot to be updated at a time is outlined. Author

N76-17127 Hughes Aircraft Co., Culver City, Calif.
DIGITAL SCAN CONVERTERS IN AIRBORNE DISPLAY SYSTEMS
G. K. Slocum and J. O. Mysing (AFAL) *In* AGARD Electron. Airborne Displays Dec. 1975 18 p (For availability see N76-17107 08-06)

Recent developments in digital scan converters (DSC) provide high quality image storage for avionics sensor displays and can simplify the pilot's tasks in radar target acquisition. Typical digital scan converter concepts and their system design implications are described for an air-to-air radar, a multimode radar and a high resolution reconnaissance sensor. Studies of operator performance in using stored digital imagery with various encoded gray levels show eight shades of gray are adequate for radar imagery but at least 16 are needed for electro-optical imagery. Tradeoffs in memory selection and digital image enhancement techniques are presented. The cost of ownership analysis shows that the high reliability, low maintenance adjustments and short repair time of digital scan converters can result in significant life cycle cost savings over analog scan converter display systems. Author

N76-17128 Marconi-Elliott Avionic Systems Ltd., Rochester (England).
ECONOMIC SCAN CONVERSION TECHNIQUES FOR INTEGRATED AVIONIC SYSTEMS
G. C. Bull and G. M. Barling *In* AGARD Electron. Airborne Displays Dec. 1975 8 p (For availability see N76-17107 08-06)

Modern cockpit display systems are making increasing use of TV raster techniques to provide a common signal format for a wide range of differing types of computed and sensor data. A principal feature of such systems is the necessary scan conversion units which should provide accurate translation of data and video picture inputs into the common raster display base. Earlier double ended scan conversion tubes have been found to have almost unacceptable problems in terms of accuracy, dynamic range and picture registration. A new technique using a tube scan converter of the single electron gun type avoids many of the problems of the earlier double ended type and permits the conversion of high resolution video pictures without the relatively high costs of the large memory requirements of equivalent digital scan converters. When however the conversion picture subject is limited in size, a new digital technique has considerably reduced the memory requirements compared with those necessary for video picture conversion. By relating the scan conversion technique to the particular task in hand, it appears probable that the cost of future scan converters can be reduced to a small proportion of the overall display system cost. Author

N76-17129 Draper (Charles Stark) Lab., Inc., Cambridge, Mass.
DISPLAY GENERATOR INSTRUCTION SET CONSIDERATIONS FOR AEROSPACE APPLICATION
Ivan S. Johnson and Stephen K. Holford *In* AGARD Electron. Airborne Displays Dec. 1975 11 p refs (For availability see N76-17107 08-06)

A tradeoff study to determine desirable characteristics in a display processor for an aerospace (space shuttle) application is reported. The assumed display device is a conventional CRT. The tradeoffs involved in specifying which instructions should be implemented in the display processor's hardware repertoire are presented. The importance of such a tradeoff focuses primarily upon the resultant software costs (size, speed of execution, time to write and de-bug) incurred as a function of whether certain instructions are implemented in the processor hardware. Other factors are size, weight, reliability, processor/display unit speed relationships, and memory implications. The tradeoff study of possible graphics capability includes most of the instructions that an aerospace display generation scheme would be confronted with - including vectors, alpha-numerics, beam control instructions (e.g., blinking, dash lines, line width, etc.) index branch, subroutine call and return, compare and skip, rotation, windowing, and special items like moving tape meter. Author

N76-17130 EMI Electronics Ltd., Hayes (England).
INTEGRATION ALGORITHM IN A DIGITAL DISPLAY STORE FOR AIRBORNE SURVEILLANCE RADAR
V. B. Hulme *In* AGARD Electron. Airborne Displays Dec. 1975 27 p refs (For availability see N76-17107 08-06)

A search for optimum integration algorithms in a multicell digital display processor for airborne surveillance and search radar is discussed. Markovian statistics are applied to evaluate performance in terms of probabilities of detection and false alarm. Results are illustrated by probability graphs characterizing the alternatives examined and a selected range of parameters. The best are ranked in order of false alarm/detection probability ratio referred to the input, for a standard performance. It is concluded that algorithms employing a simple regular decrement are superior to proportional decrement algorithms or sum and dump integrators. Author

N76-17131 Air Force Avionics Lab., Wright-Patterson AFB, Ohio.
THE DAIS DESIGN AND SYSTEM INTEGRATION ASPECTS OF ELECTRONIC AIRBORNE CONTROLS AND DISPLAYS
Nicholas A. Kopchick and S. Joel Premselaar (Reedan Assoc., Inc.) *In* AGARD Electron. Airborne Displays Dec. 1975 20 p refs (For availability see N76-17107 08-06)

The Digital Avionics Information System (DAIS) encompasses the maximum utilization of electronic airborne controls and displays to present to the pilot all pertinent and timely information necessary for both normal and degraded mission operations. The salient features include a description of the DAIS: (1) operational and system requirements, (2) control/display subsystem configuration and functional operation, and (3) system and subsystem life-cycle cost considerations. Through the increased use of common digital avionic equipments and software modules, an effort is being made in this program to directly attack the problem of rising life-cycle costs while, at the same time, maintaining or increasing given performance levels. Results of recent DAIS design studies and system analyses, based on typical close air support and air superiority missions, conducted by the Air Force Avionics Laboratory are presented. Author

N76-17132 Marconi-Elliott Avionic Systems Ltd., Rochester (England). Airborne Display Div.
THE TYPE 664 HUD WEAPON AIMING SYSTEM
J. R. Muchin *In* AGARD Electron. Airborne Displays Dec. 1975 10 p ref (For availability see N76-17107 08-06)

Head up display systems incorporating general purpose digital computers are now in wide scale operational service and their effectiveness and reliability have been demonstrated in over 1,000,000 flying hours. Later developments of this type of system have expanded the role of the HUD computer to include many weapon aiming functions which have considerably improved weapon delivery effectiveness particularly in the air to air modes. The fire control system of the YF16 prototype air combat fighter is one of the most recent systems of this type and has proved highly effective in the Edwards AFB fly-off. The latest example of this type of system is the Marconi-Elliott 664 which further extends the capabilities by the use of a fast 8K, 16 bit computer. This equipment uses MSI and LSI technology and offers a significantly increased range of weapon delivery modes at a comparable cost to earlier simple HUD systems. Author

N76-17133 Ferranti, Ltd., Edinburgh (Scotland). Inertial Systems Dept.
THE APPLICATION OF ELECTRONIC AND COMBINED DISPLAYS TO GROUND MAPPING AND NAVIGATION
W. H. McKinlay *In* AGARD Electron. Airborne Displays Dec. 1975 5 p (For availability see N76-17107 08-06)

The evolution is reviewed of navigation displays and the growth of their pictorial content. Civil and military requirements are treated. Examples of a pictorial display for transport aircraft, and a Combined Display including topographical data for military aircraft are presented. Problems of data storage and the increasing need for color are mentioned. The combined display for military aircraft is introduced and it is pointed out in particular that it permits an evolutionary approach by pilots because it retains topographical data, yet presents many new possibilities because of its versatile electronic element. Some possible future developments are mentioned and the conclusion is drawn that certain real operational constraints may be as significant as the availability of more flexible technologies. Author

N76-17134 Ferranti, Ltd., Edinburgh (Scotland). Inertial Systems Dept.
COMED: A COMBINED DISPLAY INCLUDING A FUEL ELECTRONIC FACILITY AND A TOPOGRAPHICAL MOVING MAP DISPLAY
William M. Aspin *In* AGARD Electron. Airborne Displays Dec. 1975 11 p refs (For availability see N76-17107 08-06)

The design and construction of a new combined map and electronic display (COMED) developed for use in fighter/attack aircraft are described. The operational advantages of this type of display are discussed in the context of earlier and alternative types of combined display. The principle design aims of the COMED display are described, and how these aims have been met, is explained. Author

N76-17135 Technische Univ., Berlin (West Germany). Inst. fuer Luft und Raumfahrt.
ELANDIS: A VERTICAL SITUATION DISPLAY
Wolfgang Holstein *In* AGARD Electron. Airborne Displays Dec. 1975 6 p refs (For availability see N76-17107 08-06)

An interim report of a study of display requirements for final approach management of STOL-aircraft is presented. The proposal of this electronic landing display (ELANDIS) is based on the perspective view of the vertical situation of STOL-aircraft in landing. The concept allows a continuous surveillance of the automatic landing system and provides sufficient information which enables the pilot to carry out the landing manually (if desired or necessary in case of failure). Furthermore there is a brief description of the hardware configuration of the hybrid simulation system (HSS). In its present state the HSS consists of an analog computer EAI 580, a digital computer PDP-11/20, a graphic display terminal GT 40, a simulation cockpit and a magnetic tape station M88/Ampex. The software concept gives a general view of the dataflow. Author

N76-17136 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
ASTROLABE, AN INTEGRATED NAVIGATION AND LANDING AID SYSTEM: ON BOARD AND GROUND DISPLAY OF INFORMATIONS
Jacques Dorey and Guy Ringenbach *In* AGARD Electron. Airborne Displays Dec. 1975 8 p refs In FRENCH; ENGLISH summary (For availability see N76-17107 08-06)

ONERA is developing a microwave localization system, based on the properties of synthetic antennas, which permits the two-dimensional (azimuth and elevation), simultaneous analysis of large number of targets made of low power beacons. This system ensures airspace surveillance, and at the same time provides the pilot with a visualization of the surrounding terrain (e.g. runway boundaries) with the proper perspective. It permits the integration of various functions of ground control necessary to the pilot in blind navigation. The data processing and display devices are described associated with this system: an optic device, and an integrated digital device. The results are analyzed, and the application possibilities of the system are presented. Author

N76-17137 Marconi-Elliott Avionic Systems Ltd., Rochester (England).
A MULTI-SENSOR MULTI-FUNCTION DISPLAY FOR THE PANAVIA MULTI-ROLE COMBAT AIRCRAFT
D. W. Hussey *In* AGARD Electron. Airborne Displays Dec. 1975 12 p (For availability see N76-17107 08-06)

The weapon system operator's principal access to the wide range of raw sensor and processed data available on the MRCA was implemented by the development of an integrated electronic display system. The equipment is one of the first to solely utilize a standard television raster to display both synthetic tabular and graphical data in a form directly compatible with EO Sensor television video signals. An electronically labelled multifunction keyboard allows the crew member to access and update the computing system data in a wide variety of modes using the minimum of controls and panel space. The generation of synthetic symbols directly in the raster by modulation of the video signal is achieved by a novel form of time-shared digital techniques providing high accuracy and resolution with a considerable economy of hardware. A particular feature of the system is the elimination of staircasing of the raster generated graphics. Other aspects include the achievement of high resolution and contrast under conditions of extreme cockpit ambient illumination. The system forms the basis of a new range of head down displays which are being developed for a wide range of military aircraft types. Author

N76-17138 Thomson-CSF, Issy les Moulineaux (France). Groupe Optronique.
CHARACTERISTICS OF HEAD-UP DISPLAY SYSTEMS [CARACTERISTIQUES DU COLLIMATEUR DE TIR ET DE PILOTAGE (HUD)]
M. Martin *In* AGARD Electron. Airborne Displays Dec. 1975 4 p In FRENCH (For availability see N76-17107 08-06)

Development of second-generation head-up display systems coupled to large capacity computers that may provide not only a complex visual presentation but may also undertake all computations required for air-to-air and air-to-ground firing was reviewed. Further Applications of head-up display systems to civil aviation, primarily in relation to blind flying near ground level (automated landing approach) were also discussed. It was shown that the problem of integrating the computation and symbol generation functons for both military and civil applications may be treated similarly, although military applications tend to be more complex. A general purpose computer with a capacity of 6000 16 bit words would be adequate for these applications. Physical specifications of the image and field of view were given. Transl. by Y.J.A.

N76-17139 Royal Aircraft Establishment, Farnborough (England).
A PROGRAMMABLE RASTER-BASED DISPLAY SYSTEM FOR USE WITH ELECTRO-OPTICAL SENSORS
R. G. White (Marconi Elliott Avionic Sys. Ltd.) *In* AGARD Electron. Airborne Displays Dec. 1975 9 p refs (For availability see N76-17107 08-06)

An experimental airborne, programmable raster-based electronic display system is presented, capable of generating a variety of symbology and superimposing this on a picture of the outside world provided by a forward looking daylight or low light television camera. Examples of the symbology which can be generated by the display system are described in particular the initial symbology chosen for flight trails to investigate the potential of night vision sensors for low level, high speed flight at night. The philosophy of superimposing flight information on the picture from a night vision sensor is discussed, and it is concluded that superimposed symbology is necessary if an aircraft's night time capability is to be effectively extended. Author

N76-17140 Siemens A.G., Munich (West Germany).
WILL THE FUTURE ELECTRONIC AIRBORNE DISPLAY BE STEREOSCOPIC?
R. Stark *In* AGARD Electron. Airborne Displays Dec. 1975 17 p refs (For availability see N76-17107 08-06)

Research into a method of air traffic control aimed at the realization of a cockpit display which permits the pilot to participate actively in air traffic control is reported. The goal was the three-dimensional representation of airways and aircraft ahead, as seen by the pilot. The working conditions of the pilots were examined with the aid of a simulator and scenes featuring relevant traffic situations were shot for a 3D-film. The pilot depends on a microcomputer and a color display unit for the method proposed. Data supplied by ground stations and airborne sensors are stored and processed on-line, i.e. in step with the picture data. For this purpose the object coordinates are transformed to the aircraft position and projected onto the picture screen separately for the left and right eyes. The mathematics, simulation equipment and simulation programs are described. The time requirements and the volume of data transmitted and processed are assessed. The results favor a stereoscopic display. Author

N77-16050# Advisory Group for Aerospace Research and Development, Paris (France).
VISUAL PRESENTATION OF COCKPIT INFORMATION INCLUDING SPECIAL DEVICES USED FOR PARTICULAR CONDITIONS OF FLYING
G. Perdriel Nov. 1976 85 p refs Partly in FRENCH and ENGLISH Conf. proc. held at Athens, 20-24 Sept. 1976 (AGARD-CP-201; ISBN-92-835-0181-0) Avail. NTIS HC A05/MF A01

Cockpit human factor engineering is discussed describing display devices, navigational instruments, and weapon systems. Conditions such as: size determination, target recognition, imaging techniques, and pilot performance are discussed. For individual titles, see N77-16051 through N77-16059.

N77-16051# Royal Aircraft Establishment, Farnborough (England). Dept. of Flight Systems.
THE DEVELOPMENT OF AIRCRAFT INSTRUMENTS
E. J. Lovesey *In* AGARD Visual Presentation of Cockpit

Information Including Special Devices Used for Particular Conditions of Flying Nov. 1976 15 p refs (For primary document see N77-16050 07-06)
Avail: NTIS HC A05/MF A01

A brief history of the development of aircraft cockpit instrument layouts is presented listing some of the short-comings of current instrument displays. An indication of probable trends for future aircraft information presentations is also given. Author

N77-16052# Service Technique de l'Aeronautique, Paris (France)
EVALUATION OF COCKPIT LIGHTING [CRITIQUE DE L'ECLAIRAGE DES POSTES DE PILOTAGE]
L. D. Heynemann and J. P. Chevaleraud (Centre Principal d'Expertises Medicales du Personnel Navigant, Paris) *In* AGARD Visual Presentation of Cockpit Information Including Special Devices Used for Particular Conditions of Flying Nov. 1976 9 p In FRENCH (For primary document see N77-16050 07-06)
Avail: NTIS HC A05/MF A01

Present standards regarding the lighting of cockpits (instruments, control panels, instrument panels) are discussed. Some of these regulations are criticized in reference to flight conditions. Solutions concerning the presentation of flight information is described. Transl. by E.B.

N77-16053# Forschungsinstitut fuer Anthropotechnik, Meckenheim (West Germany).
COMPARATIVE EXPERIMENTAL EVALUATION OF TWO-DIMENSIONAL AND PSEUDO-PERSPECTIVE DISPLAYS FOR GUIDANCE AND CONTROL
In AGARD Visual Presentation of Cockpit Information Including Special Devices Used for Particular Conditions of Flying Nov. 1976 15 p refs (For primary document see N77-16050 07-06)
Avail: NTIS HC A05/MF A01

The relative advantages of two and three dimensional displays are discussed. A fixed base simulation of a Do 28 airplane was used. Performance and eyepoint of regard measures were recorded as well as subjective ratings. It is shown that in flying a complex mission both displays have about the same accuracy M.C.F.

N77-16054# Advisory Group for Aerospace Research and Development, Paris (France).
THE MALCOLM HORIZON
K. E. Money, R. E. Malcolm, and P. J. Anderson *In its* Visual Presentation of Cockpit Information Including Special Devices Used for Particular Conditions of Flying Nov. 1976 3 p ref (For primary document see N77-16050 07-06)
Avail: NTIS HC A05/MF A01

The Malcolm Horizon is a bar of light which shines across the instrument panel of an aircraft cockpit driven by motors so as to move in a manner corresponding to the real horizon outside the aircraft. The motion is controlled by servo-motors which are driven by signals derived from the gyro platform of the aircraft. A series of simulator trials and flight trials have been carried out on the device in an attempt to evaluate it and further develop it, and to evaluate aircrew performance while using the device. The trials showed that the bar of light is very compelling, is in constant view regardless of where the gaze may be directed and does not interfere with the normal reading of the instruments. All of the pilots who have flown with the Malcolm Horizon reacted positively and would welcome the addition of this device to the cockpit Author

N77-16055*# National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
GROUND-REFERENCED VISUAL ORIENTATION WITH IMAGING DISPLAYS: MONOCULAR VERSUS BINOCULAR ACCOMMODATION AND JUDGEMENTS OF RELATIVE SIZE
In AGARD Visual Presentation of Cockpit Information Including Special Devices Used for Particular Conditions of Flying Nov. 1976 9 p refs (For primary document see N77-16050 07-06)
Avail: NTIS HC A05/MF A01 CSCL 01D

Monocular and binocular judgement errors are discussed for various imaging media and techniques. The judgement errors of size and distance are described for computer and sensor generated displays. M.C.F.

N77-16056# Pacific Missile Test Center, Point Mugu, Calif.
TERRAIN FOLLOWING USING STEREO TELEVISION
In AGARD Visual Presentation of Cockpit Information Including Special Devices Used for Particular Conditions of Flying Nov. 1976 10 p refs (For primary document see N77-16050 07-06)
Avail: NTIS HC A05/MF A01

An experiment was conducted to determine whether low altitude, terrain following flight could be accomplished better with stereo television than with conventional two-dimensional television. Nine subjects, both pilots and nonpilots flew a simulated F-4 aircraft using only the information supplied by an air-to-ground television system. The simulation system consisted of 12- by 30-foot, 2,000:1 scale terrain model, a gantry system carrying the television camera, a moving base cockpit, and associated computer hardware that provided the proper control stick responses. The subject's task was to fly as low as possible across a 9 mile flight corridor without going below 250 feet above ground level. A single path that varied from sea level to 4,000 feet and at a constant airspeed of 300 knots was flown by all subjects. The subjects could control only the vertical dimension of the aircraft's flight Author

N77-16057# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE PRESENTATION OF CARTOGRAPHIC INFORMATION IN PROJECTED MAP DISPLAYS
In AGARD Visual Presentation of Cockpit Information Including Special Devices Used for Particular Conditions of Flying Nov. 1976 9 p refs (For primary document see N77-16050 07-06)
Avail: NTIS HC A05/MF A01

Human factors research on the information content, coding and utilization of maps and charts designed specifically for projected map displays is discussed. Particular issues are discussed such as clutter, color coding, red light legibility, relief representation, reverse format black maps and radar-map matching; general design principles are also derived. Author

N77-16058# Aerospace Medical Div. Aerospace Medical Research Labs. (6570th), Wright-Patterson AFB, Ohio.
MATRIX ELEMENT DISPLAY DEVICES AND THEIR APPLICATION TO AIRBORNE WEAPON SYSTEMS
In AGARD Visual Presentation of Cockpit Information Including Special Devices Used for Particular Conditions of Flying Nov. 1976 8 p refs (For primary document see N77-16050 07-06)
Avail: NTIS HC A05/MF A01

The impact of two important matrix display design variables on tactical target recognition performance is discussed. Element density (i.e., the number of individual display resolution elements per degree as viewed by the observer) and the percent active area on the display surface were experimentally manipulated by adjusting the viewing distance from a rear projection screen over which a grid mask was placed. The targets were presented to subjects using zoom imagery at a simulated slant range which initially precluded recognition. As the target size increased subjects were asked to press a remote projector control button when they were virtually certain of the correct response. The results indicate little effect of percent active area (i.e., down to 55 percent) on target recognition performance for element angular subtense values between 0.75 and 3.0 minutes of arc (corresponding to element densities of from approximately 165 to 40 elements per inch at a 28 inch viewing distance). The effects of element density, however, were large and conformed to expectations derived from the limiting resolution of the visual system. Geometric mathematical derivations are provided for the relationships between element density, viewing distance, target size, sensor field of view, total number of display elements and slant range at time of target recognition Author

N77-16059# National Aerospace Lab., Amsterdam (Netherlands)
A THEORETICAL FRAMEWORK TO STUDY THE EFFECT OF COCKPIT INFORMATION
In AGARD Visual Presentation of Cockpit Information Including Special Devices Used for Particular Conditions of Flying Nov. 1976 7 p refs (For primary document see N77-16050 07-06)
Avail: NTIS HC A05/MF A01

A theoretical framework is presented, describing human operator's participation in manned vehicle systems. The human operator is described in terms commensurate with those used for other system elements, which is desirable because of the complex interaction between human functioning and his task environment (e.g., cockpit information). The result is an integrated model of the man machine situation serving as a diagnostic tool (for existing systems) and allowing the extrapolation to new situations. The theoretical framework deals with manned vehicle systems involving the human operator performing continuous control and/or decision making tasks. It will be illustrated how the effect of cockpit information (e.g., type, quality and interference of displayed information, both visual and auditory) on human functioning and mission success can be operationalized and straightforwardly investigated. Author

X77-72039 Advisory Group for Aerospace Research and Development, Paris (France).
REMOTELY PILOTED RE-USABLE VEHICLES
Oct 1975 64 p
(AGARD-CP-178) Avail: Advisory Group for Aerospace Research and Development, Paris, France NATO-Classified report

NOTICE Available to U S Government Agencies

Six papers are presented covering onboard avionics for remotely reusable attack vehicles, and data display and communication for command and control of remotely piloted vehicles. Author

07 AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors, and on-board auxiliary power plants for aircraft. For related information see also *20 Spacecraft Propulsion and Power, 28 Propellants and Fuels,* and *44 Energy Production and Conversion.*

N74-19297# Advisory Group for Aerospace Research and Development, Paris (France).
TECHNICAL EVALUATION REPORT ON FLUID DYNAMICS PANEL SPECIALISTS MEETING ON NOISE MECHANISMS
J. E. FfowcsWilliams Feb. 1974 19 p Meeting held at Brussels, 19-21 Sep. 1973
(AGARD-AR-66; AGARD-CP-131) Avail: NTIS HC $4.00

The mechanics of sound generation by turbulent flows was studied. The emphasis was on aeronautical problems arising from the field of aircraft noise control. Six separate headings which effectively categorize the subject areas of the papers presented are: (1) source identification; (2) the influence of mean flow structure on the generation and propagation of sound; (3) distinctive large eddy structures; (4) excess noise; (5) the control of jet noise; (6) problem areas likely to become more important. Author

N74-19404# Advisory Group for Aerospace Research and Development, Paris (France).
V/STOL PROPULSION SYSTEMS Technical Evaluation Report
H. Grieb (Motoren-und Turbinen-Union Muenchen GmbH) and N. A. Mitchell (Rolls Royce, Ltd.) Jan. 1974 12 p refs
(AGARD-AR-64) Avail: NTIS HC $4.00

The proceedings of a conference on propulsion systems for V/STOL aircraft are presented. The subjects discussed are: (1) propulsion system and airframe integration, (2) V/STOL propulsion system components, (3) environmental effects, and (4) V/STOL propulsion system operating experience. Author

N74-20401# Advisory Group for Aerospace Research and Development, Paris (France).
V/STOL PROPULSION SYSTEMS
Jan. 1974 415 p refs Mostly in ENGLISH, partly in FRENCH Presented at the 42d Meeting of the AGARD Propulsion and Energetics Panel, Schliersee, Germany, 17-21 Sep. 1973
(AGARD-CP 135) Avail: NTIS HC $23.75

The proceedings of a conference on V/STOL propulsion systems are presented. The subjects discussed include the following: (1) optimum engines for military V/STOL aircraft, (2) engine cycle selection for commercial short takeoff aircraft, (3) requirements for V/STOL propulsion and drive train components, (4) development of advanced technology V/STOL propeller system, (5) engine and aircraft design considerations affecting aircraft noise, (6) characteristics of lifting fans under cross flow conditions, and (7) operational experience with V/STOL propulsion systems. For individual titles, see N74-20402 through N74-20433.

N74-20402 Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
COMPARATIVE APPRAISAL OF PROPULSION SYSTEMS FOR VTOL-AIRCRAFT
Heinrich Leibach *In* AGARD V/STOL Propulsion Systems Jan. 1974 19 p (For availability see N74-20401 11-28)

An engine-oriented method for a functional description and classification of all existing and future aircraft jet propulsion systems is presented. It is assumed that all aero propulsion systems are made up of assemblies which carry out the thrust generation, thrust augmentation and thrust control functions, with various principles of operation being possible, as well as various combinations of the said assemblies. If these three fundamental functions are determined symbolically and free-of-value, it will be possible to obtain a basic description and a classification of all existing and future engines, via the determination of the energy flows. Moreover, this classification method will permit derivation and description of new, unconventional power plants. Author

N74-20403 Rolls-Royce, Ltd., Bristol (England). Engine Div.
OPTIMUM ENGINES FOR MILITARY V/STOL AIRCRAFT
R. M. Denning and N. A. Mitchell *In* AGARD V/STOL Propulsion Systems Jan. 1974 13 p (For availability see N74-20401 11-28)

The characteristics of propulsion systems for V/STOL low-level close support and air superiority aircraft are discussed. The requirements for optimum engines based on the operational requirements of the aircraft are explained. Charts, graphs, and diagrams are provided to show the evolution of military V/STOL combat aircraft and the associated propulsion systems. Author

N74-20404 Naval Air Systems Command, Washington, D.C.
FORMULATING MILITARY REQUIREMENTS
R. L. VonGerichten *In* AGARD V/STOL Propulsion Systems Jan. 1974 12 p refs (For availability see N74-20401 11-28)

The formulation of military requirements often includes conflicting elements and may follow several different paths. Many diverse technical concepts which are in varying stages of development must be considered. The formulation process is discussed and some of the technical and design considerations are highlighted. The inception of the Navy's V/STOL Fighter-Attack Program is reviewed together with some indication of the progress on the Navy's Medium V/TOL Program. Both of which are being considered for the Sea Control Ship and other applications. Additional constraints on propulsion system development and thoughts of future propulsion requirements are provided. Author

N74-20405 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche (France).
THE MOTORIZATION OF SHORT TAKE-OFF AND LANDING AIRCRAFT [LA MOTORISATION DES AVIONS A DECOLLAGE ET A ATTERRISSAGE COURTS]
Robert Laurens *In* AGARD V/STOL Propulsion Systems Jan. 1974 16 p In FRENCH (For availability see N74-20401 11-28)

The operational and environmental requirements for STOL aircraft such as airfield length, noise restrictions and pollution limitations are reviewed and commented on in view of the subsequent engine requirements. The choice of thermodynamic cycle for optimum take-off/cruise thrust matching and economical sfc and the main design parameters influencing fan noise are discussed. Special attention is paid to the improvements in engine handling made possible by the use of variable nozzles and/or variable pitch fans. This allows low thrust levels at high fan speeds, resulting in favorable engine response times, important for baulked landings and thrust reversal. Author

N74-20406 Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
INVESTIGATION OF THE RELATIVE MERITS OF DIFFERENT POWER PLANTS FOR STOL-AIRCRAFT WITH BLOWN FLAP APPLICATION
H. Grieb, W. Klussmann, and G. Weist *In* AGARD V/STOL Propulsion Systems Jan. 1974 19 p refs (For availability see N74-20401 11-28)

The relative merits of different air supply systems for STOL-aircraft with blown flap application are investigated. Under consideration are self-sustained supply units, such as gas turbine driven compressors, remote compressors driven with hot gas from the cruise engines and 2 possibilities for off-take of compressed air from the cruise engines. The air supply systems reviewed are compared with respect to the design requirements, the operating behaviour including any reactions on the cruise engines, the sensitivity to component failure and the weight penalty to be expected. Author

N74-20407 Royal Aircraft Establishment, Bedford (England).
A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE EXTERNAL-FLOW, JET-AUGMENTED FLAP
P. R. Ashill *In* AGARD V/STOL Propulsion Systems Jan. 1974 18 p refs (For availability see N74-20401 11-28)

Theoretical methods for calculating the forces and moments acting on wings with external-flow, jet-augmented flaps are discussed. One of the simplest of these relies on the analogy between the internal-flow, jet flap and the external-flow, jet flap. To date, this method has been limited in application by its reliance on either measured or assumed value of the jet-deflection angle and the thrust-recovery factor, i.e. the factor that is applied to the momentum flux leaving the exit of the engine nacelle to allow for turning and spreading losses. This paper is concerned with a semi-empirical method for predicting these parameters. The method is based on an analysis of a series of tests performed

on a wing, body and injector-powered nacelle under static conditions. The formulas derived from the analysis are combined with a theory, which is based on the jet-flap analogy, to provide estimates of the forces and moments acting on wings with external-flow, jet-augmented flaps in forward flight. Comparisons are made between this method and wind-tunnel data obtained from tests performed at the RAE and elsewhere. Author

N74-20408 Fiat S.p.A., Turin (Italy). Div. Aviazione
ENGINE CYCLE SELECTION FOR COMMERCIAL STOL AIRCRAFT
Giorgio Feo and Alfredo Capuani (Societa Aeritalia, Turin) *In* AGARD V/STOL Propulsion Systems Jan. 1974 11 p (For availability see N74-20401 11-28)

The cycle and design parameters pertinent to a turbofan to be used for STOL short haul applications have been studied. For the chosen aircraft configuration, the criteria that condition the choice of the cycle, listed in decreasing importance, have been determined as follows: (1) low noise level, (2) high specific thrust to obtain low-weight and reduced-size engines, and (3) low specific fuel consumption (s.f.c.). It is concluded that the controlling factor is the noise level requirement for airports in congested areas. In order to satisfy this and the mission operational requirements the turbofan engine is driven towards medium bypass ratios and high thrust weight ratios but with less emphasis on s.f.c. Author

N74-20409 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
WIND TUNNEL TESTING WITH ENGINE SIMULATION FOR V/STOL AIRPLANES
R. Wulf and E. Melzer *In* AGARD V/STOL Propulsion Systems Jan. 1974 14 p refs (For availability see N74-20401 11-28)

For the development of STOL and especially for VTOL airplanes with modern engines, wind tunnel testing with adequate jet and engine simulation is of great importance. Current engine systems are classified. Their main characteristics concerning the aerodynamic interference between engine and airplane or between engine and the surrounding flow field are described. Based on these aspects suitable simulation systems are discussed. The power requirement for exact simulation is estimated and in the case of compressed air supply the influence of pressure ratio and temperature is shown. Some simulators developed and used in the last few years illustrate the different testing techniques for compressed air blowing, ejectors, and tip turbine driven fans. Concluding remarks present some proposals for a future collaborative program of work in the field of engine simulation. Author

N74-20410 General Electric Co., Cincinnati, Ohio. Aircraft Engine Group.
RECENT TECHNOLOGY ADVANCES IN THRUST VECTORING SYSTEMS
Richard P. Taylor and Joseph A. Lander *In* AGARD V/STOL Propulsion Systems Jan. 1974 11 p refs (For availability see N74-20401 11-28)

The important technical challenges that must be overcome in order to make a reality of thrust vectoring of an afterburning engine for a multi-mission aircraft. Two approaches to vectoring - with and without afterburning in lift are described which have been developed to the point that they are available for direct application to an engine development program. In addition, the evaluation/selection/design criteria for vectoring systems have developed to the point where specific design and configuration considerations that are peculiar to VTOL are identified and reasonably well understood. Thus, although the engine and aircraft industry continue the search for and development of even better thrust vectoring systems and installations, it is considered that the fundamental technology and knowhow is available to proceed with a thrust vectored, afterburning engine and aircraft. Author

N74-20411 Societe Nationale Industrielle Aerospatiale, Paris (France).
SHORT HAUL AIRCRAFT ADAPTATION TO THE USE OF SHORT LANDING FIELDS [ADAPTATION MOTEURS-CELLULE DES AVIONS COURTS COURRIERS UTILISANT DES PISTES COURTES]
Pierre Guyot *In* AGARD V/STOL Propulsion Systems Jan. 1974 11 p In FRENCH (For availability see N74-20401 11-28)

The results of an engine/airframe optimization study carried out in order to investigate the effect that field length has on aircraft weight and direct operating costs are given. The study uses an aircraft with a fixed passenger load, flight plan and aerodynamic characteristics, and an engine with a fixed gas generator. The two main parameters are then wing loading and bypass ratio. It was concluded that there is a considerable penalty in operating costs for shortening the field length. Author

N74-20412 Army Air Mobility Research and Development Lab., Cleveland, Ohio.
BASIC RESEARCH REQUIREMENTS FOR V/STOL PROPULSION AND DRIVE-TRAIN COMPONENTS
John Acurio *In* AGARD V/STOL Propulsion Systems Jan. 1974 14 p (For availability see N74-20401 11-28)

The design of aircraft engines for use with V/STOL aircraft is discussed. Emphasis is placed on the aerodynamic components of the engine. The subjects discussed are as follows: (1) general requirements, (2) compressors, (3) turbines, (4) combustors, and (5) drive train concepts. Graphs of engine performance under various operating conditions are provided. Author

N74-20413 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (West Germany).
AERODYNAMIC INTERFERENCE BETWEEN FUSELAGE AND LIFTING JETS EMERGING FROM ITS LOWER PART
G. Viehweger *In* AGARD V/STOL Propulsion Systems Jan. 1974 14 p refs (For availability see N74-20401 11-28)

In a basic experimental study on a cylindrical fuselage, the change in lift and pitching moment induced by two lifting jets of high velocity, situated one behind the other, is determined. The constructional principle of the model permits a wide variation of fuselage length, of the distance between the jets and the diameter of the jet nozzles. As aerodynamic parameters the angle of attack, the location of a wing relative to the jet nozzles, the mainstream and the jets velocities are varied within a wide range. The pressure distribution on the whole surface of the cylindrical fuselage central section is measured. The results provide a survey on the influence of the different parameters. The aerodynamic problems are discussed. The experimental installation and the performance of the tests are described. Author

N74-20414 Army Air Mobility Research and Development Lab., Fort Eustis, Va.
RESEARCH TOWARD DEVELOPMENT FEASIBILITY OF AN ADVANCED TECHNOLOGY V/STOL PROPELLER SYSTEM
James Gomez, Jr. and Robert M. Levintan *In* AGARD V/STOL Propulsion Systems Jan. 1974 12 p refs Prepared in cooperation with Hamilton Standard Div., United Aircraft Corp., Windsor Locks, Conn. (For availability see N74-20401 11-28)

Analytical studies and limited hardware efforts have shown that improvements can be obtained in V/STOL propeller components through the use of improved materials and new concepts. Several of the design concepts which evolved from a baseline feasibility study were explored. Some have been partially proven and others require significantly more research than anticipated. Laboratory test work to date on the boron-aluminum blade spar indicates that the material characteristics are ideal for a propeller environment. However, the efforts expended for research on titanium gear tooth coatings have indicated that much more research is necessary. Author

N74-20415 Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
THE INFLUENCE OF THE CONTROL CONCEPT FOR V/STOL ENGINES ON THEIR STATIC AND DYNAMIC PERFORMANCE CHARACTERISTICS
K. Bauerfeind and G. Doepner *In* AGARD V/STOL Propulsion Systems Jan. 1974 13 p refs (For availability see N74-20401 11-28)

The decrease of total thrust and the changes of important engine parameters of two-spool bypass engines caused by bleeding air upstream of the combustion chamber for stabilizing and for maneuvering VTOL-aircraft in the hover or transition phase have been investigated. A variation of the engine design parameters turbine inlet temperature, total pressure ratio and bypass ratio has been considered. In each case three different control concepts have been applied: (1) the power lever position calls for a constant fuel flow, (2) the power lever position calls for a constant HP-compressor speed, and (3) the power lever position calls for a constant turbine inlet temperature. The smallest decrease in total thrust results when the HP-compressor speed is kept constant, when the total pressure ratio is 20 or above and the

bypass ratio in between 2 and 10. The design turbine inlet temperature only has a minor effect on this. But, on the other hand, the increase of turbine inlet temperature due to bleeding air is very high. The biggest decrease in total thrust occurs when the turbine inlet temperature is kept constant by the control system and when the engine has a high bypass ratio and also a high design turbine inlet temperature. Author

N74-20416* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
INTEGRATED PROPULSION/ENERGY TRANSFER CONTROL SYSTEMS FOR LIFT-FAN V/STOL AIRCRAFT
Wallace H. Deckert and L. Stewart Rolls *In* AGARD V/STOL Propulsion Systems Jan. 1974 8 p refs (For availability see N74-20401 11-28)

An integrated propulsion/control system for lift-fan transport aircraft is described. System behavior from full-scale experimental and piloted simulator investigations are reported. The lift-fan transport is a promising concept for short-to-medium haul civil transportation and for other missions. The lift-fan transport concept features high cruise airspeed, favorable ride qualities, small perceived noise footprints, high utilization, transportation system flexibility, and adaptability to VTOL, V/STOL, or STOL configurations. The lift-fan transport has high direct operating costs in comparison to conventional aircraft, primarily because of propulsion system and aircraft low-speed control system installation requirements. An integrated lift-fan propulsion system/aircraft low-speed control system that reduces total propulsion system and control system installation requirements is discussed. Author

N74-20417 Pratt and Whitney Aircraft, East Hartford, Conn.
V/STOL DEFLECTOR DUCT PROFILE STUDY
R. I. Strough and T. A. Wynosky *In* AGARD V/STOL Propulsion Systems Jan. 1974 13 p (For availability see N74-20401 11-28)

V/STOL deflection of exhaust gases creates static pressure gradients within deflector system ducting which propagate upstream and produce a nonsymmetric back-pressure distribution on the fan. Depending on the deflector design, the fan will experience a higher-than-average back-pressure at one point in the duct, and lower-than-average pressure near the deflector. If this back-pressure distortion is severe enough, engine stability can be compromised. Experimental and analytical studies were conducted to study the back-pressure distortion problem. Small-scale cold flow models of various deflector devices were tested to obtain a parametric mapping of the back-pressure disturbance as a function of bypass ratio, duct Mach number, and deflector geometric parameters. Screens of varying solidity were used to generate total pressure gradients around the duct similar to those generated by the fan. The parametric distortion patterns were then duplicated on a specially designed full-scale fan test rig, and fan surge margin degradation was related to the generated back-pressure profile. The final analysis resulted in the formulation of design ground rules which establish criteria for the disturbance proximity and magnitude that current turbomachinery can tolerate. Author

N74-20418 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche (France).
LOW SPEED TURBINE GEAR BOX [TURBINE LENTE CONTRE BOITE D'ENGRENAGES]
Victor Benaimhon *In* AGARD V/STOL Propulsion Systems Jan. 1974 17 p In FRENCH (For availability see N74-20401 11-28)

A propulsion system is proposed where a low speed highly loaded turbine driven by two gas generators is coupled directly to the rotor shaft, thus avoiding the heavy gear box. A description is given of the mechanical and aerodynamic characteristics of this propulsion system and its capability to meet the requirements various operating conditions including high speed flight with propulsion support by the turbo-jets used as gas generators for the rotor turbine. The system described is compared with a conventional propulsion system with respect to fuel consumption and maintenance cost. Author

N74-20419 Aerospace Research Labs., Wright-Patterson AFB, Ohio. Energy Conversion Lab.
COMPACT THRUST AUGMENTORS FOR V/STOL AIRCRAFT
Brian Quinn *In* AGARD V/STOL Propulsion Systems Jan. 1974 12 p refs (For availability see N74-20401 11-28)

The prospect of undertaking V/STOL and cruise flight with the same powerplant has considerable appeal and can be achieved by proper use of thrust augmenting ejectors. Proper use requires an ejector that simultaneously satisfies two conflicting requirements: high performance and installation compactness. In addition to elementary design considerations, the following paragraphs discuss the loss mechanisms to which augmentors are most sensitive and describe how they may be manipulated to produce high levels of thrust augmentation in ejectors suitable for V/STOL aircraft. Conclusions are corroborated by the results of experimental investigations of the effects of geometric constraints on the flow structure and performance of thrust augmenting ejectors. Author

N74-20420 National Research Council of Canada, Ottawa (Ontario). Gas Dynamics Lab.
THRUST PERFORMANCE OF PODDED LIFT-FANS IN CROSSFLOW
R. A. Tyler and R. G. Williamson *In* AGARD V/STOL Propulsion Systems Jan. 1974 14 p refs (For availability see N74-20401 11-28)

Experimental data relating to the thrust performance in crossflow of single, individually podded, lift-fans are discussed. Various 15-inch tip diameter fan arrangements were tested over a range of crossflow velocity ratio typical of the transition flight profiles of proposed lift-fan aircraft. Each model was operated in isolation in a manner allowing fan thrust (efflux momentum) to be assessed directly from force-balance measurements. The relevant transition conditions, in association with practical dimensional restrictions on intake geometry for separately cowled fans (in, for instance, multiple in-line arrangement) suggest that lip flow separation could be an important feature of the inflow distortion arising from crossflow. In such circumstances thrust deterioration with increasing crossflow velocity is appreciable. The measured data illustrate the influence on fan thrust sensitivity to crossflow of various installational features including fan operating point, cowl lip radius, inlet axial depth, and crossflow angle. Author

N74-20421 National Gas Turbine Establishment, Pyestock (England).
SOME ENGINE AND AIRCRAFT DESIGN CONSIDERATIONS AFFECTING NOISE
D. R. Higton and T. A. Cook (Roy. Aircraft Estab., Farnborough, Engl.) *In* AGARD V/STOL Propulsion Systems Jan. 1974 9 p ref Prepared in cooperation with Roy. Aircraft Estab., Farnborough, Engl. (For availability see N74-20401 11-28)

The general prospects for further reductions in engine noise are reviewed. The factors which determine the best combination of engine specific thrust (or by-pass ratio) and complexity of acoustic treatment are assessed. The effect of design requirements, particularly that of field length, on aircraft noise and economics is then discussed, together with the prospects for manipulating airframe design parameters in order to reduce noise. Quantitative consideration of noise shielding is not included; this can be regarded as an important effect meriting a separate study. Some of the interactions between engine and aircraft design as they affect the economics and noise of conventional short range aircraft for short to medium field lengths are analyzed. Author

N74-20422* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
INFLUENCE OF NOISE REQUIREMENTS ON STOL PROPULSION SYSTEM DESIGNS
Raymond J. Rulis *In* AGARD V/STOL Propulsion Systems Jan. 1974 17 p refs (For availability see N74-20401 11-28)

The severity of proposed noise goals for STOL systems has resulted in a new design approach for aircraft propulsion systems it has become necessary to consider the influence of the noise goal on the design of engine components, engine systems, and the integrated nacelle, separately and collectively, from the onset of the design effort. This integrated system design approach is required in order to effect an optimization of the propulsion and aircraft system. Results from extensive design studies and pertinent test programs are presented which show the effect of noise specifications on component and system design, and the trade-offs possible of noise versus configuration and performance. The design optimization process of propulsion systems for powered lift systems is presented beginning with the component level and proceeding through to the final integrated propulsion system. Designs are presented which are capable of meeting future STOL noise regulations and the performance, installation and economic penalties are assessed as a function of noise level. Author

N74-20423 Dowty Rotol Ltd., Gloucester (England).
THE INFLUENCE OF NOISE REQUIREMENTS ON STOL AIRCRAFT ENGINE DESIGN
D. G. M. Davis *In* AGARD V/STOL Propulsion Systems Jan. 1974 11 p refs (For availability see N74-20401 11-28)

The noise regulations applicable to STOL aircraft are discussed. It is stated that the current aircraft fail to meet the noise regulations and that a reduction of 10 to 15 PNdB must be achieved. An even greater reduction of 25 to 30 PNdB is required to make the aircraft acceptable to city center STOL landing areas. Aircraft performance parameters and flight path considerations which will contribute to a reduction in noise levels are described. A turbofan engine of relatively high bypass ratio fitted with a variable pitch fan is proposed as the basic power plant. Author

N74-20424 Hamilton Standard, Windsor Locks, Conn. Aircraft Systems Dept.
Q-FAN PROPULSION FOR SHORT HAUL TRANSPORTS
Arthur H. Jackson, Jr. *In* AGARD V/STOL Propulsion Systems Jan. 1974 12 p refs (For availability see N74-20401 11-28)

The design and development of quiet fans (Q-FAN) for use with short haul transport aircraft are described. The Q-FAN blade construction is analyzed to show the effectiveness in noise reduction. The Q-FAN uses variable pitch techniques and is especially effective for thrust reversal operations. The advantages of variable thrust are: (1) superior thrust response and lower engine noise on landing approach, (2) lower fuel consumption at part power conditions, (3) slightly higher thrust and lower fuel consumption at cruise, and (4) blade feathering protection from destructive engine failure. Author

N74-20425 National Research Council of Canada, Ottawa (Ontario). Div. of Mechanical Engineering.
AERODYNAMIC CHARACTERISTICS OF AN EXPERIMENTAL LIFTING FAN UNDER CROSSFLOW CONDITIONS
U. W. Schaub *In* AGARD V/STOL Propulsion Systems Jan. 1974 16 p refs (For availability see N74-20401 11-28)

The fundamental nature of crossflow distortion and the effect on lifting fan performance are discussed. The experimental procedure for determining cross flow effects is described. Diagrams are provided to show: (1) general flow curvature effect, (2) flow curvature effects in an annular inlet, and (3) crossflow/inlet flow streamline pattern. The causes and appearance of outlet plane distortion are analyzed. Graphs of the total pressure ratio-mass flow running lines of the complete fan and sub-fan elements are provided. Author

N74-20426 National Research Council of Canada, Ottawa (Ontario). Div. of Mechanical Engineering.
NOISE CHARACTERISTICS OF AN EXPERIMENTAL LIFTING FAN UNDER CROSSFLOW CONDITIONS
G. Krishnappa *In* AGARD V/STOL Propulsion Systems Jan. 1974 14 p refs (For availability see N74-20401 11-28)

The results of acoustic tests conducted on a 12-in. diameter model lifting fan, to find the effect of crossflow on its noise radiation characteristics are presented. The broadband noise levels increased with the velocity of the crossflow. The fundamental blade passing frequency and its second harmonic tones showed moderate changes in the field shapes and levels for low crossflows. At high crossflow velocities due to the presence of a partial stalled region the tone levels increased drastically. The tones generated by the rotor blades due to inflow distortions were believed to dominate over the rotor and stator interaction levels. At fan speeds close to the design point, there were only slight changes in the tone levels and field shapes at the blade passing frequency as the blade incidence excursions became less severe and rotor and stator interaction was much stronger. However, at the higher crossflow velocities the second harmonic tones showed substantial reductions in tone levels with different field shapes. Author

N74-20427 Detroit Diesel Allison, Indianapolis, Ind
COST OF OWNERSHIP FOR PROPULSION SYSTEM OF POWERED LIFT AIRCRAFT
W. L. McIntire *In* AGARD V/STOL Propulsion Systems Jan. 1974 20 p refs (For availability see N74-20401 11-28)

A discussion of the relationship of advanced propulsion technology for powered lift V/STOL aircraft and the elements of cost of ownership - development, acquisition, and operation and maintenance is presented. Competitive demonstrator programs, component technology versus aircraft, and mission requirements and implementation of design-to-cost programs are discussed as basic cost considerations for the development program element of cost of ownership. Production requirements and manufacturing methods required for new materials and advanced aerodynamic components are presented as the second cost of ownership parameter to provide acquisition costs effectively balanced with performance and cost. Finally, system performance, reliability, and maintainability are evaluated to ensure that the total cost of ownership is commensurate with the job to be done. Author

N74-20428 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany) Unternehmensbereich Flugzeuge.
PROPULSION SYSTEM OF THE VJ 101 C VTOL AIRCRAFT: PHILOSOPHY AND PRACTICAL EXPERIENCE
Werner Biehl *In* AGARD V/STOL Propulsion Systems Jan. 1974 14 p refs (For availability see N74-20401 11-28)

The design and development of the VJ 101C vertical takeoff aircraft are discussed. Emphasis is placed on optimizing the aircraft configuration with respect to the propulsion system. The special requirements for the engines and intakes to provide a vertical takeoff and supersonic flight capability are analyzed. The problem areas considered are as follows: (1) thrust modulation for attitude control, (2) afterburner thrust for vertical takeoff, (3) hot gas reingestion, (4) ground suction, (5) ground erosion, and (6) noise. Graphs of aircraft and engine performance under various flight conditions are included. Author

N74-20429 De Havilland Aircraft Co., Ltd., Downsview (Ontario) Advanced Research.
THE DEVELOPMENT OF AN INTEGRATED PROPULSION SYSTEM FOR JET STOL FLIGHT RESEARCH
J. A. Conway *In* AGARD V/STOL Propulsion Systems Jan. 1974 15 p refs (For availability see N74-20401 11-28)

The Augmentor-Wing powered lift concept provides the high lift required for STOL terminal operations by means of a close interrelationship between the propulsive and aerodynamic functions of the system. Therefore, the propulsion system is subject to more extensive design requirements than a conventional engine installation. Subsequent to extensive large scale model testing of the concept, general agreement was reached that flight research was feasible and desirable, but in view of the long development times and high costs involved, particularly in respect to engines, means would have to be found to utilize both existing engines and airframe. A de Havilland Buffalo airframe became the basis of the Augmentor-Wing flight research aircraft. The selection, modification and testing of the Rolls-Royce Spey 801 SF which became the basic power plant for the research aircraft are discussed. A description of the associated augmentor ducting is also given, together with an outline of the propulsion aspects of the first phases of testing. Author

N74-20430 Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
PROBLEMS OF V/STOL AIRCRAFT CONNECTED WITH THE PROPULSION SYSTEM AS EXPERIENCED ON THE Do 31 EXPERIMENTAL TRANSPORT AIRCRAFT
M. Lotz and P. Bartels *In* AGARD V/STOL Propulsion Systems Jan. 1974 12 p refs (For availability see N74-20401 11-28)

For V/STOL aircraft, the additional functions of the propulsion system cause some problems which do not occur on CTOL aircraft. As a consequence, the design and operation of V/STOL aircraft is more strongly influenced by propulsion-related problems. These problems are discussed based on the experience with the Do 31 jet lift transport. Hot gas reingestion largely determined the take-off technique adopted for the Do 31. Ground erosion of artificial and natural surfaces is discussed. The most important effects of jet interference in hover and transition are described. The lift engine air intakes have to provide very low thrust losses in hover, low distortion in transition and in-flight starting capability. Some aspects of hover flight control by differential thrust modulation, differential thrust vectoring and reaction control by bleed air are discussed. Finally, the influence of near field noise on the airframe structure and the possibilities of influencing community noise by exploiting the high operational flexibility of V/STOL aircraft are described. Author

N74-20431 Rolls-Royce, Ltd., Bristol (England). Engine Div.
PEGASUS ENGINE OPERATING EXPERIENCE IN THE HARRIER AIRCRAFT
R. J. Cant *In* AGARD V/STOL Propulsion Systems Jan. 1974 18 p (For availability see N74-20401 11-28)

The performance of the Pegasus engine installed in the

Harrier aircraft is discussed. The special demands made on an engine for single engine V/STOL close combat application are explained. Operational experiences on the engine are analyzed to show the effects of: (1) the vectoring nozzle system, (2) bird strikes, (3) foreign object damage, (4) aircraft stabilizing, and (5) hot gas reingestion. Author

N74-20432 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany).
THE DEVELOPMENT AND FLIGHT TESTING OF THE PROPULSION SYSTEM OF THE VAK 191 B V/STOL STRIKE AND RECONNAISSANCE AIRCRAFT
Klaus Wieland *In* AGARD V/STOL Propulsion Systems Jan. 1974 12 p (For availability see N74-20401 11-28)

The VAK 191 B has a mixed propulsion system comprising a main lift/cruise engine in the fuselage center and two lift engines installed in the front and the rear section of the fuselage. Bleed air is taken from each engine for aircraft attitude control. Design and development of the propulsion system including the control bleed system will be discussed. The type of control for the propulsion and bleed air system plays an important role towards achieving maximum performance. Extensive model testing has been done to investigate main and lift engine intake performance, lift engine relight capability and hot gas reingestion characteristics of the aircraft. The results have been proven in ground and flight testing. Full scale testing of the bleed air system has been carried out to derive steady state and dynamic characteristics. During ground and flight testing with three prototypes performance, handling and reliability of the propulsion system under VTOL and transition conditions were investigated. Some special results and comparison with predictions are presented. Author

N74-20433 Advisory Group for Aerospace Research and Development, Paris (France).
TECHNICAL EVALUATION REPORT ON 42ND PROPULSION AND ENERGETICS PANEL MEETING ON V/STOL PROPULSION SYSTEMS
H. Grieb and N. A. Mitchell *In its* V/STOL Propulsion Systems Jan. 1974 7 p refs (For availability see N74-20401 11-28)

A technical evaluation of the conference on V/STOL propulsion systems is presented. Comments are prepared concerning the papers that were submitted and the round table discussions are summarized. Recommendations are submitted concerning the future course of actions to be taken for design and development of V/STOL aircraft and engines. The questions which were used as a guide line and the main points of discussion are briefly answered P.N.F.

N75-12954# Advisory Group for Aerospace Research and Development, Paris (France).
DISTORTION INDUCED ENGINE INSTABILITY
Oct. 1974 182 p refs Lecture series held at London, 7-8 Nov. 1974, at Wright-Patterson AFB, Ohio, 11-12 Nov. 1974, and Philadelphia, 14-15 Nov. 1974
(AGARD-LS-72) Avail: NTIS HC $7.00

The design criteria for jet aircraft engines and turbomachinery to obtain minimum airflow distortion and engine instability is discussed. The sources of distortion are identified. The aerodynamic and mechanical response of selected engines under distorted flow conditions are analyzed. Techniques for predicting and measuring the stability of an engine are described. Methods for increasing the tolerance of the engine to distorted flow in order to obtain more stable operation are explained. For individual titles, see N75-12955 through N75-12961.

N75-12955 Naval Postgraduate School, Monterey, Calif.
INTRODUCTION TO DISTORTION INDUCED ENGINE INSTABILITY
Allen E. Fuhs *In* AGARD Distortion Induced Eng. Instability Oct. 1974 19 p refs (For availability see N75-12954 04-07)

Propulsion system instability, which may be caused by distorted inlet flow, is a recurring problem which must be solved in each new aircraft development program. Trends in engine and airframe design that keep distortion sensitivity as a continuing problem are discussed. Sources of inlet flow distortion are catalogued. This information is used to assess the potential difficulties in development of a variety of aircraft types. Methods for describing distortion both experimentally and conceptually are introduced. Sufficient background is stated to provide a perspective of the lecture series. Author

N75-12956 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche (France).
SOURCES OF DISTORTION AND COMPATIBILITY
R. Bouillet and J. M. Brasseur *In* AGARD Distortion Induced Eng. Instability Oct 1974 11 p refs (For availability see N75-12954 04-07)

An analysis of the sources of flow distortion and operating compatibility for jet aircraft engines was conducted. The aspects of flow distortion considered are: (1) various operating cases of air intakes, (2) air intake design and engine compatibility, (3) test facilities required to compensate the lack of theoretical data and to confirm predictions, and (4) typical examples of air intake modifications aiming at significant improvement of the internal flow. The conditions of operation considered are normal operation in which the velocity field around the aircraft in an assumed infinite atmosphere is the only factor considered, and operation under conditions of disturbances from ground effect. Author

N75-12957 Rolls-Royce, Ltd., Bristol (England). Installation Aerodynamics Dept.
AERODYNAMIC RESPONSE
R. G. Hercock and D. D. Williams *In* AGARD Distortion Induced Eng. Instability Oct. 1974 41 p refs (For availability see N75-12954 04-07)

The aerodynamic response of turbomachinery to steady and time-variant total pressure and temperature distortion is discussed. Examples of changes in compressor characteristics are presented. Experimental correlations of surge margin loss, the concept of a critical or effective spoiled sector angle and compressor sensitivity are then discussed in relation to simple theoretical ideas for circumferential distortion. The development of the distortion index approach to account for the effect of radial and mixed radial - circumferential total pressure distortion and the impact of turbulence or unsteady flow is outlined. Comments on foreign gas ingestion are made. Some current auditing procedures are described. Limitations of isolated spool rig tests are discussed, and surge hammershock data are presented. Author

N75-12958 Stevens Inst. of Tech., Hoboken, N.J. Dept. of Mechanical Engineering.
AEROMECHANICAL RESPONSE
F. Sisto *In* AGARD Distortion Induced Eng. Instability Oct 1974 13 p refs (For availability see N75-12954 04-07)

Physical mechanisms are discussed which lead to the aeromechanical response of axial-flow fan and compressor components when these machines operate with a distorted inlet flow. Steady response of blades, vanes and discs are considered briefly. Forced excitation of rotating components are treated. The specific form of the exciting gusts are elucidated. Self-excited vibrations of rotor blades and stator vanes are considered as stemming from the general degradation of flow with distortion. Shaft and disc vibrations are also discussed as possible aeromechanical responses to distorted flow. The role of various forms of damping and the use of composite materials are described with attendant problems in application through design. Remedial action available to the aeromechanical engineer is discussed with the objective of ameliorating the adverse effects of distorted-induced structural response Author

N75-12959 Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
PREDICTION TECHNIQUES
H. Mokelke *In* AGARD Distortion Induced Eng. Instability Oct. 1974 32 p refs (For availability see N75-12954 04-07)

An outline is presented on mathematical modelling for prediction of the aerodynamic response of aircraft engine compressors to steady-state and time-dependent pressure and temperature distortion. A detailed review is made of various models. In particular their assumptions, their limitations for practical applications and their scope for further development are discussed. Results predicted with the models (as far as possible compared with experimental evidence) are selected from published works. Author

N75-12960* National Aeronautics and Space Administration Flight Research Center, Edwards, Calif.
TEST TECHNIQUES, INSTRUMENTATION, AND DATA PROCESSING
William G. Schweikhard *In* AGARD Distortion Induced Eng. Instability Oct 1974 43 p refs (For availability see N75-12954 04-07)
CSCL 21E

Procedures for determining the effects of dynamic distortion on engine stability are analyzed. The test techniques, methods and types of instrumentation, and data processing functions are described. The advantages and limitations of various methods

are reported. It is emphasized that ground facility tests are only a simulation of the flight environment, that instrumentation provides only a partial representation of the physical phenomena, and that poorly organized data processing procedures can impede and even distort the final result. Author

N75-12961 Pratt and Whitney Aircraft, East Hartford, Conn.
METHODS TO INCREASE ENGINE STABILITY AND TOLERANCE TO DISTORTION
A. A. Mikolajczak and A. M. Pfeffer *In* AGARD Distortion Induced Eng. Instability Oct. 1974 17 p refs (For availability see N75-12954 04-07)

Techniques used during engine design which ensure stable engine operation over the complete flight envelope of the aircraft in which it is installed are discussed. Adequate stability margin is required to allow for the expected levels of inlet distortion, engine to engine variations, engine aging and excursions of compressor operating lines during transients. Since the stability margin can be increased by raising the surge line of a compressor, increasing its tolerance to inlet distortion and modifying the design to reduce the sensitivity to transients, all these topics are treated in some depth. Emphasis is placed on the design for adequate stability margin and minimum penalty in engine fuel consumption, cost and weight. Author

N75-22329# Advisory Group for Aerospace Research and Development, Paris (France).
SECONDARY POWER SYSTEMS FOR ADVANCED ROTORCRAFT
Raymond G. Smith (Boeing Vertol Co., Phila. Pa.) Feb. 1975 94 p refs
(AGARD-AG-206; AGARDograph-206) Avail: NTIS HC $4.75

The results are presented of a review of European manufactured Secondary Power Systems (SPS) for rotorcraft. A compilation of SPS functions, parametric SPS component data for optimization trade studies, and a trade study to select an optimum SPS are presented. The study addresses the aspects of integrated SPS (electrical, hydraulic, pneumatic and mechanical) concepts for cockpit and avionics environmental control systems, ice protection system, hoist drive system, main engine starting, auxiliary power unit and its starting system integration. System optimization and recommended selection are based on trade study parameters of weight, cost and product assurance. Author

N75-23575# Advisory Group for Aerospace Research and Development, Paris (France).
POWER PLANT CONTROLS FOR AERO-GAS TURBINE ENGINES
Mar. 1975 374 p refs In ENGLISH; partly in FRENCH Presented at the 44th Meeting of the AGARD Propulsion and Energetics Panel, Ustaoset, Norway, 9-13 Sep. 1974
(AGARD-CP-151) Avail: NTIS HC $10.00

Control requirements, control simulation techniques, and control system hardware for improved reliability of aircraft gas turbine engines are elaborated. For individual titles, see N75-23576 through N75-23601.

N75-23576 National Research Council of Canada, Ottawa (Ontario).
AEROTHERMODYNAMIC FACTORS GOVERNING THE RESPONSE RATE OF GAS TURBINES
B. D. MacIsaac and H. I. H. Saravanamuttoo (Carleton Univ.) *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 11 p refs (For availability see N75-23575 15-07)

The constraints on gas turbine response rates resulting from aerothermodynamic considerations are reviewed and the use of variable geometry to improve the response rate is discussed. Mathematical models, which have to be verified experimentally, permit a detailed investigation of engine transient response. The transient behavior of a single spool unit is quite different from that of a twin spool unit and techniques of improving the response rate of both are discussed; significant gains can be realized and the use of simulation techniques permits these to be evaluated before carrying out actual engine tests. Author

N75-23577 Centre d'Essais de Propulseurs, Saclay (France).
CONTRIBUTION OF FLIGHT SIMULATION TESTS TO THE STUDY OF TURBOMACHINE CONTROL [CONTRIBUTION DES ESSAIS EN VOL SIMULE A L'ETUDE DE LA REGULATION DES TURBOMACHINES]
Vincent Nardone and Jean Claude Ripoll *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 9 p refs In FRENCH (For availability see N75-23575 15-07)

Flight simulation tests and their use to develop controls for turbine engines under various flight conditions are discussed. Tests examined the effects of pressure, static pressure build up, and temperature at various Mach numbers. Engine response and control during the transition phase were also studied.
Transl. by E.H.W.

N75-23578 Boeing Commercial Airplane Co., Renton, Wash. Propulsion Technology Controls Group.
AN AIRFRAME MANUFACTURER'S REQUIREMENTS FOR FUTURE PROPULSION CONTROLS
Peter W. Kamber *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 17 p refs (For availability see N75-23575 15-07)

Selective allocation of service bleed is presented as a means of extending engine life for a mix of nominal and deteriorating engines while preserving a desired thrust distribution. Rating command control is examined as a means to permit simple and definitive power setting, where each power rating is uniquely associated with a pushbutton or throttle position. Hydromechanical and electronic control systems are compared and it is reported that electronics will be used for most advanced control modes. Electronic engine controls are also presented as the foundation for improved coordination with flight controls, and for on-line engine condition monitors. Author

N75-23579 Rolls-Royce, Ltd., Derby (England).
CONTROL SYSTEM REQUIREMENTS DICTATED BY OPTIMIZATION OF ENGINE OPERATION
Christopher Linley Johnson *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 5 p (For availability see N75-23575 15-07)

A pneumatic mechanical flat rating system is included in the RB 211 control system and the reason for the choice of parameters on which this operates is discussed. On this system the pilot sets up the engine rating and the control then maintains it through variations of temperature and altitude. Author

N75-23580 Hamilton Standard Div., United Aircraft Corp., Windsor Locks, Conn. Electronic Systems Dept.
ENGINE CONTROL FOR HARPOON MISSILE SYSTEM
D. A. Prue *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 14 p (For availability see N75-23575 15-07)

The fuel control system for the Teledyne CAE J402-CA-400 engine is described. The control is configured as a low cost, engine mounted, closed loop electronic system. It measures exhaust gas temperature and compressor inlet temperature as sensed parameters for acceleration. A unique and straightforward approach to hydraulic system implementation utilizes a direct engine driven centrifugal pump and a proportional solenoid fuel metering system. The pump and fuel metering components constitute one assembly installed in the engine tail cone. The control approach and the reasons for selection of the mode of control and hardware implementation are described. The engine is used as the sustainer propulsion system for the U. S. Navy harpoon missile system. Author

N75-23581 Ministry of Defence, London (England).
RELIABILITY SPECIFICATION FOR GAS TURBINE CONTROL SYSTEMS
C. G. White *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 9 p refs (For availability see N75-23575 15-07)

Reliability is a procurement requirement like any other parameter such as cost, response or program time scale. The problems peculiar to engine control systems are examined and some suggestions made. The problems of specifying reliability parameters are reviewed and methods of reliability assurance and measurement are described. Author

N75-23582 Air Force Aero Propulsion Lab., Wright-Patterson AFB, Ohio.
THE ROLE OF COMPUTERS IN FUTURE PROPULSION CONTROLS
Charles E. Bentz *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 9 p refs (For availability see N75-23575 15-07)

The role of computers in future propulsion controls is reviewed from two different viewpoints - the integrated avionics approach and the dedicated propulsion system approach. The discussion presented suggests that a dedicated computer for the propulsion system control will provide a more optimum solution in the

future in terms of cost, complexity, and reliability. An integrated avionic systems approach that also includes the propulsion system control poses many new problems in the areas of system management and hardware development that may overshadow any of the immediate benefits of using a central processor.
Author

N75-23583 Pratt and Whitney Aircraft, East Hartford, Conn.
CONTROL DESIGN CONSIDERATIONS FOR VARIABLE GEOMETRY ENGINES
W. K. Tervo and J. M. Tringali *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 8 p refs (For availability see N75-23575 15-07)

Variable cycle engine control requirements are described. Control variables and potential sensed parameters are discussed. The complexity of the job is shown to require optimal control logic. An application of optimal control techniques is presented including simulation results.
Author

N75-23584 Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
PRAC: A NEW AERO GAS TURBINE ENGINE CONTROL CONCEPT
K. Bauerfeind *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 14 p (For availability see N75-23575 15-07)

The Pressure Ratio Acceleration Control (PRAC) offers a new approach to the control of modern aero gas turbine engines. With the exception of the use of high accuracy pressure transducers mounted in a temperature controlled box directly on the engine all other system components are of today's standard of technology. A simple breadboard model of PRAC had been built and successfully tested in conjunction with an Orpheus jet engine in a high altitude test facility. A more sophisticated PRAC control system for a modern supersonic bypass engine is being tested at present in conjunction with an engine simulator and the actual fuel system hardware on a control system rig at MTU. The paper outlines the control philosophy of PRAC and presents test results achieved so far.
Author

N75-23585 Rolls-Royce, Ltd., Watford (England). Small Engine Div.
HELICOPTER ENGINE CONTROL: THE PAST 20 YEARS AND THE NEXT
Edward A. Simonis and Malcolm P. Perks *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 16 p (For availability see N75-23575 15-07)

The first 20 years of gas turbine application to helicopters and the progressive evolution of their associated fully automatic engine control systems are surveyed. It is only recently that the dominant performance and safety requirements of the control have emerged with sufficient clarity to allow them to be viewed by an overall systems engineering approach instead of as piecemeal needs. A system is outlined which offers substantial reductions in size and weight over current systems without any sacrifice in performance or safety and with marked improvement in integrity. The utilization of digital control techniques leads to simple handling from the cockpit with self monitoring facilities and unambiguous reversionary control modes. Such a system is seen as setting a pattern for control of helicopter engines of the future
Author

N75-23586 National Gas Turbine Establishment, Farnborough (England).
A DIGITAL CONTROLLER APPLIED TO THE LIMITATION OF REHEAT COMBUSTION ROUGHNESS
J. H. Waters *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 8 p ref (For availability see N75-23575 15-07)

Reheat combustion roughness or buzz could cause damaging fluctuations in jet pipe pressure in high performance reheat combustion systems. A control scheme is described which controls reheat fuel flow so as to limit the level of jet pipe pressure fluctuations to safe values. Factors which affect the design and implementation of the controller are discussed and an indication given of its performance
Author

N75-23587 Dowty Fuel Systems, Ltd., Cheltenham (England).
AFTERBURNING REGULATION CONCEPTS
K. Robinson *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 17 p (For availability see N75-23575 15-07)

Various concepts of afterburner flow regulation are examined with particular reference to bypass type engines requiring rapid thrust modulation with minimum disturbance to engine operating conditions. Logic and sequencing functions associated with selection of afterburner operation are examined. Afterburner system organization is discussed briefly and the merits and short comings of alternative concepts are argued.
Author

N75-23588 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche (France).
EVOLUTION OF TURBOREACTOR CONTROL SYSTEMS [EVOLUTION DES SYSTEMES DE REGULATION DES TURBOREACTEURS]
Andre Barbot *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 8 p In FRENCH (For availability see N75-23575 15-07)

Techniques used to develop control systems for turboreactors and the problems, advantages, and disadvantages of each method are discussed. Special attention was given to electronic and numerical techniques. The performance of the turboreactor using each technique was examined.
Transl. by E.H.W.

N75-23589 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
AN AIR INTAKE CONTROL SYSTEM FOR A SUPERSONIC FIGHTER AIRCRAFT
J. Pelkert *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 6 p (For availability see N75-23575 15-07)

A description of an air intake system of the two dimensional external compression type and its associated air intake control system is given. The AICS comprises a wedge control only. Intake operating maps, derived from small scale wind tunnel test results, are shown and the resulting selection of control signals and the control concept is presented. The performance of the intake and the AICS is substantiated by full scale wind tunnel test results. Finally the hardware implementation of the AICS from a system standpoint is also given.
Author

N75-23590 Laboratoire d'Automatique et d'Analyse des Systemes, Toulouse (France).
NUMERICAL CONTROL OF A TURBOMACHINE [REGULATION NUMERIQUE D'UNE TURBOMACHINE]
Michel Brunet, Jean Claude Laprie, and Christian Beth (Innovations et Developpements en Aerothermodynamique, Toulouse, Fr.) *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 15 p refs In FRENCH (For availability see N75-23575 15-07)

Definition, concepts, realization, and tests of a numerical control system for a turbomachine with free turbines and low power are given. The real time numerical control concept has two functions: one to obtain a performance gain in the turbomachine and two, to increase functional reliability. An examination was also made of problems posed by such a system. In particular, problems of defining the command control and determining necessary variables for a working system, modernization and identification of turbomachines, and testing the control system on a turbomachine under flight conditions to measure and verify principle results were examined.
Transl. by E.H.W.

N75-23591 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Melun (France).
SIMULATION TECHNIQUES FOR TURBOMACHINES [TECHNIQUES DE SIMULATION DES TURBOMACHINES]
Andre Barbot *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 8 p In FRENCH (For availability see N75-23575 15-07)

General problems posed by the simulation of a turbomachine are introduced. Data cover: (1) simple and complex mathematical models, (2) rapid analysis of current simulation techniques, and (3) assessment of typical turbomachine control problems and the proposal of different solutions to the problems. Special attention was given to the problem of adapting the control function to flight conditions.
E.H.W.

N75-23592 National Research Council of Canada, Ottawa (Ontario). Engine Lab.
EQUILIBRIUM PERFORMANCE ANALYSIS OF GAS TURBINE ENGINES USING INFLUENCE COEFFICIENT TECHNIQUES
E. P. Cockshutt *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 10 p refs (For availability see N75-23575 15-07)

Starting from a specified engine design point, a computer oriented technique is described for establishing the equilibrium off-design performance. The technique involves the control system approach of linearizing the governing equations at the design

point, in order to establish a matrix of engine response influence coefficients. These coefficients are then used to achieve rapid convergence as the cycle iterates to an off-design operating point. For clarity of presentation, the technique is developed for the simple turbojet cycle, but the extrapolation to turbofan cycles is indicated. By way of illustrative example of the equilibrium analysis technique, attention is given to the temporary extraction of large amounts of air bleed from a turbofan, for applications such as flap blowing and reaction controls. Engine response to this perturbation is assessed, and control implications suggested.
Author

N75-23593* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
GENERALIZED DYNAMIC ENGINE SIMULATION TECHNIQUES FOR THE DIGITAL COMPUTERS
James Sellers and Fred Teren *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 23 p refs (For availability see N75-23575 15-07)

Recently advanced simulation techniques have been developed for the digital computer and used as the basis for development of a generalized dynamic engine simulation computer program, called DYNGEN. This computer program can analyze the steady state and dynamic performance of many kinds of aircraft gas turbine engines. Without changes to the basic program, DYNGEN can analyze one- or two-spool turbofan engines. The user must supply appropriate component performance maps and design point information. Examples are presented to illustrate the capabilities of DYNGEN in the steady state and dynamic modes of operation. The analytical techniques used in DYNGEN are briefly discussed, and its accuracy is compared with a comparable simulation using the hybrid computer. The impact of DYNGEN and similar digital programs on future engine simulation philosophy is also discussed.
Author

N75-23594 National Gas Turbine Establishment, Farnborough (England).
TOTAL POWERPLANT SIMULATION
R. V. Cottington *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 24 p refs (For availability see N75-23575 15-07)

The capability of predicting the steady state performance of a gas turbine engine is extended to include the prediction of its transient behavior as well. The development and implementation of a total powerplant simulation, consisting of intake and engine, that is capable of predicting both steady state and transient performance are described. The simulation is based on the synthesis of the thermodynamic relationships describing each powerplant component. During the development stage, digital simulation techniques are used, although the simulation is finally implemented on a hybrid computer in order to achieve real time operation. Actual steady state and transient test bed results are then used, when available, to validate the simulation.
Author

N75-23595 Lucas Aerospace Ltd., Birmingham (England).
USE OF SIMULATION IN THE DESIGN, DEVELOPMENT AND TESTING OF POWER PLANT CONTROL SYSTEMS
Stephan Nye and Robert J. Vickers *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 13 p (For availability see N75-23575 15-07)

The design, development and testing of an engine control system are discussed. Two specific areas are highlighted: (1) Digital simulation using large scale computers where both engine and control system are represented by mathematical models for evaluation, feasibility and tolerance analysis; and (2) hybrid computers, where a real time digital engine simulation is used in conjunction with a speed controlled rig for real time development of the control hardware.
Author

N75-23596 Lucas Aerospace Ltd., Birmingham (England)
THE USE OF DIGITAL CONTROL FOR COMPLEX POWER PLANT MANAGEMENT
D. M. Griffiths and R. D. Powell *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 26 p refs (For availability see N75-23575 15-07)

The application of digital control techniques to complex power plants is considered by describing the general structure of a digital controller in regard to system requirements. A description is then provided of an engineered controller. The characteristics of the unit are given together with details of its construction, software, reliability and integrity targets. From this experience reasonable conclusions can be drawn with respect to its area of application and of the likely future for digital techniques.
Author

N75-23597 International Harvester Co., San Diego, Calif. Solar Div.
TEMPERATURE MEASUREMENT FOR ADVANCED GAS TURBINE CONTROLS
David A. Rohy, T. E. Duffy, and W. A. Compton *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 27 p refs (For availability see N75-23575 15-07)

Modern gas turbine engines with turbine inlet temperatures higher than metal melting temperatures must have control systems which provide subsecond response to changes in gas or metal temperatures. High quality data are required to provide for the most efficient engine operation consistent with engine safety. Recently developed instruments measure individual blade temperature, and another non-immersion gas temperature sensor, not yet fully developed, will provide accurate gas temperature data up to 1927 C. These instruments are described with present and potential uses in control systems.
Author

N75-23598 Pisa Univ. (Italy).
FLUIDIC SENSORS FOR TURBOJET ENGINES
D. Dini and M. Santochi *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 28 p refs (For availability see N75-23575 15-07)

Fluidics may replace electronics in modern advanced turbojet engine instrumentation technology for comprehensive engine condition monitoring in highly unfavourable environments. This paper discusses some fluidic sensors originally tested in our laboratory: (1) new types of rotational speed sensors utilizing air flows output being a pressure signal proportional to the value to be measured, suitable for analog and digital circuits; and (2) gas stream temperature sensors, using a thermometric bulb, or a bimetallic spring, or a capillary tube, or a turbulent jet. Corresponding experimental results are summarized and completely fluidic circuits for a small gas turbine and for fire detection in a turbojet engine are described.
Author

N75-23599 Pierburg Luftfahrtgeraete Union G.m.b.H., Neuss (West Germany)
A NEW LIGHTWEIGHT FUEL CONTROL SYSTEM FOR ELECTRICAL INPUTS
Heinz Holzem *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 30 p refs (For availability see N75-23575 15-07)

Most modern control concepts for complex aero gas turbine engines employ more and more electronic hardware for the function generating part. It was therefore necessary to define the requirements for a simple lightweight fuel metering system, basically consisting of a pumping device, manifolds, filters and an electrically controlled metering value controlled by the electronic box. Such a system has been specified and is being built and developed at present. This fuel system will be used in conjunction with the PRAC electronic control. The paper describes this system and highlights critical design and development areas.
Author

N75-23600 Dowty Fuel Systems, Ltd., Cheltenham (England).
PUMPING SYSTEM DESIGN RELATED TO FUEL SYSTEM SPECIFICATIONS
A. T. Miles *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 32 p (For availability see N75-23575 15-07)

Design of the pump in its context, the fuel system, is discussed. System requirements are related to pump limitations. So varied are the requirements that the pumps have to be specifically designed for the system. Discussion first centers on optimizing low pressure systems to minimize heat rejection to the fuel. The concepts of net positive suction head and vapor liquid ratio are contrasted in the context of cavitation. Description of two phase flow regimes leads to particular focus on the engine driven backing pump. Design philosophy to cope with contaminated fuel is followed by an analysis of turn down heat to fuel problems as they affect the high pressure dry engine pump and the afterburner pump. The large afterburner turn down flow ratio justifies the vapor core pump design and its principle of operation is outlined.
Author

N75-23601 Colt Industries, Inc., West Hartford, Conn.
ADVANCED ENGINE MOUNTED FUEL PUMP TECHNOLOGY
John E. Cygnor *In* AGARD Power Plant Controls for Aero-Gas Turbine Eng. Mar. 1975 33 p (For availability see N75-23575 15-07)

Based upon the flight envelope of a typical high performance aircraft, the relationship between the efficiency of engine

mounted fuel pumps at high fuel flow turndown ratios and the fuel heat sink available to the engine and airframe is discussed. The effect of the pump efficiency on the fuel heat sink is presented in terms of the temperature rise imparted to the fuel by the pump and fuel flow metering system. The sources of losses of conventional fuel pump and metering systems which contribute to the fuel temperature rise are identified and pump and metering systems which will reduce those losses are discussed. Examples of pump types which are applicable to advanced turbine engines are presented in terms of performance parameters and system advantages. Author

N75-29114# Advisory Group for Aerospace Research and Development, Paris (France).
TECHNICAL EVALUATION REPORT ON FLUID DYNAMICS PANEL SYMPOSIUM ON AIRFRAME/PROPULSION
E. C. Carter (Aircraft Res. Assoc., Bedford, Engl.) May 1975 14 p refs Symp. held at Rome, 3-6 Sep. 1974
(AGARD-AR-61) Avail: NTIS HC $3.25

Topics discussed at the symposium include: air intakes and airframe inlet interactions; nozzles/afterbodies flow field and airframe interference; wind tunnel testing and correlation with flight data; and integration design and accounting procedures. Main recommendations made are: there is urgent need for high quality afterbody pressure and force data; contradictory trends of drag with Reynolds number variation in windtunnel and flight must be resolved; the need for extended wind tunnel Reynolds number capability is again demonstrated, engine simulator techniques require development and validation; theoretical treatment of mixing of afterbody and jet flows and of afterbody distortion effects must be extended; theoretical treatment of intake buzz requires development. Author

N75-30161# Advisory Group for Aerospace Research and Development, Paris (France).
POWER PLANT CONTROLS FOR AERO GAS TURBINE ENGINES
Klaus Bauerfeind and C. Deane McCarthy May 1975 14 p refs Presented at 44th Propulsion and Energetics Panel Meeting, Ustaoset Hoyfjellshotell, Norway, 9-13 Sep. 1974
(AGARD-AR-80) Avail: NTIS HC $3.25

The steady state and transient performance of aero gas turbine engines in a general fashion is treated. Control concepts and computer simulation techniques are discussed and control system hardware is presented. Author

N75-30166# Advisory Group for Aerospace Research and Development, Paris (France).
AIRCRAFT NOISE GENERATION, EMISSION AND REDUCTION
Jun. 1975 188 p refs Presented at Lecture Series, Belgium, 16-17 Jun. 1975 and West Germany, 19-20 Jun. 1975 and Great Britain, 23-24 Jun. 1975; sponsored by AGARD
(AGARD-LS-77) Avail: NTIS HC $7.00

The physical properties of aircraft noise are summarized, with special emphasis on jet noise and fan-compressor-propeller-rotor noise. Topics discussed include acoustic fundamentals, noise source characteristics and interactions, atmospheric propagation, airframe noise, sonic boom, duct liner, and muffler theory. Research and technology activities related to jet engine noise and its control are discussed, and the impact of this noise on people and communities and aircraft operational procedures for noise minimization are reviewed. For individual titles, see N75-30167 through N75-30173.

N75-30167 Toronto Univ. (Ontario). Inst. of Aerospace Studies.
JET AND AIRFRAME NOISE
Herbert S. Ribner *In* AGARD Aircraft Noise Generation, Emission and Reduction Jun. 1975 17 p refs (For availability see N75-30166 21-07)

Basic notions of acoustics (wave equation, plane and spherical waves, sources, dipoles, quadrupoles) are discussed along with an account of jet noise theory, from the dilatation (simple source) point of view, and from the equivalent quadrupole point of view. The quadrupole sources are shown to dictate a basic directional pattern (self noise and shear noise) which is powerfully modified by convection and refraction effects. The refraction by mean flow velocity gradients is illustrated by laboratory experiments. Jet noise suppression theory examines the role of bypass ratio, the mechanisms of multiple jet shielding, and of reflective shielding by a surface or a gas layer. Airframe noise, distinct from jet noise and other engine noise, is traced to a number of sources on the aircraft. Methods for estimating levels, spectra, and directivity are described. Author

N75-30168 Toronto Univ. (Ontario). Inst. of Aerospace Studies.
ATMOSPHERIC PROPAGATION AND SONIC BOOM
H. S. Ribner *In* AGARD Aircraft Noise Generation, Emission and Reduction Jun. 1975 11 p refs (For availability see N75-30166 21-07)

The attenuation of sound by atmospheric molecular effects, by turbulence, and by near horizontal propagation near the ground is discussed along with refraction, focussing, and defocussing effects, shadow zones and diffraction into shadow zones. Sonic boom is introduced as a 3D analog of the 2D V-shaped wave pattern of a boat. Various aspects of sonic boom theory were developed: evolution of the 'standard' N-wave pressure v. time signature, nonstandard signatures for minimum boom, refractive effects leading to a sonic boom 'corridor' and transonic 'cutoff', maneuver effects leading to focussed 'superbooms', and atmospheric effects leading to 'spiked' and 'rounded' boom signatures. Author

N75-30169 Southampton Univ. (England). Inst. of Sound and Vibration Research.
PEOPLE, COMMUNITIES AND AIRCRAFT OPERATIONS
J. B. Large *In* AGARD Aircraft Noise Generation, Emission and Reduction Jun. 1975 14 p refs (For availability see N75-30166 21-07)

The response of people to aircraft noise, the important phases of this research, and the methodology and the data available to make the choice for establishing noise criteria are discussed. Aircraft noise control through the application of noise abatement operational procedures is discussed. A review is given of operation problems, particularly take-off and approach procedures developed for noise control purposes, and the use of monitoring to control these procedures. Computer programs and flight simulators aid in the development of these flight procedures, and their uses are briefly discussed. Author

N75-30170 Center for the Study of Noise in Society, Glastonbury, Conn.
JET ENGINE NOISE AND ITS CONTROL
John M. Tyler *In* AGARD Aircraft Noise Generation, Emission and Reduction Jun. 1975 25 p refs (For availability see N75-30166 21-07)

The noise of turbojet and turbofan engines is described and presented in a form useable by engine and aircraft designers; it deals primarily with the practical aspects of aircraft powerplant noise. Noise from the wakes of turbojet and turbofan engines, the effects of engine cycle on wake noise, and the possibilities for noise reduction using exhaust noise suppressors are discussed. Methods for exhaust noise prediction are presented. Fan and compressor noise, including a description of the mechanisms of fan and compressor noise generation, was investigated. Design practices to minimize fan and compressor noise are presented. A discussion of turbine and combustion noise, and a summary of the state of the art in the research and development stage are included. Author

N75-30171 Westland Helicopters, Ltd., Yeovil (England)
ROTORCRAFT AND PROPELLER NOISE
Martin V. Lowson *In* AGARD Aircraft Noise Generation, Emission and Reduction Jun. 1975 26 p refs (For availability see N75-30166 21-07)

The fundamentals of propeller and helicopter noise radiation phenomena are presented, including a review of the implication of subjective response. Emphasis is placed on the underlying mechanisms of rotor noise generation, both for discrete frequency and broad band noise components. Implications for noise control are discussed. Author

N75-30172 Westland Helicopters, Ltd., Yeovil (England)
DUCT ACOUSTICS AND MUFFLERS
M. V. Lowson *In* AGARD Aircraft Noise Generation, Emission and Reduction Jun. 1975 34 p refs (For availability see N75-30166 21-07)

The fundamental features of sound propagation in lined ducts, with and without flow, are reviewed. Emphasis is placed on basic physical principles, and simplified results. A set of charts for direct evaluation of sound attenuation is given. Detail predictions necessitate computer analysis based on the basic equations, together with empirical engineering input on practical duct impedance boundary conditions. The design of liners is discussed, and the engineering trade-offs required in a practical aircraft design solution are reviewed briefly. Author

N75-30173 Environmental Protection Agency, Arlington, Va. Office of Noise Abatement and Control

THE ROLE OF EPA IN REGULATING AIRCRAFT/AIRPORT NOISE

John C. Schettino and Harvey J. Nozick. *In* AGARD Aircraft Noise Generation, Emission and Reduction. Jun. 1975. 13 p. refs (For availability see N75-30166 21-07)

A principal finding in the study of aircraft and airport noise in compliance with the Noise Control Act of 1972, was that a comprehensive national program for aircraft/airport noise abatement was needed to insure that the noise control options available to the aircraft manufacturers and operators, the airport operators, the Federal Government, and other public authorities are implemented to protect the public health and welfare. To initiate implementation of this finding and to bring about near term reductions in community noise levels, regulations are proposed for noise abatement flight procedures, noise source emissions (aircraft certification), and airport noise. For the longer term, a study was conducted to determine the noise reductions required to progressively lower community noise levels resulting from aircraft operations and upon which to base a coordinated long-range aviation noise abatement and control program. The status of EPA regulations and the preliminary results of the long-range aviation noise requirements study are presented.

Author

N75-31083# Advisory Group for Aerospace Research and Development, Paris (France).

DIAGNOSTICS AND ENGINE CONDITION MONITORING

Allen E. Fuhs, ed., Richard Smyth, ed., H. Dissen, ed., Andrew Hess, ed., Dino Dini, ed., Richard Lazarick, ed., and W. R. Krupa, ed. Jun. 1975. 342 p. refs. In ENGLISH; partly in FRENCH. Conf. held at Liege, 4-5 Apr. 1974

(AGARD-CP-155) Avail: NTIS HC $9.50

Various engine monitoring techniques for aircraft turbine engines are summarized. These methods range from boroscope inspection, SOAP, and radiography to advanced concepts in flight data analysis, diagnostics, and prognostics. Data also cover economics, statistics, and function of engine condition monitoring. For individual titles, see N75-31084 through N75-31107.

N75-31084 Naval Postgraduate School, Monterey, Calif. Dept. of Aeronautics.

DIAGNOSTICS AND ENGINE CONDITION MONITORING

A. E. Fuhs. *In* AGARD Diagnostics and Engine Condition Monitoring. Jun. 1975. 18 p. refs (For availability see N75-31083 22-07)

Diagnostics and aircraft engine condition monitoring by computer are examined. Data cover computer costs, electronic reliability, prediction of impending engine malfunctions, engine control, and other instruments and data needed for computer operation.

E.H.W.

N75-31085 Pisa Univ. (Italy).

PROBLEMS IN FAULT DIAGNOSTICS AND PROGNOSTICS FOR ENGINE CONDITION MONITORING

M. Andrenucci and R. Lazzeretti. *In* AGARD Diagnostics and Engine Condition Monitoring. Jun. 1975. 10 p. refs (For availability see N75-31083 22-07)

A general discussion of major problems concerning fault detection and isolation in ECM systems is presented. The ECM concept, history and development prospects are reviewed, and various questions regarding instrumentation, sensor requirements and some critical problem areas are considered. A detailed discussion is presented on the concept of an ECM system designed to provide an extensive in-flight diagnostic and prognostic capability. The main characteristics of such a system are analyzed, considering the various aspects of fault logic, parameter selection, diagnostic and prognostic procedures and system operation. Hardware requirements and display techniques are also discussed.

Author

N75-31086 Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France). Centre D'essais de Villa Roche.

DIAGNOSIS OF THE FUNCTIONAL STATE OF A MOTOR BY MODELIZATION [DIAGNOSTIC DE L'ETAT DE FONCTIONNEMENT D'UN MOTEUR PAR MODELISATION]

A. Barbot. *In* AGARD Diagnostics and Engine. In FRENCH

(For availability see N75-31083 22-07)

A mathematical model was used to investigate engine damage and its effects on engine operation and performance. Two types of damage were considered: damage which effects performance and that damage which does not effect performance. In the case of performance effecting damage, thermodynamic parameters and the detection and localization of defects, were discussed. For non-performance effecting damage, degradation or rupture of rotating parts and metallurgic degradation of mechanical components were considered.

Transl. by E.H.W.

N75-31087 Karlsruhe Univ. (West Germany).

THEORY OF PERIODIC TURBOMACHINE NOISE AND DETERMINATION OF BLADE DAMAGE FROM NOISE SPECTRUM MEASUREMENTS

Dieter Barschdorff. *In* AGARD Diagnostics and Engine Condition Monitoring. Jun. 1975. 4 p. refs (For availability see N75-31083 22-07)

The mechanical conditions of rotor blades as deduced from vibration or noise spectra measurements are examined. Noise sources and analytical models used to compute periodic noise in the time and frequency domain are discussed. It was noted that irregularities may be observed directly in the time domain using digital averaging techniques. As compared with the Fourier amplitude spectrum of a mechanically perfect rotor stage, additional discrete spectral lines to the blade passing frequency and its harmonics indicate mechanical damage. Moreover, the amplitude distribution of the additional frequency lines can serve as an indication for the specific nature of the irregularity.

Author

N75-31088 Army Aviation Systems Command, St. Louis, Mo.

AUTOMATIC INSPECTION, DIAGNOSTIC AND PROGNOSTIC SYSTEM (AIDAPS): AN AUTOMATIC MAINTENANCE TOOL FOR HELICOPTERS

Thomas C. Belrose. *In* AGARD Diagnostics and Engine Condition Monitoring. Jun. 1975. 8 p. refs (For availability see N75-31083 22-07)

An overall effort to develop an automatic inspection, diagnostic and prognostic system (AIDAPS) for US Army aircraft is summarized. Major performance requirements of the AIDAPS system include continuous monitoring of critical systems, automatic diagnosis of malfunctions, and prediction of service life remaining in certain components. The objective of this program is to develop, on existing aircraft and engines, AIDAPS systems for ultimate field application on future aircraft such as utility tactical transport aircraft system (UTTAS), heavy lift helicopter (HLH), and advanced attack helicopter (AAH).

Author

N75-31089 Frankford Arsenal, Philadelphia, Pa. Fire Direction and Diagnostic Systems Div.

TECHNICAL DIAGNOSIS: A SYSTEMS APPROACH

R. J. Brachman. *In* AGARD Diagnostics and Engine Condition Monitoring. Jun. 1975. 18 p. (For availability see N75-31083 22-07)

The use of computer technology, in a test configuration, to direct tests, make measurements, analyze data, and produce specific output as to the specific nature of a fault in materials or operating systems, is examined. Technical diagnosis is defined and diagnostic systems design is discussed.

Author

N75-31090 Grumman Aerospace Corp., Bethpage, N.Y.

ENGINE HEALTH AND FAULT DETECTION MONITORING: ITS FUNCTION AND IMPLEMENTATION PROCEDURE

William Brenner. *In* AGARD Diagnostics and Engine Condition Monitoring. Jun. 1975. 7 p. refs (For availability see N75-31083 22-07)

The realistic factors relative to an engine health and fault monitoring system and its functions and implementation are discussed as a basis for determining the performance condition and minimum maintenance duties of a high performance aircraft engine. An approach to raise the user's confidence level will be discussed. Opinions will be voiced with reference to whom should be involved in engine health and fault detection monitoring relative to concept formulation and design.

Author

N75-31091 Riv-Officine di Villar Perosa S.p.A., Turin (Italy).

A CONTRIBUTION TO THE AERO ENGINES BEARINGS CONDITION MONITORING

S. Brignone, G. Feva, and F. Giordano. *In* AGARD Diagnostics and Engine Condition Monitoring. Jun. 1975. 20 p. refs (For availability see N75-31083 22-07)

From a survey of the existing techniques used to detect malfunctions in aircraft mainshaft bearings, it is concluded that they are mainly oriented toward the detection of the spalling fatigue initiation. It is pointed out that high speed, low loaded bearings fail mainly from surface distress caused by roller skidding or deficiencies of the lubrication system and the conclusion is

drawn that a new monitoring device should be developed based on the measure of the bearing internal speeds. This device can detect bearing failures, running conditions that might cause an early failure, and could also be used for calculating the bearing accumulated life. Suggestions as to how to make the proposed measurements are given and some experimental data are presented. Author

N75-31092 Ecole Nationale d'Ingenieurs de Constructions Aeronautiques, Toulouse (France).
STUDY OF A PREVENTIVE MAINTENANCE SYSTEM AS CLASSIFIED BY DIAGNOSTIC AND PRONOSTIC BREAKDOWNS. APPLICATION TO MARBORNE 2F MOTORS [ETUDE D'UN SYSTEME DE MAINTENANCE PREVENTIVE PERSONNALISEE PAR DIAGNOSTIC ET PROGNOSTIC DE PANNES. APPLICATION AUX REACTEURS MARBORNE 2F.3]
Paul Caspi, Andre Rault, and Olivier Esmenjaud *In* AGARD Diagnostics and Engine Condition Jun. 1975 10 p refs In FRENCH (For availability see N75-31083 22-07)

Theoretical, statistical, and mathematical modeling techniques were combined in an attempt to develop a preventive maintenance system for engines. Data are based on the state or condition of major engine components. These components were assigned grades of perfect condition, small failure, and total failure. Engine breakdowns, on a statistical basis, were then used to determine which class a particular component was assigned. The Marborne 2F engine was used for the study. Transl. by E.H.W.

N75-31093 Technische Universitaet, Brunswick (West Germany). Inst. fuer Maschinenelemente und Foerdertechnik.
SOME EXPERIENCE IN ENGINE TROUBLESHOOTING WITH INFLIGHT-DATA, RECORDED IN THE F-104G WITH THE LEADS-200
G. Dahl *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 24 p (For availability see N75-31083 22-07)

Inflight engine data, recorded during the flight test of the aircraft integrated data system (AIDS) LEADS-200 in the military fighter F-104G are processed to show their worth for accident investigation and early failure detection. These investigations are performed in close connection with an airforce test station. Author

N75-31094 Rolls-Royce, Ltd., Bristol (England). Engine Div.
THE RELATIVE ROLE OF ENGINE MONITORING PROGRAMME DURING DEVELOPMENT AND SERVICE PHASES
A. E. Davies and H. L. Newman *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 16 p (For availability see N75-31083 22-07)

These data suggest that deep analysis of engine behaviour is extremely important in the flight development and commissioning stages. Examples of flight development data acquisition programs are given. These include trend analysis for Olympus 593 engines in Concorde development aircraft, flight strain gauging of blading, and an interesting approach to a diagnostic system using an airborne computer. Author

N75-31095 National Research Council of Canada, Ottawa (Ontario).
IN-FLIGHT THRUST MEASUREMENT: A FUNDAMENTAL ELEMENT IN ENGINE CONDITION MONITORING
M. S. Chappell and J. A. Gravelle (Computing Devices Co., Ottawa) *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 15 p refs (For availability see N75-31083 22-07)

The development of an in-flight gross thrust measuring system, as applied to an afterburning turbojet engine with a fully-modulating variable-area nozzle is described. The aerothermodynamic approach is described as background to the experimental results from both ground level test bed and flight trial using a CF-5D aircraft as a test vehicle. Author

N75-31096 Ohio State Univ., Columbus.
VIBRATION DIAGNOSTICS IN HELICOPTER POWER TRAINS
D. R. Houser, M. J. Drosjack, and G. W. Hogg (Army Air Mobility R and D Lab., Ft. Eustis, Va.) *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 24 p refs (For availability see N75-31083 22-07)

The state-of-the-art of vibration diagnostics is reviewed for gears and bearings and the potential application of these techniques to helicopter usage. Related Army helicopter diagnostics research is also included. The usage of diagnostic techniques with gears and bearings in helicopter power trains is similar to that which may be encountered on gas turbine engines. A number of analysis procedures for diagnostic purposes were proposed, and some were tested. The mesh forces will produce nonsinusoidal vibrations which appear in the frequence domain as a proliferation of harmonics and side-bands of the gear meshing frequency. Author

N75-31097 Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
AN ADVANCED DIAGNOSTIC ENGINE MONITORING SYSTEM APPROACH
W. R. Krupa and K. R. Hamilton *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 11 p refs (For availability see N75-31083 22-07)

The Advanced Diagnostic Engine Monitoring System (ADEMS) is designed to monitor all of the significant engine parameters in-flight, and by the use of onboard digital computational techniques, compare the measured engine condition against normal expected design performance and also against test data related to component performance for a particular power setting. When engine performance degradation is detected, the computer automatically interrogates other engine parameters to indentify and isolate the engine component(s) that are outside normal operating limits. Out of tolerance readings are identified, and the crew is alerted to the parameter(s) and component(s) that are outside normal operating limits. Meanwhile, the computer automatically records engine parameters for post-flight analysis and long-term trending. Recording, in this sense, is by exception in order to minimize the amount of post-flight analysis. The expected payoff, when an ADEMS type system is engineered and applied to military aircraft, is a sizable reduction of overall maintenance and operational costs, improved utilization of in-service engines and spare parts, and an in-flight capability to automatically isolate and assess the impact of engine component degradation. Author

N75-31098 Rolls-Royce, Ltd., Derby (England). Engine Div.
ENGINE DATA RECORDING ON A PHANTOM AIRCRAFT: RESULTS OBTAINED TO DATE
P. A. Mucklow *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 7 p (For availability see N75-31083 22-07)

A recording system was installed in one Phantom aircraft expressly for recording Spey engine data. This provides for continuous recording in digital form of signals from 21 parameters at a rate of 1 or 2 samples/second. Significant results were obtained from this limited exercise. Author

N75-31099 Dornier-System G.m.b.H., Friedrichshafen (West Germany).
EXPERIENCE WITH F-104G FDRS EVALUATION WITH RESPECT TO ENGINE DIAGNOSTICS
Bernd Mueller and Friedrich Bott *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 11 p (For availability see N75-31083 22-07)

A Flight Data Recording System (FDRS) is being introduced in a German F-104G fighter bomber wing in order to establish FDRS technology and cost effectiveness of an operational system. It is of particular interest to determine the possibilities and benefits of a most automatic debriefing after each flight in order to refine and verify present post flight check and pilot debriefing techniques. For this purpose the conventional verbal pilot debriefing for maintenance is backed up by an automatic FDRS diagnosis evaluated by a ground computer within about 10 minutes time after landing Author

N75-31100 North Carolina State Univ., Raleigh. Dept. of Mechanical and Aerospace Engineering.
TURBOJET ENGINE GAS PATH ANALYSIS: A REVIEW
Frederick O. Smetana *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 13 p (For availability see N75-31083 22-07)

Methods for determining the thermodynamic health of a turbojet engine and of its major components are surveyed in a critical fashion from the point of view of their theoretical potential. The quantitative effects of poor health on engine performance are detailed along with the inferences which can be drawn as to the reason for the poor health. Instrumentation requirements of the various techniques are discussed. The position of gas path analysis in an overall program of failure prediction is also treated. Author

N75-31101 Carleton Univ., Ottawa (Ontario).
AN ENGINE ANALYZER PROGRAM FOR HELICOPTER TURBOSHAFT POWERPLANTS
L. J. Staples (Leigh Instruments LTD., Ontario) and H. I. H. SaraVanaMuttoo *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 9 p refs (For availability see N75-31083 22-07)

A simple thermodynamic analysis technique was described; it was developed to sense the health of a helicopter power plant with a high degree of accuracy and sensitivity. The main design objective was to develop a method of analysis which requires minimum computational power and yet will produce those cycle parameters which are prime indicators of engine condition. The single-spool gas generator, free power turbine turboshaft was selected for consideration due to its almost universal application on present and forthcoming helicopter variants of interest. Author

N75-31102 Ministry of Defence, London (England).
A MILITARY OPERATOR'S VIEW OF AERO-ENGINE LOW CYCLE FATIGUE MONITORING
P. W. Swindlehurst *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 4 p (For availability see N75-31083 22-07)

Low cycle fatigue monitoring is set in the more general context of engine condition monitoring, and the basic mechanisms of low cyclic fatigue and its influence on critical component lifting are considered. A case is argued for a limited sampling program to assess the lifting problem in a particular operation. Methods of cyclic fatigue monitoring are discussed, and a case is made for the development of a low cycle fatigue counter. Author

N75-31103 Hamilton Standard Div., United Aircraft Corp., Windsor Locks, Conn.
PARAMETER SELECTION FOR MULTIPLE FAULT DIAGNOSTICS OF GAS TURBINE ENGINES
Louis A. Urban *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 14 p refs (For availability see N75-31083 22-07)

Fundamentals of turbine engine multiple fault diagnosis are introduced, and its relationship to engine parameter selection and measurement requirements is presented. The influence of the type (thermodynamic cycle) of the engine to be diagnosed, and the nature of its expected problems, on the required parameters and the attendant measurement repeatability requirements are discussed. Author

N75-31104 KLM Royal Dutch Airlines, Amsterdam (Netherlands).
KSSU AIDS ENGINE ANALYSIS
H. Vermeulen *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 27 p (For availability see N75-31083 22-07)

Based on KLM's experience with a first generation digital AIDS the primary requirements for an AIDS for widebody aircraft included: (1) a high degree of accuracy and repeatability, (2) a high system MTBF, and (3) integration with the ARINC 573 digital flight data recorder systems. As the KSSU system concept was developed to meet not only ECM but also flight operational, flight technical and other requirements, it is evident that a pure trade-off for ECM only becomes difficult. Author

N75-31105 National Aerospace Lab., Amsterdam (Netherlands).
ENGINE CONDITION PROBLEMS IN SUPERSONIC FLIGHT
J. P. K. Vleghart *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 6 p ref (For availability see N75-31083 22-07)

A performance discrepancy of Royal Netherlands Air Force fighters could be traced to a mass flow deficiency at low corrected RPM. Engine mass flow improved significantly when replacing the first stage compressor rotor blades. Probable cause of the deficiency was air foil deterioration when applying an anticorrosion treatment to the blades. Author

N75-31106 British Airways, Middlesex (England).
ENGINE HEALTH MONITORING IN A CIVIL AIRLINE
P. Waller and E. R. White *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 14 p refs (For availability see N75-31083 22-07)

The operational effects of prematurely failed engines are reviewed with estimated economic effects. The estimated return from an engine health monitoring system is considered in relationship to the cost of implementing and running it, and it is shown that a positive financial return is only likely if the basic data acquisition and analysis equipments are readily available for other purposes. The theoretical and experienced benefits are compared, and the limitations imposed by operating such a system in a competitive commercial environment are discussed, including the effects of stringent control over financial and personnel resources. The results achieved so far are critically examined in terms of the equipment design specifications and actual performance, and also the mathematical processes employed in reducing the data. Some of the deficiencies in these processes are discussed, with proposals for their improvement. The characteristics of the RB211 engines for BAED's next aircraft, the TriStar, as relevant to engine health monitoring, are examined in relationship to the recording system to be fitted, which includes a small but powerful computer with an input/output device for communicating with the flight crew. Author

N75-31107 Pacific Airmotive Corp., Burbank, Calif. Industrial and Marine Engine Div.
AN INTEGRATED RELIABILITY PROGRAM UTILIZED FOR AIRCRAFT INDUSTRIAL AND MARINE GAS TURBINES
R. E. Weller *In* AGARD Diagnostics and Engine Condition Monitoring Jun. 1975 6 p refs (For availability see N75-31083 22-07)

Both the airline and industrial gas turbine operators have the requirement for a comprehensive maintenance and reliability program which has the flexibility of accepting changes in concept as new technology is developed. It was established and proven that on-condition and monitored maintenance type programs have not jeopardized or compromised safety or reliability. Author

N76-25169# Advisory Group for Aerospace Research and Development, Paris (France)
UNSTEADY PHENOMENA IN TURBOMACHINERY
Apr 1976 565 p refs Presented at the 46th Meeting of the AGARD Propulsion and Energetics Panel, Monterey, Calif., 22-26 Sep 1975
(AGARD-CP-177) Avail: NTIS HC $13.50

Turbomachinery unsteady aerodynamics are reviewed with emphasis on flow distortion phenomena inside subsonic, transonic and supersonic axial flow compressor stages. For individual titles, see N76-25170 through N76-25203.

N76-25170 Pratt and Whitney Aircraft, East Hartford, Conn.
THE PRACTICAL IMPORTANCE OF UNSTEADY FLOW
A. A. Mikolajczak *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 12 p refs (For availability see N76-25169 16-07)

The importance of unsteady flows is examined in relation to the performance of turbomachines operating in uniform and in distorted inlet flow, in relation to the aerodynamic stability, aeroelastic stability (flutter), and in relation to noise generation. Attention is focused primarily on flows in which the time scale for the transport of particles is comparable to the time scale of local fluctuations and where the amplitudes of the unsteady perturbations are finite. An attempt is made to identify the direction of future research towards improving the understanding of relevant unsteady flows in turbomachines. Author

N76-25171 Rolls Royce Ltd., Derby (England). Engine Div.
INFLUENCE OF UNSTEADY FLOW PHENOMENA ON THE DESIGN AND OPERATION OF AERO ENGINES
R. Hetherington and R. R. Mountz *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 18 p refs (For availability see N76-25169 16-07)

Unsteady phenomena are examined in some detail with a view to both understanding and improving the operation of turbomachines in aero engines and improving design procedures by being more explicit concerning some of the time dependent flow phenomena that exist. The following possibilities are discussed: (1) improving the design point efficiency of a compressor through an understanding of internal unsteady flow effects, and (2) selection of compressor configurations with minimum stall response to non axisymmetric and unsteady intake flow. Author

N76-25172 Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy Cramayel (France)
THE IMPACT OF UNSTEADY PHENOMENA ON TURBINE ENGINE DESIGN AND DEVELOPMENT
J. F. Chevalier *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 19 p refs In FRENCH and ENGLISH

Compressor aerodynamics are reviewed for their unsteady phenomena in order to predict problems and to introduce their solutions at the project design stage. Unsteady phenomena in airfoil cascades constitute aeroelasticity, forced vibration, rotating stall, and aerodynamic noise. Described is the overall response of a compressor, or of one compressor stage, to the effects of aircraft induced conditions of steady distortion, overall fluctuation of the airflow, and unsteady distortion. Author

N76-25173* Pennsylvania State Univ., University Park.
THE NATURE OF FLOW DISTORTIONS CAUSED BY ROTOR BLADE WAKES
B. Lakshminarayana. *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 14 p refs (For availability see N76-25169 16-07)
(Grant NsG-3012)

The distortion caused by wakes of rotor blades is one of the least understood phenomena in turbomachinery. An attempt is made to predict the decay characteristics of the defect in axial and tangential velocity components, and the decay of the maximum radial velocity inside the rotor wake using the momentum integral analysis. The predictions agree well with the experimental data taken at the exit of an axial flow fan operating at zero incidence. The measurements are carried out with a three sensor hot wire probe. The wake width is found to grow linearly with distance downstream and the defect in tangential velocity inside the rotor wake decays fastest of the three components. An empirical expression is also provided for the axial velocity profile of a rotor wake. Author

N76-25174* Massachusetts Inst. of Tech., Cambridge. Gas Turbine Lab.
EXIT FLOW FROM A TRANSONIC COMPRESSOR ROTOR

William T. Thompkins, Jr. and Jack L. Kerrebrock. *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 23 p refs (For availability see N76-25169 16-07)
(Grant NGR-22-009-383)

The three dimensional unsteady flow field behind a transonic compressor rotor with a design pressure ratio of 1.6 at a tip Mach number of 1.2 has been resolved on the blade passing time scale. Quantities determined were total and static pressures, tangential flow angle, and radial flow angle. The spatial and temporal resolution achieved was sufficient to determine velocity components inside individual blade wakes and in the surrounding flow. From these measurements the flow structure is described at stations immediately behind the rotor and one chord downstream. Some dominant features of the flow just behind the rotor are large radial velocity components, large static pressure fluctuations near the blade wakes, and definite unsteadiness (in rotor coordinates) of the wakes. The wake behavior one chord downstream is described in terms of the effect of the strong mean swirl on the behavior of shear disturbances. In the outer portion of the annulus, where the mean flow approximates a *solid body rotation*, a strong, persistent oscillatory flow is found with 16 periods in the circumference as roughly predicted by theory. In the inner portion of the annulus the disturbances *attenuate axially*. Author

N76-25175 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
UNSTEADY PHENOMENA IN TURBOMACHINES, AS REVEALED BY VISUALIZATIONS AND MEASUREMENTS

Jean Fabri and Jacques Paulon. *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 22 p refs In ENGLISH and FRENCH (For availability see N76-25169 16-07)

Theoretical and experimental studies are reported of the instabilities observed in axial transonic compressors functioning at rotating speeds higher than nominal. The tests described, and analyzed by means of a quasi one dimensional theory, have been performed on fixed and mobile cascades. Author

N76-25176 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
EXPLORATORY RESEARCH ON THE AEROELASTICITY OF TURBINE BLADES AND GUIDE WAVES
Henri Loiseau, Gerard Lepoint, and Brigitte Maquennehan. *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 8 p refs In ENGLISH and FRENCH (For availability see N76-25169 16-07)

Flutter configurations have been analyzed in a test compressor in order to define initial conditions of flutter and major design parameters. Their detailed determination is not possible unless a straight cascade wind tunnel is used. A rig has been developed, based on linear theory, in order to establish a wind tunnel where all types of flutter observed in compressors can be investigated in subsonic, transonic and supersonic flow conditions. Author

N76-25177* Hamilton Standard, Windsor Locks, Conn.
APPLICATION OF ROTOR MOUNTED PRESSURE TRANSDUCERS TO ANALYSIS OF INLET TURBULENCE
Donald B. Hanson. *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 18 p refs (For availability see N76-25169 16-07)
(Contract NAS1-12505)

Miniature pressure transducers installed near the leading edge of a fan blade were used to diagnose the non-uniform flow entering a subsonic tip speed turbofan on a static test stand. The pressure response of the blade to the inlet flow variations was plotted in a form which shows the space-time history of disturbances ingested by the rotor. Also, periodically sampled data values were auto- and cross-correlated as if they had been acquired from fixed hot wire anemometers at 150 equally spaced angles around the inlet. With a clean inlet and low wind, evidence of long, narrow turbulence eddies was easily found both in the boundary layer of the fan duct and outside the boundary layer. The role of the boundary layer was to follow and amplify disturbances in the outer flow. These eddies frequently moved around the inlet with a corkscrew motion as they passed through. Author

N76-25178 Technische Hochschule, Aachen (West Germany). Inst. fuer Strahlantriebe und Turboarbeitsmaschinen.
RESULTS OF MEASUREMENTS OF THE UNSTEADY FLOW IN AXIAL SUBSONIC AND SUPERSONIC COMPRESSOR STAGES
H. E. Gallus. *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 18 p refs (For availability see N76-25169 16-07)

A measurement program is reported for unsteady flow in a one stage axial flow compressor with subsonic flow, and another one with supersonic flow. Measuring techniques and results of first measurements are presented. Author

N76-25179 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Luftstrahlantriebe.
ANALYSIS OF UNSTEADY FLOW IN A TRANSONIC COMPRESSOR BY MEANS OF HIGH-RESPONSE PRESSURE MEASURING TECHNIQUES
H. B. Weyer and H. G. Hungenberg. *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 18 p refs (For availability see N76-25169 16-07)

Experimental investigations on the fluctuating flow inside a transonic axial flow compressor were studied by applying modern pressure measuring techniques, as there are pressure transducers of high natural frequency and accurately reading methods for determining the corresponding time averaged values. These techniques were used for the examination of the fluctuating wall pressures at the rotor blade tip and of the unsteady total pressures just downstream of the rotor. Some results of these investigations demonstrate the possibilities offered by modern measuring techniques to analyze the unsteady flow in transonic compressors. The flow phenomena at the blade tip sections, as well as the instationary flow behavior downstream of the rotor including the blade wake development, are considered as functions of mass flow rate. Author

N76-25180 Leicester Univ. (England). Dept. of Engineering.
MATHEMATICAL MODELLING OF COMPRESSOR STABILITY IN STEADY AND UNSTEADY FLOW CONDITIONS
A. G. Corbett and R. L. Elder (Cranfield Inst. of Tech.). *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 14 p refs (For availability see N76-25169 16-07)

As multistage compressor surge creates an operating limitation for turbojet and turbofan engines, prediction of surge and the effect of parametric changes upon it may be used to improve design. Considered are mathematical models, involving dynamic stage interaction, which can be used to simulate compressor surge under steady and unsteady conditions. Various models were produced based upon the principles of conservation of mass, linear momentum and energy applied to a one dimensional flow using steady state stage characteristics to introduce the effects of the blading. These models are evaluated for their surge prediction capabilities (with steady inlet conditions). It is shown that experimental results may be reproduced quite accurately

using digital simulation techniques and stability criteria applied to linearized system equations The most adequate model was used to investigate the response of the model to ramp type and sinusoidal changes in inlet total pressure, these typifying non-periodic and periodic variations The steady state surge line appeared to have little relevance, instantaneous conditions were arising which could not be tolerated in steady conditions Author

N76-25181 Vrije Universiteit, Brussels (Belgium)
UNSTEADY CONTRIBUTIONS TO STEADY RADIAL EQUILIBRIUM FLOW EQUATIONS
Ch Hirsch *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 12 p refs (For availability see N76-25169 16-07)

The contributions to the meridional axisymmetric through flow in axial compressors arising from the unsteady part of the flow are examined The nonsteady terms occurring in an axisymmetrical radial equilibrium are derived from the general flow equations through an exact averaging process Based on a wake model a theoretical evaluation of these terms is presented and their contribution to the radial distribution of flow functions is discussed on the basis of the inclusion of these terms in a meridional flow calculation program (based on finite elements) With the use of a periodic sampling and averaging techniques, an experimental evaluation of the unsteady contributions is obtained behind a single rotor compressor stage Author

N76-25182 Centro Applicazioni Militari dell'Energia Nucleare, Pisa (Italy)
GAS TURBINE TRANSIENT OPERATING CONDITIONS DUE TO AN EXTERNAL BLAST WAVE IMPULSE
D. Dini, A. DiGiorgio, and S. Cardia *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 22 p refs (For availability see N76-25169 16-07)

The aerodynamic response of an aero gas turbine to time variant total pressure inlet distortion is considered as sonic boom signature from a supersonic aircraft or air blast wave overpressure Various methods which have been developed for simulating sonic bangs are briefly described, and in particular the experimental work in progress for generation of strong shock wave signatures to simulate the effects on a turbojet engine in flight Mass flow in aero gas turbine engines and unsteady measurements are considered Prediction of the steady state performance is extended to include transient behavior Propulsion system instability caused by inlet flow, distorted as consequence of strong shock waves, as well as possible responses of axial flow fan and compressor components are discussed in view of experimental correlation Author

N76-25183* National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio
TURBOFAN COMPRESSOR DYNAMICS DURING AFTERBURNER TRANSIENTS
Anatole P Kurkov *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 12 p refs (For availability see N76-25169 16-07)

The effects of afterburner light-off and shut-down transients on the compressor stability are investigated The reported experimental results are based on detailed high response pressure and temperature measurements on the TF30-P-3 turbofan engine The tests were performed in an altitude test chamber simulating high altitude engine operation It is shown that during both types of transients, flow breaks down in the forward part of the fan bypass duct At a sufficiently low engine inlet pressure this resulted in a compressor stall Complete flow breakdown within the compressor was preceded by a rotating stall At some locations in the compressor, rotating stall cells initially extended only through part of the blade span For the shutdown transient the time between first and last detected occurrence of rotating stall is related to the flow Reynolds number An attempt was made to deduce the number and speed of propagation of rotating stall cells Author

N76-25184* National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio
THE EFFECT OF CIRCUMFERENTIAL DISTORTION ON FAN PERFORMANCE AT TWO LEVELS OF BLADE LOADING
Melvin J. Hartmann and Nelson L Sanger *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 26 p refs (For availability see N76-25169 16-07)

Single stage fans designed for two levels of pressure ratio or blade loading were subjected to screen induced circumferential distortions of 90 degree extent Both fan rotors were designed for a blade tip speed of 425 m/sec, blade solidity of 1 3 and a hub-to-tip radius ratio of 0 5 Circumferential measurements of total pressure, temperature, static pressure, and flow angle were obtained at the hub, mean and tip radii at five axial stations. Rotor loading level did not appear to have a significant influence on rotor response to distorted flow. Losses in overall pressure ratio due to distortion were most severe in the stator hub region of the more highly loaded stage. At the near stall operating condition tip and hub regions of (either) rotor demonstrated different response characteristics to the distorted flow No effect of loading was apparent on interactions between rotor and upstream distorted flow fields Author

N76-25185 Cranfield Inst of Technology (England)
DYNAMIC INTERNAL FLOWS IN COMPRESSORS WITH PRESSURE MALDISTRIBUTED INLET CONDITIONS
R E Peacock and J Overli (Norges Tekniske Hoegskole) *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 14 p refs (For availability see N76-25169 16-07)

By installing in its intake region a series of distortion screens of various geometries, a low speed lightly loaded compressor was subjected to a range of pressure distortions, broadly classified as square wave and sine wave in the circumferential sense. The effects upon overall performance, rotor normal force coefficient and rotor detailed static pressure distributions was discussed, as well as the cross-coupling effect from the rotor to the distortion Two domains of rotor reaction are isolated, one precipitated by a leading edge promoted perturbation, the other by a trailing edge promoted perturbation The magnitude of lift or normal force overshoot is found to be a function of a velocity parameter related to the time rate of change of blade incidence Author

N76-25186* Pennsylvania State Univ, University Park Dept of Mechanical Engineering
AXIAL FLOW ROTOR UNSTEADY RESPONSE TO CIRCUMFERENTIAL INFLOW DISTORTIONS
Edgar P. Bruce *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 13 p refs (For availability see N76-25169 16-07)
(Grant NrG-3031, Contract N00014-67-A-0226-0005; NR Proj. 098-038, Proj. SQUID)

The unsteady response of an axial flow fan rotor to steady, circumferential inflow velocity and stagnation pressure distortions is assessed by two different methods These are (1) investigation of the unsteady normal force and pitching moment on a chordwise element of a rotor blade, and (2) investigation of the variation of the stagnation pressure distortion between the inlet and exit of the rotor Experimental measurements of these unsteady characteristics are presented as a function of the geometry of the rotor -- stagger angle, solidity and steady angle of incidence -- for sinusoidally varying circumferential distortions with different numbers of distortion cycles These measurements are compared with several theoretical analyses While these comparisons indicate some of the deficiencies which exist in the theories, the existence of an unsteady cascade effect and the ability of the theories to adequately predict the trend of the unsteady response due to variations in reduced frequency, rotor stagger angle, solidity and mean incidence angle is clearly demonstrated Author

N76-25187 Rolls-Royce Ltd, Derby (England) Engine Div
THE RELATIONSHIP BETWEEN STEADY AND UNSTEADY SPECIAL DISTORTION
C. Freeman *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 16 p refs (For availability see N76-25169 16-07)

Simple theories of turbulence are used to develop a model that relates the fluctuating special distortion to the time average special distortion. This model uses the relationship between the fluctuating total pressure, the fluctuating velocities, the Reynolds stress and the mean velocity gradient. These fluctuating total pressures are then used with a correlation coefficient to determine the amplitude of the fluctuating average total pressure over part of the compressor face Comparisons are made between the method and experiment to show that the method describes many features of the flow Author

N76-25188 Cincinnati Univ., Ohio
TRANSMISSION OF CIRCUMFERENTIAL INLET DISTORTION THROUGH A ROTOR
W R Wells, W Tabakoff, and C. J Savell (GE Co., Cincinnati, Ohio) *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 10 p refs (For availability see N76-25169 16-07)

Analytical methods of predicting the propagation of stationary circumferential distortion patterns through a rotor are presented The analysis considers the effects of finite blade chord length and Mach number on the transmission by a semi actuator disc

theory. In addition, a more basic theory using the method of distributed singularities with thin airfoils is discussed to account for the effect of finite solidity on the distortion transmission. This thin airfoil theory is limited to the case of no steady loading on the rotor. The results of the analytical analysis is compared with existing experimental results. Author

N76-25189 Pratt and Whitney Aircraft, East Hartford, Conn.
MULTIPLE SEGMENT PARALLEL COMPRESSOR MODEL FOR CIRCUMFERENTIAL FLOW DISTORTION
Robert S. Mazzawy *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 14 p refs (For availability see N76-25169 16-07)

A compressible nonlinear model for prediction of the flow field of a circumferentially distorted compressor has been developed by using multiple parallel segments and by accounting for deviations from undistorted compressor performance. The model is applicable to large amplitude inlet circumferential distortions of total pressure and/or temperature, as well as circumferential variations of exit static pressure, with the restriction that the circumferential extent of the distortion is large relative to circumferential blade spacing. The distorted compressor stability criterion is based upon the limit of static pressure rise capability for a single distorted flow segment. This model requires the undistorted performance characteristics for each blade row; however, a modified version based upon the overall compressor performance gives an accurate approximation when detailed blade row characteristics are not available. Author

N76-25190 Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
THE EFFECT OF TURBULENT MIXING ON THE DECAY OF SINUSOIDAL INLET DISTORTIONS IN AXIAL FLOW COMPRESSORS
H. Mokelke *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 30 p refs (For availability see N76-25169 16-07)

A small perturbation actuator disc theory is presented for the prediction of the decay of sinusoidal flow distortions in high hub tip ratio axial compressors with steady, circumferential inlet maldistribution. The theory accounts for the turbulent mixing of the flow upstream and within the compressor. Decay rates and circumferential phase shifts of first, second, fourth and eighth order cosine wave pressure and velocity perturbations are calculated for equal amplitudes and phases of the four total pressure disturbances upstream of the compressor. The results are compared with interstage traverse data obtained from a 4-stage axial flow compressor. A comparison between corresponding analytical results obtained from the same theory neglecting viscosity and the experimental data is also performed. It is found that turbulent mixing has little influence on the development of the first order disturbance but that the influence grows rapidly as the order of the disturbance increases. Author

N76-25191 National Research Council of Canada, Ottawa (Ontario). Mechanical Engineering Div.
THE RESPONSE OF A LIFTING FAN TO CROSSFLOW-INDUCED SPATIAL FLOW DISTORTIONS
Uwe W. Schaub *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 14 p refs (For availability see N76-25169 16-07)

During transition maneuvers from fan supported to wing supported flight VTOL lifting fans routinely encounter extremely large spatial crossflow distortions. The variation in fan performance and the character of the flow distortions responsible for this variation were explored experimentally and on the basis of a simple analytical model of a lifting fan. The inflow and exit plane distortions in this model were generated by potential flow models, and the fan through flow was calculated on the basis of an arbitrary number of discrete circumferential fan segments. The lifting fan performance was predicted and compared with experiments over a wide range of transition conditions, and it is shown that while the crossflow causes large circumferential nonuniformities, the overall performance becomes seriously degraded only at large crossflows and large fan speeds. Author

76-25192* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
SOME CURRENT RESEARCH IN UNSTEADY AERODYNAMICS: A REPORT FROM THE FLUID DYNAMICS PANEL
W. J. McCroskey *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 13 p refs (For availability see

The highlights of a recent discussion by representatives of the fluid dynamics and structures and materials panels are reported with emphasis on the fundamental aspects of unsteady fluid mechanics. Topics include linearized potential flow theory, transonic flow calculations, unsteady boundary layers, dynamic stall, transonic buffet, and techniques for measuring unsteady pressures. Author

N76-25193* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
SOME ASPECTS ON UNSTEADY FLOW PAST AIRFOILS AND CASCADES
B. Satyanarayana (Cambridge Univ., England) *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 11 p refs (For availability see N76-25169 16-07)

The unsteady boundary layer due to a gust propagating past an isolated airfoil and on airfoils in cascade was measured with a hot wire anemometer in a low speed gust tunnel. Coherent signals were obtained by a phase lock averaging technique that was implemented in an on-line analysis using a PDP 12 computer. Changes in a boundary layer shape factor, noise level, and pressure gradient were correlated over a complete gust cycle. It is concluded that the character of the boundary layer changes from laminar to turbulent and back to laminar during the course of a gust cycle at certain chordwise positions. These measurements help explain certain anomalies that were observed during a previous study of the pressure fluctuations due to gust loadings on airfoils and cascades. Author

N76-25194 Air Force Aero Propulsion Lab., Wright-Patterson AFB, Ohio.
A CASCADE IN UNSTEADY FLOW
Francis R. Ostdiek *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 13 p refs (For availability see N76-25169 16-07)

A low speed atmospheric inlet cascade wind tunnel was constructed to obtain a flow which has a sinusoidal variation in flow direction. A stationary five blade cascade was held in a 7.62 x 25.4 cm test section. The wind tunnel inlet, which included guide vanes, was forced to oscillate by a motor driven crank about an axis transverse to the cascade. The vanes guided the flow along the instantaneous axis of the inlet and, thus, achieved a variable flow direction at any prescribed frequency in the 0 to 16 Hz range while the flow magnitude was nearly constant. Each surface of the center airfoil contained ten static pressure ports. The pressure fluctuations over most of both surfaces were near sinusoidal and the cyclic average showed little dependence on frequency or velocity. The pressure fluctuations decreased in amplitude along the chord on the pressure surface and changed phase on the suction surface near mid-chord. The pressures on both surfaces were adjusted by slow moving waves and showed only a small change in phase angle with increased frequency. The unsteady pressure profiles are in excellent agreement with theory near the leading edge. Author

N76-25195 General Motors Corp., Indianapolis, Ind. Detroit Diesel Allison Div.
THE UNSTEADY AERODYNAMIC RESPONSE OF AN AIRFOIL CASCADE TO A TIME-VARIANT SUPERSONIC INLET FLOW FIELD
Sanford Fleeter, Allen S. Novick, and Ronald E. Riffel *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 14 p refs (For availability see N76-25169 16-07)
(Contract F44620-74-C-0065)

The time dependent aerodynamic cascade phenomena related to the unsteady pressure disturbance and varying incidence in the cascade entrance flow field were investigated over a cascade inlet Mach number range of 1.53 to 1.63 with cascade static pressure ratios of 1.15 to 1.47. The range of the reduced frequency varied from approximately 0.03 to 0.12. The dynamic data obtained is presented in the form of the amplitude of the unsteady pressure and its phase as referenced to the sidewall transducer immediately downstream of the oscillating wedge. This data demonstrated the effect of the reduced frequency, cascade static pressure ratio, and the cascade inlet Mach number on the time variant pressure as measured on the sidewall in the cascade entrance flow field and on the pressure and suction surfaces of one of the cascaded advanced design transonic airfoils. Author

N76-25196 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
VON KARMAN VORTEX STREETS IN THE WAKES OF SUBSONIC AND TRANSONIC CASCADES

Ortwin Lawaczeck *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 13 p refs (For availability see N76-25169 16-07)

A flash of very short duration as a spark light source together with a schlieren optics arrangement is used to show that the wake flow behind the blades of turbine cascades consists - under certain flow conditions - of v Karman vortex streets A method is described to estimate the shedding frequency of the vortices by evaluation of schlieren pictures By this way the corresponding Strouhal number can be computed Author

N76-25197 Naval Surface Weapons Center Dahlgren, Va
ON THE ANALYSIS OF SUPERSONIC FLOW PAST OSCILLATING CASCADES
W R Chadwick, J K Bell, and M F Platzer (Naval Postgraduate School) *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 13 p refs (For availability see N76-25169 16-07)

Supersonic flow past oscillating finite cascades with subsonic leading edge locus is analyzed by solving the nonlinear transonic small perturbation equation Using the properly approximated Rankine-Hugoniot equations for the oscillating head shocks and continuing by the method of characteristics the entrance flow field into the cascade is computed and the influence of blade thickness on the aerodynamic pressure distributions is determined For the single oscillating wedge the solution is in good agreement with Carrier's exact solution and it is found that single blades exhibit a pronounced effect of blade thickness throughout the lower frequency range, which appears to be alleviated by cascading. For zero blade thickness, the linearized characteristics theory is recovered. Sample calculations with this theory for complete cascade configurations are in excellent agreement with recent results indicating the possibility of supersonic torsional cascade flutter over a wide range of parameters. Author

N76-25198 Stevens Inst. of Tech., Hoboken, N.J. Dept. of Mechanical Engineering.
PRELIMINARY RESULTS FOR SINGLE AIRFOIL RESPONSE TO LARGE NONPOTENTIAL FLOW DISTURBANCES
P. V. K. Perumal and F. Sisto *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 17 p refs (For availability see N76-25169 16-07)
(Contract N00014-67-A-0202-0016, NR Proj. 094-393)

The unsteady response of a flat plate airfoil to large nonpotential flow disturbances in the form of a translating rectangular grid of eddy array is evaluated. A suitable stream function to represent the translating nonpotential vortex array is chosen. The problem is solved in two stages, namely, auxiliary solution and time marching solution. By auxiliary solution is meant the solution of the problem which completely neglects the presence of the wake vortex sheet and treats time as a parameter; this results in a steady flow type of analysis. The time marching part of the analysis increments time by equal steps starting from zero time, makes use of the auxiliary solution, keeps track of the shedding and growth of the wake vortex sheet, evaluates the unsteady response, and continues along with time axis up to any specified maximum time limit. Preliminary numerical results from a computer program are presented. Author

N76-25199* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
THE PASSAGE OF A DISTORTED VELOCITY FIELD THROUGH A CASCADE OF AIRFOILS
John J. Adamczyk *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 11 p refs (For availability see N76-25169 16-07)

An analysis has been developed to predict the unsteady force and moment generated by the passage of a timewise periodic total pressure distortion through an arbitrary cascade of airfoils The mathematical formulation of this analysis is based on the assumption that the magnitudes of the timewise fluctuations of the variables which describe the flow field are small compared to their time average values. This assumption permits the development of a linear unsteady perturbation analysis about a steady flow field In addition to this linearization assumption the fluid medium is assumed to be incompressible and inviscid. The mathematical development begins by decomposing the velocity field surrounding an infinite cascade of airfoils into its irrotational and rotational components The rotational component is associated with an upstream unsteady total pressure distortion and is defined in terms of the vorticity field associated with the distortion pattern The irrotational component is further decomposed into a steady and unsteady part. A combined analytical and numerical procedure has been developed to solve the field equations which govern the rotational and irrotational velocity fields. Results of this analysis show a strong influence of mean loading on the unsteady force generated by the passage of a one dimensional gust through a cascade of compressor blades Author

N76-25200 Texas A&M Univ., College Station Dept. of Aerospace Engineering
UNSTEADY AIRLOADS ON A CASCADE OF STAGGERED BLADES IN SUBSONIC FLOW
B M. Rao and W P. Jones *In* AGARD Unsteady Phenomena in Turbomachinery Apr 1976 10 p refs (For availability see N76-25169 16-07)

The Jones-Moore numerical lifting surface technique is applied to predict the airloads and moments on an airfoil of a staggered cascade of rotor blades in subsonic flow Circumferential distortion due to inlet flow conditions is expressed as an interblade phase lag and both cases of oscillating airfoils and oscillatory inflow are considered. Results are obtained for several values of frequency, stagger angle, blade spacing, and interblade phase lag. Author

N76-25201 Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mechanical Engineering.
AN ON-ROTOR INVESTIGATION OF ROTATING STALL IN AN AXIAL-FLOW COMPRESSOR
M. R. Sexton, W. F. OBrien, Jr., and H. L. Moses *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 10 p refs (For availability see N76-25169 16-07)
(Contract N00014-67-A-0226-0005; NR Proj. 098-038)

Rotating stall is an unsteady phenomenon in axial flow compressors involving rapid pressure changes and lift variations on the rotating blades of the compressor. Measurements of the surface pressures on the rotor blade provide information to study the variation of lift of the rotating blade, and to improve the general understanding of rotating stall. Such on-rotor measurements require special pressure transducers, mounting techniques and data transmission systems. A multichannel radio telemetry system was used in this investigation to transmit simultaneous pressure measurements from up to six transducers mounted on a rotating blade. Measurements were made on both the pressure and suction sides of the blade, at different span locations. Results include rotor blade surface pressure measurements for compressor flow rates up to and including stall. Pressure variations during the dynamic stall event were used to determine the lift time variations on the blade. Author

N76-25202 Cambridge Univ. (England). S.R.C. Turbomachinery Lab.
DETAILED FLOW MEASUREMENTS DURING DEEP STALL IN AXIAL FLOW COMPRESSORS
Ivor J. Day *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 10 p refs (For availability see N76-25169 16-07)

Detailed measurements have been obtained for the flow in a stalled three stage compressor of high hub tip ratio which is operating deep in the rotating stall regime. Using high frequency transducers and a conditional sampling procedure made it possible to obtain information on the detailed structure of the stall cells and to prepare an overall picture of the flow field in the compressor. The results of the measurements show some new features which are at variance with conventional ideas about stall cells. Author

N76-25203 Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
THE PREDICTION OF THE BEHAVIOUR OF AXIAL COMPRESSORS NEAR SURGE
N. Orner, D. Adler, and J. Isenberg *In* AGARD Unsteady Phenomena in Turbomachinery Apr. 1976 16 p refs (For availability see N76-25169 16-07)

A new approach to the understanding of the problem of unsteady behavior of axial compressors near surge is developed This approach is based on the stability analysis of the equations of motion. It takes into account the three dimensional character of the flow in an axial compressor. A numerical solution procedure is described and its flow charts are given. Results of calculation are compared with experiments for two cases. The importance of some of the parameters influencing the phenomenon is discussed. Author

N76-25208 Advisory Group for Aerospace Research and Development, Paris (France).
MODERN PREDICTION METHODS FOR TURBOMACHINE PERFORMANCE
Jun. 1976 164 p refs Presented as a lecture series at Munich, 14-15 Jun. 1976 and London, 17-18 Jun. 1976
(AGARD-LS-83) Copyright. Avail: NTIS HC $6.75

The opening remarks are presented of a lecture series in which techniques for the prediction of turbomachine performance prediction were discussed. The topics covered in the series were: propulsion and flight system simulation, compressor and turbine performance prediction systems; design selection and optimization of axial-flow fan and compressor units for engine application; computation of turbomachine flow fields; and, advanced propulsion system development. A.S.K.

N76-26209 Motoren- und Turbinen-Union Muenchen G.m.b.H (West Germany)

AIRCRAFT GAS TURBINE CYCLE PROGRAMS: REQUIREMENTS FOR COMPRESSOR AND TURBINE PERFORMANCE PREDICTION

K. Bauerfeind *In* AGARD Mod. Prediction Methods for Turbomachine Performance Jun. 1976 12 p (For availability see N76-26208 17-07)

Typical design applications for an engine performance program are shown. A characteristic structure is presented of a thermodynamic engine model for steady state performance prediction. A technique for determining nondimensional engine performance is derived from non-dimensional component performance. Compressor and turbine characteristics are also discussed. A.S.K.

N76-26210 Iowa State Univ. of Science and Technology, Ames.

COMPRESSOR AND TURBINE PERFORMANCE PREDICTION SYSTEM DEVELOPMENT: LESSONS FROM THIRTY YEARS OF HISTORY

George K. Serovy *In* AGARD Mod. Prediction Methods for Turbomachine Performance Jun. 1976 19 p refs (For availability see N76-26208 17-07)

Methods are reviewed for prediction of aerodynamic performance of aircraft propulsion system turbomachinery configurations. Progress is traced in the two classes of methods which can predict only overall performance characteristics or maps. These methods were conceived at least thirty years ago and are not only used, but continue to be the subject of research today. Prediction methods which include flow field definition in the blade passages of compressors and turbines are described. Author

N76-26211 Rolls-Royce Ltd., Derby (England). Compressor Research Dept.

AXIAL FLOW COMPRESSOR PERFORMANCE PREDICTION

R. A. Wall *In* AGARD Mod. Prediction Methods for Turbomachine Performance Jun. 1976 34 p (For availability see N76-26208 17-07)

Owing to the nature of axial flow compressors, performance prediction is characteristically difficult to achieve by theoretical analysis, and therefore recourse to gross empiricism, laced with theory, is fundamental to methods employed. Factors determining the performance requirements of compressors, and the physical mechanisms which control their ability to satisfy these requirements, are discussed to expose the nature of compressors. Compressor design optimization is described to illustrate how effective compromise can be achieved between design point performance and various off-design excursions demanded by turbomachine performance. Typical performance prediction methods which reflect the nature of compressors and quantify their performance characteristics, are described with some reference to the influence of engine environmental factors. Potential developments are discussed which could influence the type of design employed in future engines. Author

N76-26212 Dynatech R/D Co., Cambridge, Mass. Engineering Mechanics Dept.

FLOW FIELD AND PERFORMANCE MAP COMPUTATION FOR AXIAL-FLOW COMPRESSORS AND TURBINES

Richard A. Novak *In* AGARD Mod. Prediction Methods for Turbomachine Performance Jun. 1976 27 p refs (For availability see N76-26208 17-07)

The current research emphasis on two-dimensional computing schemes, and upon the compressor rather than on the turbine, is not the result of bias. Currently, rapid progress is being made on the implementation of quasi-three-dimensional techniques. Computing techniques whose objective is to define the detailed flow field within a blade row are described. The problems associated with axisymmetric performance computation for the axial turbine are also discussed. The discussion and development of the system is in the context of axial compressors. Author

N76-26213 Creare, Inc., Hanover, N.H. Fluids/Thermal Engineering Div.

DESIGN OPTIMIZATION AND PERFORMANCE MAP PREDICTION FOR CENTRIFUGAL COMPRESSORS AND RADIAL INFLOW TURBINES

David Japikse *In* AGARD Mod. Prediction Methods for Turbomachine Performance Jun. 1976 15 p refs (For availability see N76-26208 17-07)

The initial specification of compressor and turbine geometry and performance characteristics, including operating maps, can follow different paths depending on the degree of departure from previous design experience. Principal attention is focused on totally new design problems requiring systematic design optimization to meet performance criteria under diverse operating conditions. The fundamental flow physics involved for both the centrifugal compressor and radial inflow turbine are briefly reviewed with principal attention focused on the strategy used for selecting optimum stage configurations. The performance map is obtained from the final step of this design optimization exercise. Author

N76-26214 Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France). Dept. Thermodynamique et Performances Direction Technique.

CHARACTERIZATION OF COMPONENTS PERFORMANCE AND OPTIMIZATION OF MATCHING IN JET-ENGINE DEVELOPMENT

Alain G. Habrard *In* AGARD Mod. Prediction Methods for Turbomachine Performance Jun. 1976 19 p refs (For availability see N76-26208 17-07)

Design and development of jet-engines require prediction and later, characterization through test analysis of the performance of the engine and its components. Knowledge of component characteristics is generally synthesized in mathematical models which contribute highly to efficient design and development. At the beginning of development (i.e. before first runs of prototype engines) models are essentially based on estimates and rig test results. Problems are then encountered when engine test results are compared to prediction. Methods using engine test analysis to identify component operating characteristics as installed in the engine and leading to models more representative of aerothermodynamic behavior of engines, are presented. Such models appear to be very useful tools during the various phases of development. Application and coordination with tests are discussed and particularly relative matching of components and control schedules optimization. Author

N76-26215 Defence Scientific Information Service, Ottawa (Ontario).

BIBLIOGRAPHY ON MODERN PREDICTION METHODS FOR TURBOMACHINE PERFORMANCE

A. S. Reeves *In* AGARD Mod. Prediction Methods for Turbomachine Performance Jun. 1976 31 p (For availability see N76-26208 17-07)

A bibliography is presented on numerical techniques for predicting the performance of turbomachines. Topics include boundary layer methods, axial flow compression, turbine blades, damping factors and modern engine design concepts. A.S.K.

08 AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots

N74-25550# Advisory Group for Aerospace Research and Development, Paris (France).
ACTIVE CONTROL SYSTEMS FOR LOAD ALLEVIATION, FLUTTER SUPPRESSION AND RIDE CONTROL
Mar. 1974 77 p refs
(AGARDograph-175; AGARD-AG-175) Avail: NTIS HC $7.00

Papers are presented which were selected to define the present status of industrial applications of active control technology in reducing loads on modern aircraft, and the future potential of active control for aircraft flutter suppression. For individual titles, see N74-25551 through N74-25555.

N74-25551 Lockheed-California Co., Burbank.
EFFECT OF YAW DAMPER ON LATERAL GUST LOADS IN DESIGN OF THE L-1011 TRANSPORT
Frederick M. Hoblit *In* AGARD Active Control Systems for Load Alleviation, Flutter Suppression and Ride Control Mar. 1974 p 1-10 refs (For availability see N74-25550 15-02)

In the design of the L-1011 transport, the reduction lateral gust loads, in continuous turbulence, due to the presence of a yaw damper was reflected in the limit design loads. The resulting load reduction was about 27 percent. In establishing the limit design loads, both the mission analysis and design envelope forms of continuous turbulence gust loads criteria were used. Account was taken, under both forms of criteria, of the fraction of time the damper might be inoperative. The effect of saturation of the damper at the limit-load level was also taken into account. This effect was determined by means of time-history analyses in which the input was a random gust velocity and the rudder angle limits (governed by available hinge moment) were included in the simulation. Author

N74-25552 British Aircraft Corp., Filton (England). Commercial Aircraft Div.
THE EFFECT OF ACTIVE CONTROL SYSTEMS ON STRUCTURAL DESIGN CRITERIA
N. F. Harpur *In* AGARD Active Control Systems for Load Alleviation, Flutter Suppression and Ride Control Mar. 1974 p 11-22 refs (For availability see N74-25550 15-02)

The design criteria for fixed wing aircraft are considered in relation to the active control systems. The reduction of static design loads, engine failure and surge loads, gust loads, and fatigue design loads are discussed along with the improvement of flutter characteristics. F.O.S.

N74-25553* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
STATUS OF TWO STUDIES ON ACTIVE CONTROL OF AEROELASTIC RESPONSE AT NASA LANGLEY RESEARCH CENTER
Irving Abel and M. C. Sandford *In* AGARD Active Control Systems for Load Alleviation, Flutter Suppression and Ride Control Mar. 1974 p 23-48 refs (For availability see N74-25550 15-02)
CSCL 01B

The application of active control technology to the suppression of flutter was successfully demonstrated during two recent studies in the Langley transonic dynamics tunnel. The first study involved the implementation of an aerodynamic-energy criterion, using both leading- and trailing-edge controls, to suppress flutter of a simplified delta-wing model. Use of this technique resulted in an increase in the flutter dynamic pressure of approximately 12 percent for this model at a Mach number of 0.9. Analytical methods used to predict the open- and closed-loop behavior of the model are also discussed. The second study, which is a joint effort with the Air Force Flight Dynamics Laboratory, was conducted to establish the effect of active flutter suppression on a model of the Boeing B-52 Configured Vehicle (CCV). Some preliminary results of this study indicate significant improvements in the damping associated with the critical flutter mode. Author

N74-25554 Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
FLUTTER CONTROL BY MODIFICATION OF AN EIGEN VALUE
J. Angelini *In* AGARD Active Control Systems for Load Alleviation, Flutter Suppression and Ride Control Mar. 1974 p 49-56 In FRENCH; ENGLISH summary (For availability see N74-25550 15-02)

A technique for defining an active control system to stabilize a multiple degree of freedom coupling of modes on an aircraft is presented. This technique modifies only the value of the unstable root of the characteristic equation and keeps unchanged the corresponding eigen vector and the other generalized characteristics. Considering this property, it is hoped that this method leads to the least possible interaction with the system. Author

N74-25555 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany)
ACTIVE FLUTTER SUPPRESSION ON WINGS WITH EXTERNAL STORES
G. Haldi, A. Lotze, and O. Sensburg *In* AGARD Active Control Systems for Load Alleviation, Flutter Suppression and Ride Control Mar. 1974 p 57-76 refs (For availability see N74-25550 15-02)

A control system is described, which is able to suppress flutter of wing-external store combinations. The aerodynamic flutter suppression forces are generated by movable vanes, attached to the stores, which are moved by a feedback signal from the store motion in such a way, that these forces damp the store motion. By adjusting the phase of the servoloop it is possible to have an active flutter-system below the flutter-speed of the passive system. This arrangement can be used to excite the flutter-mode at subcritical speeds. By switching off the servoloop, damping and frequency can be evaluated. The active flutter suppression system can also be used for reducing the level of externally forced vibration on stores which could occur through excitation by buffet or gusts. Tests results for an elastic wind-tunnel model are given and compared with analytical predictions. Correlation is very good, considering the complexity of the problem. Author

N74-30430# Advisory Group for Aerospace Research and Development, Paris (France).
THE TREATMENT OF INTERACTION OF HANDLING QUALITIES, STABILITY, AND CONTROL ON STRUCTURAL LOADS BY CURRENT SPECIFICATIONS Summary Report
Clifford F. Newberry (Boeing Co., Wichita, Kans.) Jun. 1974 15 p refs
(AGARD-R-621) Avail: NTIS HC $4.00

Aircraft structural loads arise not only from such sources as maneuvers, landings, gusts and taxiing, but are developed and influenced by aircraft handling qualities, stability and control characteristics. The structure, the aerodynamics, and the control system are jointly considered to evaluate the capability to solve the interaction problem. Usage and adequacy of existing specifications are considered. Factors which influence the decision to use advanced control techniques and analytical studies and tests to insure technical integrity are explored. Author

N74-31429# Advisory Group for Aerospace Research and Development, Paris (France).
ADVANCES IN CONTROL SYSTEMS
May 1974 313 p refs In ENGLISH partly in FRENCH Conf. Presented at 17th Meeting of the Guidance and Control Panel of AGARD, Gello, Norway, 24-26 Sep. 1973
(AGARD-CP-137) Avail: NTIS HC $18.75

The proceedings of a conference on control systems for aircraft control, engine control, and automatic pilots are presented. The subjects discussed include the following: (1) applied control theory, (2) control system performance optimization, (3) control system architecture and reliability, (4) application of advanced control systems, and (5) integrated flight control and operations. The characteristics of control systems for specific types of aircraft are analyzed. The development and application of fly by wire techniques are reported. The use of computers as an aid to flight control system design is explained. For individual titles, see N74-31430 through N74-31457.

N74-31430 Systems Technology, Inc., Hawthorne, Calif.
A HISTORICAL PERSPECTIVE FOR ADVANCES IN FLIGHT CONTROL SYSTEMS
Duane McRuer and Dunstan Graham *In* AGARD Advan. in Control Systems May 1974 7 p refs (For availability see N74-31429 21-02)

A brief history of the investigations into the nature of aircraft control and stability is presented. The activities of early investigators are examined and some of their accomplishments are cited. The historical eras are divided into the periods of 1890 to 1934, 1934 to 1947, and 1947 to the present. Examples of stability developments for specific aircraft are cited. Author

N74-31431 Office of the Assistant Chief of Staff (Air Force), Washington, D.C.
THE DIGITAL AIRPLANE AND OPTIMAL AIRCRAFT GUIDANCE
Allen D. Dayton *In* AGARD Advan. in Control Systems May 1974 14 p refs (For availability see N74-31429 21-02)

The use of optimal flight path guidance for aircraft in satisfying various military and civilian mission requirements is discussed. The concepts, systems, and algorithms which make optimal aircraft flight path guidance feasible are presented. The digital airplane which is based on a large digital computation capability, a digital data bus, sensors, and display systems is used as an example. The development of the methodology and algorithms for directing the aircraft is investigated. Author

N74-31432 Norges Tekniske Hoegskole, Trondheim.
SOME INTEGRITY PROBLEMS IN OPTIMAL CONTROL SYSTEMS
Ole A. Solheim *In* AGARD Advan. in Control Systems May 1974 10 p refs (For availability see N74-31429 21-02)

A multivariable feedback control system is defined as being of high integrity if it remains stable under failure conditions. Integrity problems encountered in optimal control systems are investigated. Two types of failure conditions are considered, namely actuator failure and sensor failure. As to the structure of the control system, a linear feedback law with feedback from all the state variables is considered. Systems with state estimators are also dealt with. The integrity problem is discussed based on the eigenvalues of the closed-loop system. Some design procedures are suggested. Finally, some numerical results are presented. Author

N74-31433 Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (West Germany)
APPLICATION OF MODAL CONTROL THEORY TO THE DESIGN OF DIGITAL FLIGHT CONTROL SYSTEMS
Ulrich Hartmann *In* AGARD Advan. in Control Systems May 1974 21 p refs (For availability see N74-31429 21-02)

The design of digital flight control systems is substantially simplified by using modal design methods. The theory of modal design is based on a state space description of the control system. For a desired pole distribution of the control system this theory directly provides a gain matrix for the feedback of the state variables. Due to the fact that all state variables are not always available, the problem of estimating non-measurable state variables arises. For solving this problem the theory of observers can be used. It shows however that an observer is not in a position to provide without adaptation usable estimated values of the missing state variables for the complete flight range. For solving practical design problems a minimum order observer is therefore particularly suitable as it is generally easier to obtain programmable approximation laws for the small number of parameters of this observer. It was further attempted to circumvent the estimation problem by the following means: (1) simplification of the state equations to eliminate non-measurable state variables, (2) transformation of the state vector and, (3) appropriate selection of the desired pole distribution. It showed that in this way a prompt and direct design of discrete-time flight control systems is possible. Two examples are used to demonstrate the results of simulations and flight tests: The design of a pitch attitude control system and a roll/yaw control system for a STOL aircraft. Author

N74-31434* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
COMPUTER-AIDED DESIGN OF CONTROL SYSTEMS TO MEET MANY REQUIREMENTS
A. A. Schy, W. M. Adams, Jr., and K. G. Johnson *In* AGARD Advan. in Control Systems May 1974 7 p refs (For availability see N74-31429 21-02)
CSCL 01C

A method is described for using nonlinear programing in the computer-aided design of airplane control systems. It is assumed that the quality of such systems depends on many criteria. These criteria are included in the constraints vector (instead of attempting to combine them into a single scalar criterion, as is usually done), and the design proceeds through a sequence of nonlinear programing solutions in which the designer varies the specification of sets of requirements levels. The method is applied to design of a lateral stability augmentation system (SAS) for a fighter airplane, in which the requirements vector is chosen from the official handling qualities specifications. Results are shown for several simple SAS configurations designed to obtain desirable handling qualities over all design flight conditions with minimum feedback gains. The choice of the final design for each case is not unique but depends on the designer's decision as to which achievable set of requirements levels represents the best for that system. Results indicate that it may be possible to design constant parameter SAS which can satisfy the most stringent handling qualities requirements for fighter airplanes in all flight conditions. The role of the designer as a decision maker, interacting with the computer program, is discussed. Advantages of this type of designer-computer interaction are emphasized. Desirable extensions of the method are indicated. Author

N74-31435 Air Force Avionics Lab., Wright-Patterson AFB, Ohio.
A DESIGN PROCEDURE UTILIZING CROSSFEEDS FOR COUPLED MULTILOOP SYSTEMS
Paul S. Basile and R. E. Curry (MIT, Cambridge) *In* AGARD Advan. in Control Systems May 1974 10 p refs (For availability see N74-31429 21-02)

A frequency-domain design procedure for decoupling multi-input, multi-output systems is described; the frequency domain has the advantage of providing insight and ease of satisfying specifications that are difficult to meet with state-space methods. A design procedure for a two-input, two-output system without crossfeeds is presented first; crossfeeds are then introduced to alter the open loop dynamics, and the design procedure is applied to the modified plant. The constraints on the choice of crossfeeds are discussed. Extension to a two-input, three-output system is made when one of the outputs is dominated by another; guidelines for choosing the crossfeeds are given. This procedure is applied to design a lateral cruise control system for the space shuttle orbiter; exact decoupling with crossfeeds results in excellent closed loop response. Author

N74-31436 Norwegian Defence Research Establishment, Kjeller (Norway). Div. for Electronics.
CONSTRUCTION OF SUBOPTIMAL KALMAN FILTERS BY PATTERN SEARCH
Nils Christophersen and Truls Lange-Nielsen *In* AGARD Advan. in Control Systems May 1974 6 p refs (For availability see N74-31429 21-02)

A systematic method for the optimal determination of parameters in suboptimal Kalman filters is presented. Such simplified filters are frequently necessary in order to implement a Kalman filter on a small special purpose computer. In order to optimize the performance of these filters, a parameter optimization problem may be involved. The method of solution is a modified version of Rosenbrock's pattern search. This is a direct search, permitting a very wide class of performance measures not necessarily analytical in nature. The example given is the determination of a suboptimal filter for a hybrid marine navigation system with thirty state variables. Author

N74-31437 Singer Co., Little Falls, N.J. Kearfott Div.
USE OF ADVANCED CONTROL THEORY AS A DESIGN TOOL FOR VEHICLE GUIDANCE AND CONTROL
P. M. Brodie *In* AGARD Advan. in Control Systems May 1974 10 p (For availability see N74-31429 21-02)
(Contract F08635-71-C-0227)

A technique is demonstrated which permits the numerical solution of the linear optimal regulator problem to be used as a generalized design tool. In particular this technique affords simplification over the usual frequency domain methods for high order guidance and control systems while retaining compatibility with the frequency domain especially for stability analysis. In addition to making a more rapid solution to the design problem possible, the structure of the optimal controller lends itself to the combination of the guidance and control problems into a single optimum or best solution. Author

N74-31438 Norges Tekniske Hoegskole, Trondheim.
OPTIMAL CONTROL OF STOCHASTIC SYSTEMS WITH UNSPECIFIED TERMINATION TIMES
Rolf Henriksen *In* AGARD Advan. in Control Systems May 1974 10 p refs (For availability see N74-31429 21-02)

A game-theoretic approach to optimal control problems of discrete-time stochastic systems with unspecified termination times is presented. In somewhat the same sense as stochastic systems with fixed termination times may be regarded as a kind of single-experiment (fixed samplesize) games, stochastic systems with unspecified termination times may be regarded as a kind of sequential games. A major part of the paper is devoted to the synthesis of Bayes control policies for truncated control processes, a term which is quite analogous to truncated sequential games. Two simple examples are given. Author

N74-31439 Royal Aircraft Establishment, Farnborough (England). Avionics Dept.
FLIGHT CONTROL SYSTEM DEVELOPMENT IN THE UK
D. Kimberley and P. W. J. Fullam *In* AGARD Advan. in Control Systems May 1974 13 p refs (For availability see N74-31429 21-02)

The development of automatic flight control systems in the U.K. is described. Military and civilian applications of control system development are reported. The requirements of a control system are defined with respect to mission performance, system integration, similar redundancy, and control actuation. Specific examples of control installation and flight test results are included. The flight test results indicate that a full time fly by wire system is feasible and represents a prerequisite to system exploitation in the form of such concepts as control configured vehicles. Author

N74-31440 Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
F-15 EAGLE FLIGHT CONTROL SYSTEM
Edward H. McDonald *In* AGARD Advan. in Control Systems May 1974 8 p (For availability see N74-31429 21-02)

The high performance demands of the flight control systems of today's fighter type aircraft normally are associated with undesirable complexity. How this complexity was minimized, the hardware solution to historical design problems, and how the solution evolved are discussed. A narration includes the pre-hardware design phase during which time exhaustive simulator analyses were made. The unique integration of flight controls with other aircraft systems is revealed along with limited performance and test results. The more significant subcomponents/systems are separately addressed; namely the automatic flight control system, the stabilator actuator, and the control stick boost and pitch compensator package. In conclusion, overall salient capabilities are enumerated which substantiates the existing high confidence level relative to the system. Author

N74-31441 Thomson-CSF, Issy les Moulineaux (France). Groupe Optronique de la Div.
NEW CONCEPTS OF VISUALIZATION FOR AIRCRAFT AND SPACE SHUTTLES [NOUVEAUX CONCEPTS DE VISUALISATION POUR AVIONS ET NAVETTES SPATIALES]
M. Coussediere *In* AGARD Advan. in Control Systems May 1974 9 p In FRENCH (For availability see N74-31429 21-02)

Instrumentation systems adaptable to aircraft and space shuttle visualization concepts are reported. The systems considered include head-up displays, electric attitude direction indicators, electric horizontal situation indicator, engine display, multi-function display, and radar visualization meters. Simulation results and possible advantages of these systems over conventional ones are discussed. Transl. by E.H.W.

N74-31442 Royal Aircraft Establishment, Farnborough (England). Controls and Displays Div.
ON THE DESIGN AND EVALUATION OF FLIGHT CONTROL SYSTEMS
F. R. Gill *In* AGARD Advan. in Control Systems May 1974 13 p refs (For availability see N74-31429 21-02)

An analysis of flight test results of control systems for fighter and transport aircraft is presented. The systems under consideration employ conventional linear control policies with the design being based on a parameter optimization technique. The two modes which are discussed are a pitch rate maneuver demand system for the fighter aircraft and an ILS glide path and flare system for the transport aircraft. Studies to replace linear control by variable gain policies are discussed. The reasons for and the principles of the variable gain control policies are outlined. The principles of flight evaluation methods employed with the control system tests are included. Author

N74-31443 Honeywell, Inc., Minneapolis, Minn.
A FLY-BY-WIRE FLIGHT CONTROL SYSTEM FOR DECOUPLED MANUAL CONTROL
A. J. VanDierendonck, K. Bassett (AFFDL), and E. E. Yore *In* AGARD Advan. in Control Systems May 1974 7 p refs (For availability see N74-31429 21-02)
(Contract F33615-72-C-1266)

A sight line autopilot (SLAP) was designed for the AC-130 Gunship to improve the gun pointing ability. This paper presents the unique design procedure and development philosophy that was used. It emphasizes the peculiarities of this weapon delivery concept, the problem areas and the results of the design. Multi-axes coupling, digital computer control, available measurements, and optimistic performance requirements prompted the use of modern control design techniques. Optimal control laws were generated for all modes and submodes. No classical analysis was performed. Proportional-plus-integral control was included to reduce nonlinear effects. Both linear and nonlinear simulation results verified that the autopilot met the optimistic performance requirements in spite of poor performing servo-actuators, which limited the bandwidth of control laws. More recently, ground and flight tests have been performed. Author

N74-31444 Laboratoire Central de Telecommunications, Paris (France).
DEFINITION AND SIMULATION OF A DIGITAL FILTER AND PILOT DEVICE UTILIZING MODERN DESIGN TECHNIQUES OF FILTRATION CONTROL [DEFINITION ET SIMULATION D'UNE BOUCLE DIGITALE DE PILOTAGE D'ENGIN UTILISANT LES TECHNIQUES MODERNES DE FILTRAGE ET DE COMMANDE]
C. A. Darmon and H. Euzen *In* AGARD Advan. in Control Systems May 1974 13 p refs In FRENCH (For availability see N74-31429 21-02)

Modern optimal control techniques used to define and simulate digital filters for pilot devices are discussed. Noise measurements, system dynamics, and physical properties of the device are examined. Transl. by E.H.W.

N74-31445 Advisory Group for Aerospace Research and Development, Paris (France).
AN EXPERIMENTAL INVESTIGATION INTO DUPLEX DIGITAL CONTROL OF AN ENGINE WITH REHEAT
J. F. O. Evans and K. A. Helps *In its* Advan. in Control Systems May 1974 14 p (For availability see N74-31429 21-02)

The application of cross-monitoring computers with a hydromechanical back-up system to control a P.S. 60 jet engine is discussed. The choice of a digital control system was based on the complexity of modern engine control requirements especially at the reheat end of the system. Total hydromechanical control without the computer results in complexity and increased costs. The digital system is well suited to the functions of scheduling, decision making, time-varying parameters, and nonlinearity conditions. The features of the digital equipment in high integrity systems are analyzed. The basic control system and the reversionary mode of the system are examined. The results of performance tests using the computer controlled system are reported. Author

N74-31446 Boeing Commercial Airplane Co., Seattle, Wash.
APPLICATION OF REDUNDANT DIGITAL COMPUTERS TO FLIGHT CONTROL SYSTEMS
R. L. Schoenman *In* AGARD Advan. in Control Systems May 1974 13 p (For availability see N74-31429 21-02)

The use, operations, and failure modes of a redundant digital system for aircraft control are discussed. Emphasis is placed on the flight critical aspects such as automatic landing, command augmentation, and fly by wire control. The rationale for selecting digital flight control systems is explained. Specific application of digital flight control systems to the supersonic transport aircraft is analyzed. The system topics which are affected by the digital system are: (1) effect of cross-channel voting on reliability, (2) cross-channel voting mechanization, (3) input-output interface, and (4) the effect of actuator configuration. Block diagrams are included to show the interrelationships of the computer signals and components. Author

N74-31447 Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (West Germany).
REALIZATION AND FLIGHT TESTS OF AN INTEGRATED DIGITAL FLIGHT CONTROL SYSTEM
Robert K. Zach *In* AGARD Advan. in Control Systems May 1974 20 p refs (For availability see N74-31429 21-02)

The introduction of digital computers into modern aircraft control systems for the integration of all the functions in a complex automatic flight control system is discussed. In order to realize such practical systems economically, the functional requirements for the computer and interface were first derived by the analysis of the tasks and by the hybrid simulation of the functions, where the aircraft and actuators were simulated on an analog computer and the AFCS on a general purpose digital computer. Based on these requirements, a free programmable in-flight simulator was designed, built and flown in the test aircraft. This equipment is compatible with the laboratory hybrid simulation equipment. The in-flight simulator allows experiments of different control laws, and was used to check and prove the required control form for a special digital system developed for flight control. As is shown, this latter system fulfills all the functional requirements and consists of a small digital computer, an interface for signal conversion and a pilots control panel. All functions of a modern AFCS, such as stabilizer, automatic approach, automatic landing and other autopilot functions as well as preflight and inflight tests were integrated, by programming the semiconductor memory. The flight trials of this system in the test aircraft showed the satisfactory functioning of the system over the whole aircraft flight envelope. The good control characteristics were confirmed with the measured responses in flight. Author

N74-31448 LTV Aerospace Corp., Dallas, Tex. Systems Div.
APPLICATION OF DIGITAL FLY-BY-WIRE TO FIGHTER/ATTACK AIRCRAFT
Ryland A. Baldwin *In* AGARD Advan. in Control Systems May 1974 10 p refs (For availability see N74-31429 21-02)

Some of the benefits to be derived from digital fly-by-wire flight control systems applied to attack/fighter aircraft are presented. An integrated stability augmentation system and control augmentation system mechanization is described. Design criteria are reviewed and trade studies that were made to establish the proper level of redundancy are described. The resulting quadruplex system configuration is presented showing interfaces with digital processors. Computer studies undertaken to support selection of the proper digital word length and iteration rate are summarized, and the effect of variations of these parameters upon system performance is shown. A brief description of the data handling system and the computer requirements are included along with a block diagram summarizing the integrated system. Performance of the digital flight control system is compared to that of the analog system now in use in the A-7 aircraft. Open loop test data of a laboratory test configuration in which aircraft control laws are programmed are given. Author

N74-31449 Marconi-Elliott Avionic Systems Ltd., Rochester (England). Flight Controls Div.
THE DESIGN AND DEVELOPMENT OF THE MRCA AUTOPILOT
D. I. Jackson and J. M. Corney *In* AGARD Advan. in Control Systems May 1974 11 p (For availability see N74-31429 21-02)

The design and development of an autopilot and a flight director system are described. Emphasis is placed on the problem of ensuring flight safety in the low altitude autopilot modes. The subjects considered are: (1) design philosophy, (2) system configuration and control, (3) hardware development, and (4) software implementation. The system is designed to provide automatic control of the aircraft in pitch and lateral planes in a variety of operating modes. A flight director is included which provides signals to the pilot's instruments to enable the pilot to monitor the autopilot performance and to use the signals for flight path guidance if an autopilot malfunction occurs. Author

N74-31450* National Aeronautics and Space Administration. Flight Research Center, Edwards, Calif.
DESIGN AND FLIGHT EXPERIENCE WITH A DIGITAL FLY-BY-WIRE CONTROL SYSTEM IN AN F-8 AIRPLANE
Dwain A. Deets and Kenneth J. Szalai *In* AGARD Advan. in Control Systems May 1974 10 p refs (For availability see N74-31429 21-02)
CSCL 01C

A digital fly-by-wire flight control system was designed, built, and for the first time flown in an airplane. The system, which uses components from the Apollo guidance system, is installed in an F-8 airplane as the primary control system. A lunar module guidance computer is the central element in the three-axis, single-channel, multimode, digital control system. A triplex electrical analog system which provides unaugmented control of the airplane is the only backup to the digital system. Flight results showed highly successful system operation, although the trim update rate was inadequate for precise trim changes, causing minor concern. The use of a digital system to implement conventional control laws proved to be practical for flight. Logic functions coded as an integral part of the control laws were found to be advantageous. Although software verification required extensive effort, confidence in the software was achieved.
Author

N74-31451 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
DIGITAL FLY-BY-WIRE CONTROL SYSTEM WITH SELF-DIAGNOSING FAILURE DETECTION
R. Onken, H. P. Joenck, L. Tacke, and M. Gottschlich *In* AGARD Advan. in Control Systems May 1974 7 p refs (For availability see N74-31429 21-02)

A solution is presented to the problem of achieving real fail-safe behaviour for fly-by-wire systems, no longer depending on the reliability of the monitor/voter device and the probability of the occurrence of dormant errors. This is accomplished by the use of stand-by redundancy in conjunction with selfdiagnosing failure detection which is independent of the control signal state. Each redundant unit is autonomous with respect to the failure detection, such that, depending on the inspection rate, perfect information about the reliability status of the system, including the failure detection itself, is available at any time. The feasibility of this approach is demonstrated by the fly-by-wire system which is installed and successfully flown in a HFB 320 jet aircraft.
Author

N74-31452 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
B-52 CONTROL CONFIGURED VEHICLES PROGRAM
R. P. Johannes and G. O. Thompson *In* AGARD Advan. in Control Systems May 1974 10 p refs Prepared in cooperation with Boeing Co. (For availability see N74-31429 21-02)

A test program to evaluate the control configured vehicles (CCV) program is discussed. The purpose of the program is to validate achievable results of the CCV system concepts on large flexible aircraft, such as the B-52. The four concepts which are involved in the flight test are: (1) ride control, (2) flutter mode control, (3) maneuver load control, and (4) augmented stability. The potential benefits of the CCV concept and the results of the ride control system flight tests are analyzed. Author

N74-31453 National Aerospace Lab., Amsterdam (Netherlands).
FLIGHT EXPERIENCE WITH AN EXPERIMENTAL ELECTRICAL PITCH-RATE-COMMAND/ATTITUDE-HOLD FLIGHT CONTROL SYSTEM
H. A. Mooij *In* AGARD Advan. in Control Systems May 1974 8 p refs (For availability see N74-31429 21-02)

The introduction of electrical primary flight control systems makes studies in many aspects of their application highly desirable. One important aspect is the development of handling qualities criteria as a guide for system design. To this end an experimental pitch-rate-command/attitude-hold flight control system installed in a Beechcraft Queen Air-80 was used in two flight research programs. Results of these programs are discussed in this paper. The first program is related to pilot workload reduction for the safe execution of two-segment noise-abatement approaches. The other program is aimed at in-flight determination of pilot-aircraft system performance as well as pilot describing function and remnant information. Author

N74-31454 Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (West Germany).
INTEGRATED FLIGHT CONTROL SYSTEM FOR STEEP APPROACH
Gunther Schaenzer and Hartmut H. Boehret *In* AGARD Advan. in Control Systems May 1974 12 p refs (For availability see N74-31429 21-02)

The approach of extremely short runways surrounded by high obstacles has to be made on steep and curved approach profiles. The flight path and the aerodynamic flow condition have to be controlled more accurately as compared with

conventional approach procedures. The resulting problems concerning flight mechanics and control will be discussed and the requirements for an integrated flight control system will be derived. The characteristics of a sub-optimal flight control system controlling the flight path and the aerodynamic flow condition via elevator and throttle with limited state vector feedback will be demonstrated by simulation- and flight tests results for automatic approach and landing. Author

N74-31455 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
V/STOL AIRCRAFT CONTROL/DISPLAY CONCEPT FOR MAXIMUM OPERATIONAL EFFECTIVENESS
Kenneth W. McElreath, James A. Klein (Collins Radio Co.), and Ralph C. Thomas (Collins Radio Co.) *In* AGARD Advan. in Control Systems May 1974 8 p refs (For availability see N74-31429 21-02)

Vertical/Short Takeoff and Landing (V/STOL) aircraft and their unique missions define four requirements for a practical and suitable IFR control/display system: (1) maximum flight profile flexibility, (2) flight control precision, (3) low pilot workload, and (4) simplicity at low cost. A system concept which has made significant progress in meeting these requirements is described. The system concept is that of retaining the human pilot as an active control element, augmented by an integrated system of displays, steering computation, and automatic control elements. The task allocation between the pilot and the automatic portion of the system optimizes the pilot's flexibility and control effectiveness in the control tasks for which he is most suited, complemented by the precision and reduction in workload afforded by automatic control techniques. The approach taken in the development of the system was to first define the mission tasks to be performed and the system constraints. Analysis and pilot-in-the-loop simulation determined the most effective control scheme and the optimum human-automatic interface. Flight testing then validated the system concepts in hardware form aboard a CH-3E helicopter test bed. Author

N74-31456 Royal Aircraft Establishment, Bedford (England).
AUTOSTABILIZATION IN VTOL AIRCRAFT: RESULTS OF FLIGHT TRIALS WITH SC 1
H. W. Chinn *In* AGARD Advan. in Control Systems May 1974 16 p refs (For availability see N74-31429 21-02)

The flight control system developed for the SC 1 jet lift VTOL research aircraft is described and an account given of its behaviour throughout the flight envelope: vertical take-off and landing, transition and conventional flight. The system, which provided artificial directional stability in the yaw and maneuver demand in the pitch and roll axes, gave a stable aircraft while retaining a high degree of maneuverability. Comparison is made with existing handling criteria and the ways in which demand systems inevitably contravene certain of these criteria are discussed. Author

N74-31457* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
FLIGHT TEST OF AN AUTOMATIC APPROACH AND LANDING CONCEPT FOR A SIMULATED SPACE SHUTTLE REPRESENTED BY THE NASA CONVAIR 990 AIRCRAFT
Donald W. Smith, Frederick G. Edwards, John D. Foster, and Fred J. Drinkwater, III *In* AGARD Advan. in Control Systems May 1974 9 p refs (For availability see N74-31429 21-02)
CSCL 01C

Unpowered automatic approaches and landings were conducted to study navigation, guidance, and control problems associated with terminal area, approach, and landing operation for the space shuttle. A Convair 990 aircraft was equipped with a digital flight-control computer connected to the aircraft control systems and displays. The flight tests evaluated, from 11,300 m to touchdown, the performance of a navigation and guidance concept that utilized blended radio/inertial navigation with VOR, DME, and ILS as the ground radio navigation aids. The results from 36 automatic approaches and landings are analyzed. Preliminary results indicate that this concept may provide sufficient accuracy that automatic landing of the unpowered shuttle orbiter can be accomplished on a conventional size runway. Author

N76-29245# Advisory Group for Aerospace Research and Development, Paris (France)
STALL/SPIN PROBLEMS OF MILITARY AIRCRAFT
Jun. 1976 242 p refs Presented at the Flight Mech Panel Specialists Meeting, Rhode Saint Genese, Belgium, 18-21 Nov. 1975
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Stall/spin aspects of aircraft design are discussed in relation to the high angle of attack problem. For individual titles, see N76-29246 through N76-29266

N76-29246 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
THE STALL/SPIN PROBLEM
Robert J. Woodcock and Robert Weissman (ASD) *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun 1976 12 p refs (For availability see N76-29245 20-08)

Stall/spin problems still plague aircraft designers. The development of spin tunnel and free flight model testing techniques is traced, prospects of improved aerodynamics are indicated, and some flight control system capabilities outlined, with reference to experience with some recent airplanes. Recovery from spins and post-stall gyrations is emphasized but a need for more emphasis on designing for resistance to loss of control is advocated. Author

N76-29247 General Dynamics/Fort Worth, Tex.
THE STALL/SPIN PROBLEM - AMERICAN INDUSTRY'S APPROACH
Charles A. Anderson *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 8 p (For availability see N76-29245 20-08)

An attempt is made to detail what has caused stall/spin problems, what options are open to the aircraft designer to reduce stall/spin susceptibility, and some of the current evaluation criteria that are available. Also, the various analytical and experimental tools and flight test techniques available today are reviewed. An assessment is then made of the usefulness of each of these guidelines, tools, and techniques. Finally, a recommended procedure for determining the stall/spin susceptibility and characteristics is presented. Author

N76-29248 Aeroplane and Armament Experimental Establishment, Boscombe Down (England)
COMPARISON OF THE SPIN AND LOW INCIDENCE AUTOROTATION OF THE JAGUAR STRIKE AIRCRAFT
R. J. Blamey *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 10 p refs (For availability see N76-29245 20-08)

From the extensive flight trials on Jaguar high incidence and spin behavior, a number of interesting results emerged. Compared to the classical high incidence spin mode with a rather less common low incidence autorotation which appeared during Jaguar evaluation trials. Author

N76-29249 British Aircraft Corp., Preston (England).
A COMPARISON OF MODEL AND FULL SCALE SPINNING CHARACTERISTICS ON THE LIGHTNING
B. R. A. Burns *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 12 p (For availability see N76-29245 20-08)

Lightning spinning history is reviewed and a comparison is made of the characteristics as shown by vertical wind tunnel, helicopter drop model and full scale flight trials. The comparison is made in terms of both qualitative interpretation of the spin and recovery behavior and measured data. It is shown that the three types of tests exhibited good qualitative agreement in all important respects. Only a limited quantitative comparison is possible because of limitations of the measured data and differences between the test techniques. The test results are related to service experience and some observations are made about the interpretation of spinning test results and the need for simplicity in pilot's operating notes. Author

N76-29250 Northrop Corp., Hawthorne, Calif.
DESIGN TECHNOLOGY FOR DEPARTURE RESISTANCE OF FIGHTER AIRCRAFT Aircraft Div.
A. Titiriga, Jr., J. S. Ackerman, and A. M. Skow *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 13 p refs (For availability see N76-29245 20-08)

Methods are presented for predicting departure characteristics of aircraft during the design stages prior to model or flight tests. The significance of longitudinal pitching moment characteristics with respect to sideslip is discussed and correlated with flight test data. The use of departure parameters is discussed and examples are presented which show good correlation with flight test results. A computer graphics display of the aircraft driven by actual flight test data has proven to be extremely helpful in visualizing complex motions of an aircraft. In particular this

technique shows great promise in aiding both pilots and engineers in describing disorienting post stall gyrations that may be encountered during stall/spin flight testing of an aircraft. Author

N76-29251* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
RESULTS OF RECENT NASA STUDIES ON SPIN RESISTANCE
Joseph R. Chambers, William P. Gilbert, and Sue B. Grafton *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 12 p refs (For availability see N76-29245 20-08)
CSCL 01C

Some of the factors which contribute to good stall/spin characteristics of a current fighter configuration indicate that the design of airframe components for inherent spin resistance is very configuration dependent and that few generalizations can be made. Secondary design features, such as fuselage forebody shape, can have significant effects on stability characteristics at high angles of attack. Recent piloted simulator studies and airplane flight tests have indicated that current automatic control systems can be tailored so as to provide a high degree of spin resistance for some configurations without restrictions to maneuverability. Such systems result in greatly increased pilot confidence and increased tactical effectiveness. Author

N76-29252 Institut de Mecanique des Fluides de Lille (France).
APPLICATION OF STATIC AND DYNAMIC AERODYNAMIC COEFFICIENTS TO THE MATHEMATICAL CORRELATION OF WIND TUNNEL TEST RESULTS ON AIRCRAFT SPINS [APPLICATION DES MESURES DE COEFFICIENTS AERODYNAMIQUES STATIQUES ET DYNAMIQUE A DES RECOUPEMENTS PAR CALCUL DES VRILLES OBTENUES EN SOUFFLERIE]
Marc Vanmansart *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 9 p In FRENCH (For availability see N76-29245 20-08)

A conventional light aircraft model with efficient control surfaces and comparatively easy spin characteristics was used to validate the modelling of spin maneuvers by correlating vertical wind tunnel results with static and dynamic aerodynamic coefficients. It was first concluded that these coefficients must be measured while the aircraft is in continuous rotation; these measurements must take into account the efficiency of the control surfaces, which is itself strongly affected by the general flow pattern, and are only applicable to the case of comparatively mild spins. In the case of modern military aircraft, however, spins are usually more complex and violent, and measurements of forced oscillations while the model is in continuous rotation should presumably be included. Transl. by Y.J.A.

N76-29253 Aeronautica Macchi S. p. A., Varese (Italy).
STALL BEHAVIOR AND SPIN ESTIMATION METHOD BY USE OF ROTATING BALANCE MEASUREMENTS
Ermanno Bazzocchi *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 16 p (For availability see N76-29245 20-08)

Experimental work is reported in the field of wind tunnel investigation of stall behavior, in the evaluation of the characteristics of lateral control devices, in the measurement of the aerodynamic coefficients to determine lateral-directional stability and the analytical study of the spin. This research has required the development of special test equipment, measurement methods and calibration systems. A description and data is given on the test equipment adopted, its use and some of the results obtained. Author

N76-29254 Ghent Univ. (Belgium).
STABILITY OF HELICOIDAL MOTIONS AT HIGH INCIDENCES
F. C. Haus *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 20 p (For availability see N76-29245 20-08)

Mathematical solutions are found for three kinds of problems. (1) to compute the equilibrium condition of steady motion, when the aircraft follows a helicoidal descending path around a vertical axis; (2) to establish the linear equations governing perturbations about the steady state, and to determine the characteristic modes of the resulting motion; and (3) to integrate the nonlinear equations of motion and to determine the manner in which an aircraft can reach a steady state motion, or depart from it - (entry into or recovery from a spin). Such mathematical operations provide insight into the mechanics of spinning motion even though aerodynamic coefficients are not known very accurately at the present time. Author

N76-29255 Institut de Mecanique des Fluides de Lille (France).
EFFECTS OF AIRFRAME DESIGN ON SPIN CHARACTERISTICS [EVOLUTION DES CARACTERISTIQUES DE LA VRILLE EN FONCTION DE L'ARCHITECTURE DES AVIONS]
Jean Gobeltz *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 15 p In FRENCH (For availability see N76-29245 20-08)

The effects of changes in the airframe geometry during the last few decades on aircraft spin characteristics were reviewed. The type of aircraft considered ranged from low speed, pre-world war II, propeller driven aircraft, through the early jet aircraft with moderate sweepback, to the most recent jet aircraft with pronounced sweepback. The contribution of the various airframe components such as control surfaces, flaps, airbrakes, fins, fuselage, wings, etc. was discussed in addition to other relevant factors such as inertial characteristics, external loads, rockets, etc. Special emphasis was placed on the Mirage 3 and Lightning aircraft. Y.J.A.

N76-29256 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
LIMITING FLIGHT CONTROL SYSTEMS
David K. Bowser *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 12 p refs (For availability see N76-29245 20-08)

The development and application of various types of automatic flight control systems for high angle of attack augmentation and limiting are reported. Considerations included are improved handling qualities for maximum tracking effectiveness, reduced pilot workload, control configured vehicles, stall inhibitors, and departure prevention systems. Author

N76-29257* National Aeronautics and Space Administration, Ames Research Center, Moffett Field, Calif.
ASYMMETRIC AERODYNAMIC FORCES ON AIRCRAFT AT HIGH ANGLES OF ATTACK - SOME DESIGN GUIDES
Gary T. Chapman, Earl R. Keener, and Gerald N. Malcolm *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 9 p refs (For availability see N76-29245 20-08)
CSCL 01A

Aerodynamic side forces on forebodies are considered that are produced by two types of flow: asymmetric vortices on bodies of revolution and nonuniform flow separation on square bodies with rounded corners under spinning conditions. Steady side forces that can be as large as the normal force are produced by asymmetric vortices on pointed forebodies. This side force has a large variation with Reynolds number, decreases rapidly with Mach number, and can be nearly eliminated with small nose bluntness or strakes. The angle of attack where the side force first occurs depends primarily on body geometry. The theoretical techniques to predict these side forces are necessarily semi-empirical because the basic phenomenon is not well understood. The side forces produced by nonuniform flow separation under spinning conditions depend extensively on spin rate, angle of attack, and Reynolds number. The application of simple crossflow theory to predict this side force is inadequate much below angles of attack of 90 deg. Author

N76-29258* National Aeronautics and Space Administration Langley Research Center, Langley Station, Va.
STALL/SPIN TEST TECHNIQUES USED BY NASA
Joseph R. Chambers, James S. Bowman, Jr., and Gerald N. Malcolm (NASA Langley) *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 12 p refs (For availability see N76-29245 20-08)
CSCL 01C

Unique test techniques and facilities are reported which are used to predict the stall/spin characteristics of highly maneuverable military aircraft. Three of the more important test techniques are: (1) flight tests of dynamically scaled models; (2) rotary balance tests; and (3) piloted simulator studies. Recent experience has indicated that the extension of piloted simulation techniques to high angles of attack provides valuable insight as to the spin susceptibility of fighter configurations during representative air combat maneuvers. In addition, use of the technique is an effective method for the development and evaluation of automatic spin prevention concepts. Author

N76-29259 Institut de Mecanique des Fluides de Lille (France).
EFFECTS OF STATIC MOMENTS FROM ROCKETS OR ASYMMETRIC LOADS ON AIRCRAFT SPINS [ACTION SUR LA VRILLE, PAR MOMENT STATIQUE, DE FUSEES ET DE CHARGEMENTS DISSYMETRIQUES]
Jean Gobeltz and Lucien Beaurain *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 11 p refs In FRENCH (For availability see N76-29245 20-08)

Vertical wind tunnel test results performed on different scale models to investigate aircraft spin maneuvers were discussed. Two areas were considered: (1) the use of rockets carried on aircraft, to be fired as an emergency device during spins. The application of this concept has so far been limited to light aircraft, although certain qualitative conclusions may be valid for other types of aircraft, including military aircraft. (2) the influence of asymmetrical loads on spins for aircraft of all types: military, light, transport. In the case of military aircraft, geometrical asymmetries were also discussed. Transl. by Y.J.A.

N76-29260 Centre d'Essais en Vol, Bretigny-sur-Orge (France).
A NEW ANALYSIS OF SPIN, BASED ON FRENCH EXPERIENCE ON COMBAT AIRCRAFT [UNE NOUVELLE ANALYSE DE LA VRILLE BASEE SUR L'EXPERIENCE FRANCAISE SUR LES AVIONS DE COMBAT]
Claudius LaBurthe *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 9 p In FRENCH; ENGLISH summary (For availability see N76-29245 20-08)

Relatively few aircraft are lost owing to sinking, stalling or spinning. Among other reasons, this favorable result may be attributed to a particular emphasis put on pilot instruction about aircraft behavior at high angles of attack. But in view of the unfavorable influence of wing loading this situation might deteriorate with new aircraft. Some test results are analyzed as regards the nature of losses of control. The major influence of inertia is thus demonstrated. Limits of credibility for stall warning systems, based upon angle of attack measurement, are then deduced. Author

N76-29261 Messerschmitt-Boelkow-Blohm G m.b H., Hamburg (West Germany).
SPIN INVESTIGATION OF THE HANSA JET
Herbert Neppert *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 7 p refs (For availability see N76-29245 20-08)

Spin characteristics of the Hansa jet from calculation, vertical spin tunnel and flight have been compared. As a result of the superstall a special form of flat spin with low rate of rotation is obtained. An analysis is carried out and various recovery methods are given. Author

N76-29262 Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France)
FLIGHT TEST METHODS FOR THE STUDY OF SPINS [METHODES D'ESSAIS DE VRILLES EN VOL]
J. P. Duval *In* AGARD Stall/Spin Probl. of Mil Aircraft Jun. 1976 8 p In FRENCH (For availability see N76-29245 20-08)

A system of instruments and techniques developed to investigate aircraft spin maneuvers was described. Both ground-based systems (telemetry, real-time and delayed-time measurements) and airborne systems (instrument management, cameras, etc.) are described and discussed. The Alpha-Jet aircraft is used as an example to illustrate the technique used, including the importance of preliminary wind tunnel test results and the subsequent logical sequence of flight tests. Recent flight test results were illustrated. Transl. by Y.J.A.

N76-29263 Grumman Aerospace Corp., Calverton, N.Y.
F-14A STALL SPIN PREVENTION SYSTEM FLIGHT TEST

Charles A. Sewell and Raymond D. Whipple *In* AGARD Stall/Spin Probl. of Mil Aircraft Jun. 1976 7 p refs (For availability see N76-29245 20-08)

The evaluation of various spin prevention design concepts for the F-14 Tomcat by analytical, simulational, and experimental methods is described. Preparation of the test vehicle is detailed showing unique emergency systems and qualification testing of these systems. Operational aspects of the flight test program including the problem devising a system flexible enough to permit in-flight optimization of design parameters is treated. The gradual shift in emphasis from spin prevention, which was accomplished with relative ease, to departure amelioration for enhanced air combat effectiveness is documented. An overview of the final ARI with associated subsystems is given. Author

N76-29264 Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
SPIN FLIGHT TEST OF THE JAGUAR, MIRAGE F1 AND ALPHA-JET AIRCRAFT [ESSAIS DE VRILLES DU JAGUAR, DU MIRAGE F1 ET DE L'ALPHA-JET]
J. Differ, J. P. Duval, and J. Plessy *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 6 p In FRENCH (For availability see N76-29245 20-08)

A series of flight tests designed to investigate spin characteristics on the following aircraft were described: Jaguar, Mirage F1, and Alpha-Jet. The case of the Alpha-Jet is especially interesting in view of its training role. Results obtained during these tests were described and compared to wind tunnel tests predictions. Transl. by Y.J.A.

N76-29265 General Dynamics/Fort Worth, Tex.
YF-16 HIGH ANGLE OF ATTACK TEST EXPERIENCE
John P. Lamers *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 14 p (For availability see N76-29245 20-08)

The objective of high angle of attack flight tests was to clear the aircraft for the air combat maneuvering test phase. This was to be accomplished by validation of predicted aerodynamic data, and a comprehensive evaluation of handling qualities and flight control system performance during aggressive simulated tactical maneuvering. The program also included a realistic evaluation of the effectiveness of special automatic control system features designed to enhance high angle of attack maneuverability, handling qualities, and departure resistance. Of particular interest were the effects of the active control system (command and stability augmentation) and relaxed static stability concepts upon stall/spin characteristics and recovery capability. Engine operating characteristics at high angle of attack, high angle of sideslip, low airspeed conditions were also of interest. Results show excellent high angle of attack flight characteristics, good correlation with NASA spin model results, and normal flight control system operation over the range of conditions tested. Author

N76-29266 Naval Air Systems Command, Washington, D.C.
US NAVY FLIGHT TEST EVALUATION AND OPERATIONAL EXPERIENCE AT HIGH ANGLE OF ATTACK
Alexander F. Money and Donald E. House (Naval Air Test Center) *In* AGARD Stall/Spin Probl. of Mil. Aircraft Jun. 1976 10 p refs (For availability see N76-29245 20-08)

An overview is presented of the problem areas presently considered most significant in the high angle of attack flight regime in U.S. Navy aircraft. The U.S. Navy philosophy of high angle of attack flight testing is also discussed, with examples of some of the more recent programs. Author

X77-72038 Advisory Group for Aerospace Research and Development, Paris (France).
NIGHT AND ALL-WEATHER GUIDANCE AND CONTROL SYSTEMS FOR FIXED-WING AIRCRAFT
Nov 1976 208 p Presented at the 2nd Tech. Meeting of the Guidance and Control Panel of AGARD, Cheltenham, England, 3-7 May 1976
(AGARD-CP-211) Avail. Advisory Group for Aerospace Research and Development, Paris, France NATO-Classified report

NOTICE Available to U.S. Government Agencies

Topics discussed include operational needs and problems, piloting and navigation, electro-optical sensor design, modelling, evaluation and application, approach and landing problems, and the man machine interface and overall system design. Author

09 RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels, shock tube facilities, and engine test blocks. For related information see also *14 Ground Support Systems and Facilities (Space)*.

N74-21899# Advisory Group for Aerospace Research and Development, Paris (France)
A REVIEW OF CURRENT RESEARCH AIMED AT THE DESIGN AND OPERATION OF LARGE WINDTUNNELS
Mar. 1974 55 p refs
(AGARD-AR-68) Avail: NTIS HC $5.75

The proceedings of a conference on wind tunnel design are presented. The subjects discussed are: (1) wind tunnel design and operation, (2) testing techniques, (3) special techniques for engine simulation, (4) techniques for high lift and V/STOL testing, (5) problems of testing at transonic speeds, and (6) fluid motion problems. Author

N74-31733# Advisory Group for Aerospace Research and Development, Paris (France).
LARGE WINDTUNNELS: REQUIRED CHARACTERISTICS AND THE PERFORMANCE OF VARIOUS TYPES OF TRANSONIC FACILITY
R. C. Pankhurst, ed. (Min. of Defense, London) Jun. 1974 156 p refs In ENGLISH; partly in FRENCH
(AGARD-R-615) Avail: NTIS HC $11.00

A series of reports were prepared to analyze the requirements and characteristics of transonic wind tunnels. Some of the subjects considered are: (1) the effects of flow turbulence and noise on aerodynamic phenomena in wind tunnels, (2) testing time requirements in steady and unsteady wind tunnel measurements, (3) design principles for transonic wind tunnels, and (4) methods for correcting wall constraints in transonic wind tunnels. For individual titles, see N74-31734 through N74-31741.

N74-31734 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
EFFECTS OF FLOW TURBULENCE AND NOISE AND AERODYNAMIC PHENOMENA AND WINDTUNNEL RESULTS
R. Michel *In* AGARD Large Windtunnels: Required Characteristics and the Performance of Various Types of Transonic Facility Jun. 1974 27 p refs In ENGLISH and FRENCH (For availability see N74-31733 21-11)

An account is given of the influence of stream turbulence and noise on transition in laminar boundary layers and on the development of boundary layers that are already turbulent. This is followed by a discussion of the effects of turbulence and noise on wind tunnel measurements of overall force and moment coefficients and on phenomena associated notably with interactions between shockwaves and boundary layers. These considerations are vital to the extrapolation of wind tunnel results to full-scale conditions and to the specification of Reynolds number and flow quality requirements for future aerodynamic testing facilities. Author

N74-31735 Nationaal Lucht-en Ruimtevaartlaboratorium, Amsterdam (Netherlands).
NOTES CONCERNING TESTING TIME REQUIREMENTS IN STEADY AND UNSTEADY MEASUREMENTS
J. W. G. VanNunen *In* AGARD Large Windtunnels: Required Characteristics and the Performance of Various Types of Transonic Facility Jun. 1974 19 p (For availability see N74-31733 21-11)

The importance of time factors in conducting transonic wind tunnel tests is discussed. Emphasis is placed on the requirements for force and pressure measurements in steady flow conditions, pressure measurements on oscillating models for flutter calculations, and investigations of aerodynamic buffeting. The specific time requirements for various types of wind tunnel tests are analyzed to show the variations in the tunnel operations. Diagrams of the various wind tunnel model arrangements and data reduction techniques are included. Author

N74-31736 ARO, Inc., Arnold Air Force Station, Tenn. Karman Gas Dynamics Facility.
EXPERIMENTAL STUDIES IN A LUDWIEG TUBE TRANSONIC TUNNEL
C. J. Schueler *In* AGARD Large Windtunnels: Required Characteristics and the Performance of Various Types of Transonic Facility Jun. 1974 46 p refs Prepared in cooperation with AEDC (For availability see N74-31733 21-11)

In support of the development of a high Reynolds number transonic tunnel (HIRT), extensive use has been made of a 1/13-scale model of the facility. The studies included measurement and analysis of the boundary layers at the charge tube exit (entrance to nozzle), at the nozzle (contraction) exit, and in the test section, tunnel start time, test section Mach number flow uniformity, flow response time, pressure distributions on a two-dimensional airfoil model, force measurements on cones, an investigation of the influence of plenum volume and an investigation of the acoustics of the exhaust system. The results of the experimental work show the feasibility of obtaining high Reynolds numbers in a transonic tunnel with a Ludwieg tube drive system. Author

N74-31737 Aeronautical Research Inst. of Sweden, Stockholm. Engineering Dept.
APPLICATION OF THE GASOMETER STORAGE CONCEPT TO A TRANSONIC WINDTUNNEL MEETING THE LAWS SPECIFICATION
C. Nelander and B. Oeverby *In* AGARD Large Windtunnels: Required Characteristics and the Performance of Various Types of Transonic Facility Jun. 1974 7 p refs (For availability see N74-31733 21-11)

A drive system to improve the flow quality in a transonic test section of an intermittent wind tunnel. The system proposed consists of a piston and a U-tube gasometer for air storage. The construction of the device is illustrated and the method of operation is explained. The advantages and disadvantages of the proposed system are analyzed. Author

N74-31738 Royal Aircraft Establishment, Farnborough (England).
THE DESIGN OF HIGH-REYNOLDS-NUMBER, TRANSONIC WINDTUNNELS: SOME GENERAL PRINCIPLES
P. G. Pugh *In* AGARD Large Windtunnels: Required Characteristics and the Performance of Various Types of Transonic Facility Jun. 1974 22 p refs (For availability see N74-31733 21-11)

The general principles governing the design of a high-Reynolds-number transonic wind tunnel are examined. After a brief review of the essential design aims, the choice of size and operating pressure is discussed. With a rationale for these parameters established, means of achieving them are considered; in particular, the relative merits of various types of drive system are discussed. Author

N74-31739 Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
ADDENDUM TO A SURVEY OF CORRECTING WALL CONSTRAINTS IN TRANSONIC WINDTUNNELS
J. C. Vayssaire *In* AGARD Large Windtunnels: Required Characteristics and the Performance of Various Types of Transonic Facility Jun. 1974 21 p refs (For availability see N74-31733 21-11)

Methods for correcting wall constraints in transonic wind tunnels are discussed. Using linearized compressible flow theory, the influence of wingspan upon lift interference factors is examined. The streamline curvature correction is also considered, together with the influence of the position of the pressure datum in relation to that of the model. The characteristics of porous walls are considered with the proposal that a porous wall may be calibrated by comparing a test result with theoretical grid results computed for several values of porosity parameter in the boundary conditions. Author

N74-31740 Royal Aircraft Establishment, Farnborough (England).
SOME OBSERVATIONS ON OPTIONS FOR A LARGE TRANSONIC WINDTUNNEL
P. G. Pugh and D. Kuechemann *In* AGARD Large Windtunnels: Required Characteristics and the Performance of Various Types of Transonic Facility Jun. 1974 6 p refs (For availability see N74-31733 21-11)

The design parameters for transonic wind tunnel development are discussed. The two types of specifications which influence

the design parameters are defined. Specific considerations concern: (1) provision for exceptional tests, (2) the quality of the flow, and (3) heat transfer from the wind tunnel model. The effects of flow instability in the wind tunnel are analyzed.
Author

N74-31741 Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
REVIEW OF SOME PROBLEMS RELATED TO THE DESIGN AND OPERATION OF LOW SPEED WINDTUNNELS FOR V/STOL TESTING, ADDENDUM
M. Carbonaro *In* AGARD Large Windtunnels: Required Characteristics and the Performance of Various Types of Transonic Facility Jun. 1974 3 p refs (For availability see N74-31733 21-11)
(AGARD-R-601)

A method of calculating wall interference in transonic wind tunnels by using a vortex lattice to simulate the wind tunnel walls is discussed. The method includes the effects of wake curvature and wake displacement due to the wind tunnel walls. The flow distortions produced by a wind tunnel model are examined with respect to the minimum test speed and the maximum model-to-tunnel dimension ratio. Additional test procedures involving ventilated walls, simulated ground effect, and flow disturbances in the tunnel circuit are briefly noted.
Author

N74-34680# Advisory Group for Aerospace Research and Development, Paris (France).
THE NEED FOR A LARGE TRANSONIC WINDTUNNEL IN EUROPE. SECOND REPORT OF THE LARGE WINDTUNNELS WORKING GROUP
Aug. 1974 46 p refs
(AGARD-AR-70) Avail: NTIS HC $5.50

The Second Report of the Large Windtunnels Working Group of the AGARD Fluid Dynamics Panel is presented. The group confined its further considerations to the need for and definitions of a large transonic windtunnel in Europe. The engineering studies on the proposed four options for the tunnel drive system are reviewed; engineering of all four appears to be feasible but at higher cost than anticipated. The Group still cannot recommend a preferred option technical grounds, but recommends that following further work a selection should be made before the end of 1975. The program of further work necessary to provide the information needed for selection of a preferred option is defined, together with recommendations on how it should be shared between National Programs and on Independent Technical Project Group, with coordination as required by the MiniLaWs Group of the Fluid Dynamics Panel. It is concluded that the reasons given on the need for a large European transonic windtunnel still apply, and no change is required in the standard specification of the windtunnel.
Author

N75-30198# Advisory Group for Aerospace Research and Development, Paris (France).
A CATALOGUE OF EUROPEAN HYPERSONIC WIND TUNNEL FACILITIES
Jun. 1975 58 p
(AGARD-R-619) Avail: NTIS HC $4.25

European hypersonic windtunnels are listed and the following information is given about them: location, name of facility, and personnel concerned; description and testing capabilities, type of facility, details of working section, model mounting, and size at zero and nonzero incidence; instrumentation and other diagnostic equipment, and performance. For high enthalpy facilities, the data is plotted in terms of density versus velocity; for other facilities as RE/cm. Mach number showing operating boundaries. Nozzle exit diameter, useful core diameter, axial Mach number gradient, angular flow deviation, 'reservoir' conditions, gases used, frozen degree of dissociation, limiting velocity, for continuous flow tunnels and for low-density tunnels a graph of mass flow rate versus static pressure are included where available.
Author

N76-11110# Advisory Group for Aerospace Research and Development, Paris (France).
A FURTHER REVIEW OF CURRENT RESEARCH AIMED AT THE DESIGN AND OPERATION OF LARGE WIND TUNNELS
Sep. 1975 130 p refs
(AGARD-AR-83) Avail: NTIS HC $6.00

Work completed previously describing projected areas considered to be relevant to the design and operation of large wind tunnels was reviewed in the light of progress made. Comments and recommendations are made. In each one of the four fields of work selected, two conveners, one from each side of the Atlantic, brought together the foremost workers in that field to discuss what needs to be done, how the work should proceed, and how it could be shared. Altogether 132 research workers from nine countries participated and made valuable contributions. Topics of importance, including some which require particular attention, were also identified and divided into three categories: problems for which sufficient effort is currently being devoted, problems not currently attracting enough attention but where some activities are expected soon, and problems where positive action is necessary.
Author

N76-23283# Advisory Group for Aerospace Research and Development, Paris (France).
RANGE INSTRUMENTATION, WEAPONS SYSTEMS TESTING AND RELATED TECHNIQUES
Feb. 1976 362 p refs Partly in ENGLISH and FRENCH
(AGARD-AG-219; AGARDograph-219; ISBN-92-835-0157-8)
Avail: NTIS HC $10.50

Papers are presented which deal with test range instrumentation techniques and systems, test range facilities and requirements. Capabilities, proposed facility improvements, and techniques which have been developed for solving particularly significant problems as well as continuing critical problems are described. Emphasis is placed on weapons systems testing. For individual titles, see N76-23284 through N76-23303.

N76-23284 Radio Corp. of America, Moorestown, N.J. Missile and Surface Radar Div.
THE EVOLUTION OF TEST RANGES AND THE CHANGING REQUIREMENTS THEY SERVE, AN OVERVIEW
Victor W. Hammond and John W. Bornholdt *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 10 p (For availability see N76-23283 14-09)

The why of test ranges in general is examined along with the trends in test support requirements that have and are continuing to evolve Range Metric Instrumentation Systems. Historical trends in requirements are discussed and compared with the systems and techniques that have evolved over the period considered; that are available and in use; available but not being exploited; and unavailable but readily within the grasp of modern technology. A postulation of tomorrow's test range based on a brief analysis of technology, and the realities of problems--such as inflation, encroachment, and others, is presented.
Author

N76-23285 BDM Corp., Albuquerque, N.Mex.
STANDARD PROCEDURES/MEASURES OF EFFECTIVENESS FOR AIR FORCE OPERATIONAL TEST AND EVALUATION (CONSTANT IMPROVEMENT TASK 2)
R. B. Buchanan, J. W. Dyche, W. H. Norris, George Lutz, David P. Vanarsdale, John I. Keener, Donald E. Simon (RCA, Moorestown, N. J.), Milton Heinberg (RCA, Moorestown, N. J.), George Havermahl (RCA, Moorestown, N. J.), John T. Nopanen (RCA, Moorestown, N. J.) et al. *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 12 p refs (For availability see N76-23283 14-09)

The broad aspects of operational test and evaluation (OT and E) are reviewed. Certain areas are expanded to illustrate direct application of the principles of standardization for OT and E.
Author

N76-23286 White Sands Missile Range, N.Mex. Optics Div.
DISTANT OBJECT ATTITUDE MEASUREMENT SYSTEM (DOAMS)
Lowell Yates *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 16 p refs (For availability see N76-23283 14-09)

A brief history of the development of design criteria for tracking telescopes, including the Distant Object Attitude Measurement System (DOAMS), is presented. Missile attitude, event, and miss-distance data requirements are developed in terms of image content. The optical system modulation transfer function (MTF) is considered to include all known sources of image degradation, i.e., atmospheric turbulence, focus error, image motion, film and optics. Correlation of image content with the MTF demonstrates a technique for the development of telescope performance parameters and their extrapolation into design and test requirements. To record high-resolution images with low

distortion at high sampling rates in a desert environment involves two major design problems that are discussed: the development of an athermalized optical system that will maintain precise alignments over a wide range of temperature, and the development of mechanical structures that prevent degradation of the image by camera vibrations and high acceleration tracking rates. The dual telescope features an f/4, 2,500-mm-focal-length objective with a 360-frame-per-second 70-mm prism camera, and an f/8, 5,000-mm-focal-length objective with a 125 frame-per-second 70-mm pin-registered camera. Author

N76-23287 Radio Corp. of America, Moorestown, N.J. Missile and Surface Radar Div.
RADAR DETECTION AND TRACKING IN GROUND CLUTTER
R. D. Mitchell, M. R. Paglee, G. M. Sparks, and G. H. Stevens. *In* AGARD, Range Instrumentation, Weapons Systems Testing and Related Techniques, Feb. 1976, 20 p, refs (For availability see N76-23283 14-09)

The results are presented of a developmental program designed to provide automatic detection, acquisition, and tracking of high speed artillery projectiles with an existing C-band precision instrumentation radar. The goals established for the system were detection and acquisition of projectiles with a clutter-to-signal ratio of 30 db, in less than one second after firing; projectiles were to be tracked through the entire trajectory to near impact. The detection process utilized a recursive digital clutter rejection filter and an FFT processor. Tracking was accomplished using multiple pole fine-line filters in conjunction with clutter guard gates and automatic PRF switching. Preliminary test results indicate detection and tracking of 18 of the 20 projectiles fired in the test. Author

N76-23288 Services Techniques de l'Armement Francaise, Arcueil. Service des Equipements de Champs de Tir
THE STRADA LANDING TRAJECTOGRAPHY SYSTEM [LE SYSTEME DE TRAJECTOGRAPHIE D'ATTERRISSAGE STRADA]
Christian Giffard and Jean Pierre Marvillet. *In* AGARD, Range Instrumentation, Weapons Systems Testing and Related Techniques, Feb. 1976, 12 p, refs. In FRENCH (For availability see N76-23283 14-09)

The STRADA system was developed to accurately reconstruct and display, in near-real time, the trajectories of aircraft during approach and landing and thereby allow the development and certification of automatic landing systems. The system utilizes modern electron optics techniques in conjunction with a real-time computer integrated with an observation system. It is based on the LIDAR laser radar system providing the spherical coordinates from a passive optical reflector, which is the only special-purpose hardware that must be installed on the aircraft. The required performance specifications, a general description of the STRADA system a detailed study of its various components, the data reduction techniques, and the role assigned to the computer are described. Resolution of the safety problems associated with the laser system and atmospheric signal propagation was explained, as well as information on projected applications, manning, and cost optimization. Transl. by Y.J.A.

N76-23289 Edgerton, Germeshausen and Grier, Inc., Albuquerque, N. Mex. Test and Evaluation Dept.
THE HITVAL PROGRAM INSTRUMENTATION
Robert L. Chaney. *In* AGARD, Range Instrumentation, Weapons Systems Testing and Related Techniques, Feb. 1976, 8 p (For availability see N76-23283 14-09)

The HITVAL Program, a joint U. S. Army and Air Force test sponsored by the Director of Defense Research and Engineering (DDR&E), was conducted to determine the probability of hit by antiaircraft gun systems firing at fixed-and rotary wing aircraft. The HITVAL test was one element of a larger program to validate and improve mathematical aircraft attrition models. The HITVAL Program tested five gun systems and produced a large and comprehensive empirical data base from over two thousand gun-aircraft engagements. These data also have possible application to problems of tactics, gun system and crew performance, and training. Instrumentation and techniques developed for the HITVAL Program contributed significantly to the state-of-the-art in the measurement of gun performance parameters and represent advances in resolution, accuracies, and data handling for these and other generic systems and for evaluation test programs. Author

N76-23290 Air Force Armament Lab., Eglin AFB, Fla.
AIRCRAFT/STORES COMPATIBILITY ANALYSIS AND FLIGHT TESTING
Charles S. Epstein. *In* AGARD, Range Instrumentation, Weapons Systems Testing and Related Techniques, Feb. 1976, 13 p, refs (For availability see N76-23283 14-09)

The state-of-the-art in the field of aircraft/store compatibility testing has been expanded through new photographic, analytic, wind tunnel, and computer techniques. An in-depth explanation of the latest analysis and flight test techniques is given including the unique marriage of the wind tunnel and the high speed digital computer in the preflight analysis of data, and the photo imaging technique of flight test data reduction. Auth r

N76-23291 Messerschmitt-Boelkow-G m b H., Ottobrunn (West Germany). Unternehmensbereich Apparate
OPTIMIZATION OF FREE FLIGHT MEASUREMENTS FOR MISSILES
L. Stiklorus. *In* AGARD, Range Instrumentation, Weapons Systems Testing and Related Techniques, Feb. 1976, 50 p, refs (For availability see N76-23283 14-09)

A series of parameters regarding the performance and the analysis of free flight measurements was investigated to obtain general information about their influence on the accuracy of the aerodynamic stability coefficients to be determined. The findings attained are used to select these parameters in the course of further free flight tests in such a way that optimum results are achieved. Three different missiles were investigated. For two missiles the output data were obtained theoretically by using a digital computer program; for the third free flight measurement data were available. The analysis is based on the Newton-Raphson method, applying the maximum-likelihood principle. For the C sub Z and C sub M coefficients expressions with terms up to the fifth power were considered. In the case of a ballistic missile during the boost phase, the variation of the stability parameter as a function of Mach number, approximated by a polynomial of second power, was determined. In addition, biases of output data and initial values of the state variables were computed in all cases. Author

N76-23292 Army Test and Evaluation Command, Aberdeen Proving Ground, Md.
PROJECTILE AIRBURST AND IMPACT LOCATING SYSTEM (PAILS)
William B. Milway. *In* AGARD, Range Instrumentation, Weapons Systems Testing and Related Techniques, Feb. 1976, 8 p (For availability see N76-23283 14-09)

A system developed to solve the difficult problem of accurately scoring the location of airbursts or impacts from artillery and mortar projectiles is described. Such solutions as acoustics, electro-optics, and radar were analyzed on the basis of reliability, accuracy, cost, utility, and development potential. Selected was a range only radar trilateration system operating in the C band. Subsequently, a single prototype radar was fabricated to further explore field implementation of the concept. Field testing of the prototype is now underway with fabrication and application of the complete system to follow successful verification of risk areas. Author

N76-23293 Vega Precision Labs., Inc., Vienna, Va.
A TRACKING AND CONTROL SYSTEM USING PULSED TRANSMISSIONS
Raymond F. Irby. *In* AGARD, Range Instrumentation, Weapons Systems Testing and Related Techniques, Feb. 1976, 16 p, refs (For availability see N76-23283 14-09)

Three specific versions of the pulsed tracking and control systems with the associated vehicle-borne equipment, are described. Principles of operation are discussed. Author

N76-23294 General Dynamics/Electronics, San Diego, Calif.
RMS: A POSITION LOCATION SYSTEM FOR MODERN MILITARY WEAPONS TESTING AND EVALUATION
Willard S. Cushman. *In* AGARD, Range Instrumentation, Weapons Systems Testing and Related Techniques, Feb. 1976, 15 p (For availability see N76-23283 14-09)

The General Dynamics Range Measurement System (RMS) which can track over one thousand targets in real time with accuracies within two meters of true position is described. Author

N76-23295 Motorola, Inc., Scottsdale, Ariz. Government Electronics Div.
AN INTEGRATED TARGET CONTROL SYSTEM

B. W. Bell and R. D. Smith (Naval Air Systems Command) *In* AGAHD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb 1976 11 p (For availability see N76-23283 14-09)

The ITCS (Integrated Target Control System) which is a modern control system developed, tested, and currently in operational use by the United States Navy is described. The ITCS integrates the C3 (command, control, and communications) functions into a single two-way communication link. Specifically, ITCS transmits commands to the drone, receives telemetry from the drone and provides drone position by tracking in range, azimuth, and elevation. The ITCS is also capable of simultaneous control of multiple drones. The major topics are: (1) background leading to the initiation of the development program, (2) system description including the major components, (3) the employment scenario describing usage of ITCS, (4) a functional description covering pertinent technical details, (5) test programs successfully demonstrating ITCS capabilities, and (6) application of ITCS to major range complexities. Author

N76-23296 Yuma Proving Ground, Ariz.
PRECISION AIRCRAFT TRACKING SYSTEM (PATS)
William W. Steele *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 6 p (For availability see N76-23283 14-09)

An operational laser tracking system for manned aircraft is described and its operating and maintenance characteristics summarized. Data collection and reduction techniques including calibration in real-time and off-line are also described. Laser safety considerations are addressed. An operating cost comparison is made between the laser tracker, conventional cinetheodolites, and semi-automated cinetheodolites on the basis of tests of completely reduced data. Potential future laser tracking applications are discussed with anticipated impact on instrumentation requirements. Author

N76-23297 Air Force Special Weapons Center, Kirtland AFB, N.Mex. Test and Evaluation Systems Program Office.
MINIMAL ERROR TRAJECTORIES ON LINE
Eugene J. Pollock *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 20 p refs (For availability see N76-23283 14-09)

A technique is described for operating instrumentation in a nearly errorless tracking mode to yield correct trajectory on line. This technique uses a polynomial description of the target trajectory to predict target location and overcome time tagging and tracking errors encountered in conventional tracking systems. A fading memory polynomial filter of degree 2 recursively updates the trajectory estimate from sensor levied displacement errors. Systematic errors of the instrument are identified and eliminated, improving the accuracy of the trajectory data. These errors are evaluated and the instrument calibrated from stellar observations. A highly accurate time base provides network synchronization of trajectory determination. Typical applications as a trajectory measuring instrument and a suitable data source for remotely operated long focal length theodolites are noted. Author

N76-23298 Messerschmitt-Boelkow G.m.b.H., Munich (West Germany).
NEAR GROUND TELEMETRY SYSTEMS
Horst Kaltschmidt *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 40 p refs (For availability see N76-23283 14-09)

Telemetry systems which are applied in weapons test ranges are reviewed. The basic concept FM, PAM and PCM telemetry is explained including the data storing system in the groundstation. The special properties and effects of modulation concepts and of near ground wave propagation including board and ground antennas are described. Author

N76-23299 Army Electronic Proving Ground, Fort Huachuca, Ariz. Development Section
USE OF AUTOMATED SYSTEMS BY THE ELECTROMAGNETIC ENVIRONMENTAL TEST FACILITY IN ELECTROMAGNETIC COMPATIBILITY ANALYSES
Ralph McCluskey *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb 1976 9 p refs (For availability see N76-23283 14-09)

Automated electromagnetic compatibility testing of military communications equipment and weapons systems is conducted at the Electromagnetic Environmental Test Facility of the United States Army Electron Proving Ground. The evolutionary progression of electromagnetic compatibility testing from yesterday's costly, time-consuming field-testing process to the automated, rapid test facilities of today is discussed. Testing methodology and analytical techniques associated with tactical modeling and interference prediction are addressed to provide a comprehensive delineation of the electromagnetic compatibility assessment process. Author

N76-23300 Gable Corp., San Diego, Calif.
AIR COMBAT MANEUVERING RANGE
Frederic A. Bardshar and George W. Eaton *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 20 p (For availability see N76-23283 14-09)

A new concept in range instrumentation for effective and measured training and analysis of fighter pilots in high performance missile equipped aircraft is described. The air combat maneuvering range (ACMR) instrumentation system analyzes and displays the dynamics of launch platform, missile, and target in a manner permitting accurate recognition of envelope and development of optimized tactics. The ACMR instrumentation system provides markedly improved training effectiveness and economy. Author

N76-23301 Air Force Special Weapons Center, Kirtland AFB, N.Mex. Test and Evaluation Systems Program Office
DETERMINATION OF INSTRUMENTATION REQUIREMENTS FOR USAF RANGES
June G. Brenton (Dikewood Corp., Albuquerque, N. Mex.), Lawrence J. Smith (Dikewood Corp., Albuquerque, N. Mex.), Terrence G. Wheeler, Richard K. Trask, Jerald D. Miller, James J. Avitabile, and David M. Pearson (General Research Corp., Santa Barbara, Calif.) *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 34 p (For availability see N76-23283 14-09)

In a program to improve the capabilities of USAF ranges, requirements for range instrumentation were determined by the range functions that had to be performed to fulfill the needs of the range users. The ranges are used for operational training and testing. These activities are generally conducted in the context of performing specific missions. Through analysis of the missions, the range functions that will be needed were identified. For the purpose of this analysis, generalized mission descriptions were developed to depict representative combat and support missions of the Air Force. From these descriptions, criteria for evaluating effectiveness of performance during each mission phase were defined. The mission information impacting instrumentation requirements are summarized in ten matrices pertaining to safety, threat, targets, scoring, time-space-position information, command/control/communications, data, facilities/logistics, air/land space, and meteorology. Author

N76-23302 Martin Marietta Aerospace, Orlando, Fla.
MISSILE RADAR GUIDANCE LABORATORY
R. D. Monroe and P. C. Gregory *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 20 p (For availability see N76-23283 14-09)

An improved radar guidance laboratory which allows simultaneous infrared simulation for developing and testing point tracker radar and IR dual mode guidance systems which will be operational in the 1980's is described. These guidance systems will be tested for target acquisition, discrimination, and tracking capabilities under precisely controlled conditions in a dynamic, real-time simulated environment. The radar guidance types can be passive, semi-active or active, covering a frequency range from 0.5 to 18.0 GHz. The IR guidance systems can be passive at 3 to 5 or 8 to 14 microns. A short review of system requirements is furnished, and the major laboratory subsystems are described, with emphasis on the features of the rotational and translation motion systems, anechoic chamber, linear array target antenna system, radar generation system, IR target system, and computation. The principal new design features of this laboratory are the linear array target antenna system and the radar generation system which provides for four distinct radar emitters each of which can simulate simultaneous, independent RF sources. These sources can be surveillance, SAM, search or early warning radars, plus radar returns from illuminated targets, and types of pulsed and continuous wave ECM signals. Phenomena such as atmospheric attenuation, Doppler shift, target cross section deviation, and glint are also simulated. Criteria used to specify the required system performance, the reasons for criteria selection, and the laboratory test results are also included. Author

N76-23303 BDM Corp., Albuquerque, N.Mex.
ROLE OF SIMULATION IN OPERATIONAL TEST AND EVALUATION
C. P. Semmens, W. H. Norris, and R. B. Buchanan *In* AGARD Range Instrumentation, Weapons Systems Testing and Related Techniques Feb. 1976 4 p (For availability see N76-23283 14-09)

The OT and E (Operational Test and Evaluation) process is included as an integral part of the system acquisition process, and is the recognized method of measuring and assessing the military utility, operational effectiveness, and operational suitability of proposed systems. The effective use of simulation to reduce cost of OT and E is illustrated. Proper selection, application, and use of simulations increase the productivity of the OT and E process by reducing costs, providing otherwise unattainable data, and offering more timely and valid results. The logic and techniques of simulation application are also applicable to the development process and joint NATO exercises. An example is included of the application of large scale simulation to extend the results of field testing. Author

N76-25213# Advisory Group for Aerospace Research and Development, Paris (France).
WIND TUNNEL DESIGN AND TESTING TECHNIQUES
Mar. 1976 488 p refs Proc. of the Fluid Dyn. Panel Symp., London, 6-8 Oct. 1975
(AGARD-CP-174) Copyright Avail: NTIS HC $12.50

Fluid dynamics in wind tunnel model design, testing, and interference problems for subsonic and transonic ground test facilities are detailed. For individual titles, see N76-25214 through N76-25259.

N76-25214* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
THE CRYOGENIC TRANSONIC WIND TUNNEL FOR HIGH REYNOLDS NUMBER RESEARCH
Robert A. Kilgore, Jerry B. Adcock, and Edward J. Ray *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 19 p refs (For availability see N76-25213 16-09)
(L-10032) CSCL 14B

Based on theoretical studies and experience with a low speed cryogenic tunnel and with the transonic cryogenic tunnel, the cryogenic wind tunnel concept has been shown to offer many advantages with respect to the attainment of full scale Reynolds number at reasonable levels of dynamic pressure in a ground based facility. The unique modes of operation available in a pressurized cryogenic tunnel make possible for the first time the separation of Mach number, Reynolds number, and aeroelastic effects. Author

N76-25215 Royal Aircraft Establishment, Bedford (England).
THE ECT DRIVE SYSTEM: A DEMONSTRATION OF ITS PRACTICABILITY AND UTILITY
P. G. Pugh, W. A. Beckett, and T. G. Gall *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 15 p refs (For availability see N76-25213 16-09)

A description is given of the construction and operation of a small, ECT driven, transonic wind-tunnel. The dynamics of each essential feature of the ECT drive are considered in turn. The flow generated by an ECT drive is shown to be of very high quality. Further, via a discussion of some typical aerodynamic tests that have been performed in the tunnel, it is shown that such a high flow quality is not merely a desideratum. Rather, it is an absolute necessity if many important classes of tests are ever to be successfully conducted in large wind tunnels with short running times. Author

N76-25216 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. fuer Stroemungsmechanik.
THE LUDWIEG TUBE: A PROPOSAL FOR A HIGH REYNOLDS NUMBER TRANSONIC WIND TUNNEL
H. Ludwieg, H. Grauer-Carstensen, and W. Lorenz-Mayer *In* AGARD Wind tunnel Design and Testing Tech. Mar. 1976 11 p refs (For availability see N76-25213 16-09)

After a brief review of the historical development of the Large European High Reynolds Number Tunnel (LEHRT) and its specifications the advantages and flexibility of a Ludwieg tube drive system are outlined. Special emphasis is given to the development of the boundary layer in the charge tube and its influence on the flow quality in the test section. The theoretical predictions of boundary layer growth are confirmed by experimental results. An improved prediction method for the turbulence in the test section is given. Means to affect the turbulence in order to meet the LEHRT requirements are outlined. After a short review of the development of cost estimates some options are discussed which promise significant reduction in construction costs without impairing performance. These solutions are the application of prestressed concrete for large parts of the construction, lowering the stagnation temperature by an amount of approximately 50 C, and operation at cryogenic temperatures. Author

N76-25217 Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France) Dept d'Aerothermodynamique
CONCEPT AND DESIGN OF AN INJECTOR DRIVEN PRESSURIZED TRANSONIC WIND TUNNEL
R. Michel, A. Mignosi, and C. Quemard *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 9 p refs In FRENCH; ENGLISH summary (For availability see N76-25213 16-09)

An injector driven pressurized wind tunnel, which represents at a 1/10 the scale the project proposed by ONERA for a very high Reynolds number transonic facility, has been built. A description of this tunnel is given as well as the results obtained by studying the problems relating to the functioning of an injector driven tunnel. Author

N76-25218 Technion - Israel Inst. of Tech., Haifa. Dept of Aeronautical Engineering.
INDUCTION WIND TUNNEL PERFORMANCE: TEST SECTION FLOW QUALITY AND NOISE MEASUREMENTS
J. Rom, J. Bralla, and A. Seginer *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 8 p refs (For availability see N76-25213 16-09)

Flow quality measurements obtained in the 60cm x 80cm IDT are presented and discussed with particular emphasis on the noise and pressure fluctuations. Measurements of the flow uniformity in the test section, over the Mach number range of 0.4 to 1.15 obtained by the operation of a circumferential injector, are presented. Extension of the Mach number range to low supersonic Mach numbers is discussed. Measurements of turbulence by a hot wire system are presented showing that the turbulence level is between 0.5 to 1.0. The high turbulence level at the nozzle walls decays to a reasonable level at a distance of less than 5cm from the walls. Noise measurements were performed using microphones installed in various positions in the test section, injector exit and first diffuser. Model vibrations were measured by high speed photography. The vibrations are found to depend on the natural frequency of the model sting balance system. When this frequency is in the vicinity of 20 to 30Hz, resonance vibrations are excited by the injector pressure fluctuations that are concentrated in this low frequency range. The overall flow steadiness is demonstrated by results of buffet onset measurements on a model of a delta wing airplane which correlated well with the flight test results. Author

N76-25219 Lockheed-California Co., Burbank.
NOISE AND FLOW MANAGEMENT IN BLOWDOWN WIND TUNNELS
Edward L. Whitfield *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 7 p refs (For availability see N76-25213 16-09)

A 4-foot blowdown wind tunnel was designed to specifications oriented almost exclusively toward supersonic operation, with the result that flow quality at subsonic and transonic speeds was unduly compromised. Several recent tunnel modifications, designed to correct this deficiency, have resulted in a reduction of the test section pressure unsteadiness such that the present level compares favorably with that found in closed circuit, continuous wind tunnels. Experimental efforts with a 1/12-scale model tunnel, used for the purpose of establishing suitable modifications, are recounted. Model and full scale tunnel data indicate that a significant reduction in throttle valve induced noise levels can be obtained by breaking up the valve discharge flow into a large number of small jets. This approach yields low turbulence flow even with a pressure ratio across the valve as large as 30:1. Author

N76-25220 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany)
LOW SPEED TUNNELS WITH TANDEM TEST SECTIONS: A CONTRIBUTION TO SOME DESIGN PROBLEMS

Bernd Ewald *In* AGARD Wind Tunnel Design and Testing Tech Mar 1976 14 p refs (For availability see N76-25213 16-09)

The building expenses of a low speed wind tunnel are a function of test section size and maximum speed. During the design of the tunnel a combination of both must be chosen which gives the best cost effectiveness for the proposed use of the tunnel. The main disadvantage of the tandem test section layout is its great overall length. Minimum required length of undisturbed test section flow field was derived from various test requirements and model scale considerations. Modern numerical flow field calculation methods were used to find out the test section flow field distortion induced by the main nozzle and the intermediate nozzle between the test sections. Optimum nozzle designs for uniform exit velocity induce considerable flow field distortions upstream into the settling chamber respectively into the large test section in the case of the intermediate nozzle of a tandem test section layout. This upstream distortion may be compensated to some extent by a slight expansion at the rear end of the first test section. Calculated results for this compensation are given. Another contribution to minimum overall length may be found in the design of the settling chamber. A novel design of cooled honeycomb gives the required cooling performance in combination with low drag and good flow quality. In combination with this study a wide variety of wind tunnel cooling schemes was investigated in detail; results and criteria for the final selection of the cooling system are included. Author

N76-25221 National Aerospace Lab., Amsterdam (Netherlands).
DESIGN AND CALIBRATION OF THE 1/10TH SCALE MODEL OF THE NLR LOW SPEED WIND TUNNEL LST 8X6
J. C. A. VanDitshuizen *In* AGARD Wind Tunnel Design and Testing Tech Mar 1976 14 p refs (For availability see N76-25213 16-09)

A model was built at scale 1:10 of the LST 8x6 wind tunnel to investigate the aerodynamic design features and provide additional information concerning unconventional items such as a throttle for augmentation of the circuit loss factor and a system for intermittent ventilation. The design philosophy is outlined, followed by a survey of the results of the calibration. Where possible theoretical predictions and experimentally obtained data have been compared. The results indicate that the requirements which are set for the full scale tunnel will be met. Author

N76-25222 Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
HIGH-PERFORMANCE COMPACT WIND TUNNEL DESIGN
Ernstfried Thiel *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 6 p (For availability see N76-25213 16-09)

Optimum conception and geometry of a large low speed wind tunnel, which will be equipped with two test sections of different size in order to enlarge the operational spectrum, is discussed. For a conventional wind tunnel type with a closed circuit two possibilities lend themselves to the test section arrangement: the tandem configuration or a system of exchangeable test sections. An optimum solution with regard to construction volume, economic utilization of the installed power, and good flow quality led to the idea of the multitube multifan compact wind tunnel, a configuration in which each of the two different test section areas is linked with a corresponding number of diffuser tubes, each of which end after the first two corners in a separate fan with an adjacent diffuser. Author

N76-25223* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
THE RATIONALE AND DESIGN FEATURES FOR THE 40 BY 80/80 BY 120 FOOT WIND TUNNEL
K. W. Mort, M. W. Kelly, and D. H. Hickey *In* AGARD Wind Tunnel Design and Testing Tech Mar 1976 5 p refs (For availability see N76-25213 16-09)
CSCL 14B

A substantial increase in the test capability of full scale wind tunnels is considered. In order to determine the most cost effective means for providing this desired increase in test capability, a series of design studies were conducted of various new facilities as well as of major modifications to the existing 40- by 80 foot wind tunnel. The most effective trade between test capability and facility cost was provided by repowering the existing 40 by 80 foot wind tunnel to increase the maximum speed from 200 knots to 300 knots and by the addition of a new 80- by 120-foot test section having a 110 knot maximum speed. The design of the facility is described with special emphasis on the unique features, such as the drive system which absorbs nearly four times the power without an increase in noise, and the large flow diversion devices required to interface the two test sections to a single drive. Author

N76-25224* Calspan Corp., Buffalo, N.Y. Aerodynamic Research Dept.
EXPERIMENTS WITH A SELF-CORRECTING WIND TUNNEL
R. J. Vidal, J. C. Erickson, Jr., and P. A. Catlin *In* AGARD Wind Tunnel Design and Testing Tech Mar 1976 13 p refs Sponsored in part by NASA and the AF (For availability see N76-25213 16-09)
(Contract N00014-72-C-0102)

The feasibility of controlling the flow actively through the walls of a transonic, porous wall wind tunnel in order to minimize wall interference effects on a test model is demonstrated. The method is based upon measuring the components of the disturbance velocity at discrete points along an imaginary surface in the flow field within the tunnel. A mathematical formulation of the flow field exterior to the surface including the boundary condition for unconfined flow, i.e., that all disturbance vanish at infinite, is used to determine if these measured velocity components are consistent with that boundary condition. If they are not, the theory provides a better approximation to the velocity component for unconfined flow, and the flow through the tunnel walls is readjusted iteratively until the measured quantities are consistent with unconfined flow. A brief review of theoretical methods is followed by a description of the Calspan self correcting wind tunnel design and operation, calibration with and without active wall control. Typical results obtained by approximating a conventional porous wall wind tunnel for an 0012 airfoil show that active wall control largely reproduces the correct shock wave position, eliminates wall interference of lift and drag, and reduces the interference effects on pitching moment to 10%. Author

N76-25225 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
ADAPTIVE WALL TRANSONIC WIND TUNNELS
Jean-Pierre Chevallier *In* AGARD Wind Tunnel Design and Testing Tech. Mar 1976 8 p refs In FRENCH, ENGLISH summary (For availability see N76-25213 16-09)

To remedy the difficulties at application of wall correction effects in high transonic flow with nonlinear phenomena, a new concept has been proposed. It consists in an active control of the perturbation component normal to the wall, based on the iterative calculation of the virtual flow in an unlimited domain outside the tunnel section. The paper deals with the principle and the application means of the new testing process, preliminary study of a pilot facility, the first results obtained in two dimensional flow, and the conclusions concerning the development of this process. Author

N76-25226* Southampton Univ. (England). Dept. of Aeronautics and Astronautics
A LOW SPEED SELF STREAMLINING WIND TUNNEL
M. J. Goodyer *In* AGARD Wind Tunnel Design and Testing Tech Mar 1976 [illegible] p refs Sponsored by NASA (For availability see N76-25213 16-09)

A two dimensional test section in a low speed wind tunnel is producing flow conditions free from wall interference. The test section has flexible top and bottom walls, and rigid sidewalls from which the models are mounted spanning the tunnel. All walls are unperforated, and the flexible walls are positioned by screw jacks. To eliminate wall interference the wind tunnel itself supplies the information required in this streamlining process, when run with the model present. Measurements taken at the flexible walls are used by the tunnel computer to check wall contours. When the static pressure distribution in the test section along a contoured flexible wall matches that computed for an imaginary flow field passing over the outside of the same contour, the wall is a streamline in an infinite flow field and the test section flow is free from wall interference. A series of iterations brings the walls from straight to streamlines. Illustrative aerodynamic data is presented, taken on a bluff body and a lifting wing. Author

N76-25227 National Aerospace Lab., Amsterdam (Netherlands)
THE EFFECT OF FINITE TEST SECTION LENGTH ON WALL INTERFERENCE IN 2-D VENTILATED WIND TUNNELS

J. W. Sleeff and W. J. Piers. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 11 p refs (For availability see N76-25213 16-09)

The effect of the ventilated walls on the flow in the wind tunnel is usually described by a so called homogeneous boundary condition. In the classical approach a linear h b c is used which is further based on the assumption that the ventilated walls are of infinite length. The classical theory has been extended to include a modification, which makes it possible to take into account the finite length of the test section, inclusion of higher order effects leading to a consistent second order theory. The results indicate that the length to height ratio of the test section is an important parameter in ventilated wall interference, model position and plenum pressure can be used to minimize wall interference effects. Author

N76-25228 National Aeronautical Establishment, Ottawa (Ontario).
INFLUENCE FUNCTION METHOD IN WIND TUNNEL WALL INTERFERENCE PROBLEMS
M. Mokry. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 10 p refs (For availability see N76-25213 16-09)

A new general method is described for computation of wind tunnel wall interference effects in subsonic linearized flows. The influence function, introduced as a fundamental solution satisfying the prescribed wind tunnel boundary conditions, plays the central role in the present analysis. The method is applied to subsonic flow past an airfoil between perforated walls, and compared with measurements from the 15 in. x 60 in. test section of a 5 ft blowdown wind tunnel. Further examples concern a multi-component airfoil, finite cascades of blades, and the vortex sheet rollup behind a wing in a wind tunnel. Author

N76-25229 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
WALL CORRECTIONS FOR TRANSONIC THREE-DIMENSIONAL FLOW IN VENTILATED WIND TUNNELS
Xavier Vaucheret and Jean-Charles Vayssaire (Avions Marcel Dessault). *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 18 p refs In FRENCH, ENGLISH summary (For availability see N76-25213 16-09)

After a brief explanation of the necessity for wall corrections, two methods for calculating correction factors are then considered: the analytical method and the vortex lattice method. The expected accuracy and some practical examples demonstrate the possibilities of these two methods. The methods for defining wind tunnel ventilated walls are analyzed. The detailed method for obtaining the law to define aerodynamic permeability as a function of Mach number is thoroughly explained. Examples applied to industrial tests demonstrate the methods used. Criteria based on the confidence level which can be grated to correction permit graphs to be plotted for defining the size of wind tunnel models. Author

N76-25230 Aeronautical Research Inst. of Sweden, Bromma.
FLOW PROPERTIES OF SLOTTED WALLS FOR TRANSONIC TEST SECTIONS
Sune B. Benolt and Hans Sorensen. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 11 p refs (For availability see N76-25213 16-09)
(Grant AF-AFOSR-2184-72)

A theoretical and experimental study is reported on flow through slotted walls under a variety of conditions. The ultimate objective is to make possible accurate numerical computation of transonic flows around models in slotted test sections. Considered is slot flow configuration typical of two dimensional, low lift tests at high subsonic free stream Mach numbers. With the test section empty the slot flow is outwards, into the plenum chamber, and this remains true over a large part of the test section when the model is introduced. From oil flow pictures and pressure measurements in and around the slots it is concluded: that the slot flow is slightly influenced by the presence of the wall boundary layer, that the flow within the slot is attached and approximately inviscid although influenced by boundary layer formation, that the flow enters the plenum chamber as a thin free jet, and that the transverse velocity in the jet and slot is too large for a linear pressure drop equation to be sufficiently accurate. When the slot flow turns back over the rear end of the model it may admit stagnant air from the plenum chamber into the test section; the ability of the slot to maintain a pressure difference across the wall is then necessarily reduced. Based on these observations a tentative flow model is proposed, yielding a relationship between

N76-25231 ARO, Inc., Arnold Air Force Station, Tenn. Von Karman Gas Dynamics Facility.
EXPERIMENTS TO ASSESS THE INFLUENCE OF CHANGES IN THE TUNNEL WALL BOUNDARY LAYER ON TRANSONIC WALL CROSSFLOW CHARACTERISTICS
R. F. Starr. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 11 p refs Sponsored by the AF (For availability see N76-25213 16-09)

The equivalent porosity of the test section wall in a transonic wind tunnel with a fixed geometric porosity and varying wall boundary layer displacement thickness, has been investigated. Previous experiments have demonstrated that the boundary layer displacement thickness on the wall influences the wall crossflow characteristic. Experimental data from a Ludwieg tube type of transonic tunnel are compared to data from conventional transonic tunnels in the Mach number range from 0.95 to 1.15. The displacement thickness studied is comparatively thin and represents typical values which will be encountered in future high Reynolds number transonic tunnels. Based on the change in static pressure measured on a cone cylinder model, it is shown that a factor of two variation in the tunnel wall displacement thickness results in an equivalent wall porosity change of less than one percent in the range 0.13 less than or equal to displacement thickness/d less than or equal to 0.28, where d is the wall hole diameter. Author

N76-25232 Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
THE COMPUTATION OF TRANSONIC FLOWS PAST AEROFOILS IN SOLID, POROUS OR SLOTTED WIND TUNNELS
D. Catherall. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 10 p refs (For availability see N76-25213 16-09)

A method is described for computing two dimensional inviscid flows at transonic speeds in wind tunnels in which the transonic small perturbation equation is solved. Because of the use of coordinate transformations, which transform the infinite physical plane into a finite computing one, far field boundary conditions are relatively easy to obtain and apply. The effect of tunnel walls on the flow has been modelled by using the usual homogeneous wall boundary condition. Comparisons are made with some experimental results and the free air and tunnel versions are used to assess the ability of linear subsonic theory to predict tunnel interference corrections when the flow is transonic. Author

N76-25233 National Aerospace Lab., Amsterdam (Netherlands).
TWO-DIMENSIONAL TUNNEL WALL INTERFERENCE FOR MULTI-ELEMENT AEROFOILS IN INCOMPRESSIBLE FLOW
O. DeVries and G. J. L. Schipholt. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 7 p refs (For availability see N76-25213 16-09)

A singularity method has been applied to calculate two dimensional tunnel wall corrections for multi-element aerofoils. The calculations show, that the well known corrections due to Glauert can be applied for a single aerofoil, except the pitching moment correction above 15 deg angle of attack, but that the Glauert approach fails in the case of trailing edge flap deflections. The results of the calculations agree with the strong non linear results found by De Jager and Van de Vooren for a hinged flat plate at zero incidence. Author

N76-25234 British Columbia Univ., Vancouver. Dept. of Mechanical Engineering.
A LOW-CORRECTION WALL CONFIGURATION FOR AIRFOIL TESTING
C. D. Williams and G. V. Parkinson. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 7 p refs (For availability see N76-25213 16-09)

The reduction of wind tunnel wall corrections in airfoil testing by a transversely slotted wall opposite the suction side of the test airfoil, and by a solid wall opposite the pressure side, is considered. The solid elements of the slotted wall are symmetrical airfoils at zero incidence. This geometry permits the flow to assume closely the streamline pattern for unconfined flow, without degrading the flow quality through shear layer mixing near the test airfoil. The theory uses the potential flow surface source/element method, with Kutta conditions satisfied on the test airfoil and the wall slats. In experiments using a range of sizes of airfoils of three different profiles, good agreement with the predictions of the theory has been obtained. It appears that

the pressure difference across the wall and the transverse velocity through the slots. Author

N76-25235 Lockheed-Georgia Co., Marietta
DETERMINATION OF LOW SPEED WAKE BLOCK AGE CORRECTIONS VIA TUNNEL WALL STATIC PRESSURE MEASUREMENTS
J. E. Hackett and D. J. Wilsden *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 9 p refs (For availability see N76-25213 16-09)

A theoretical method has been defined for determining wind tunnel solid/bubble and viscous blockage from wind tunnel wall and roof pressure measurements involving lifting or non-lifting, powered or unpowered models. Three finite span line sources are used which are defined by five geometric and two flow parameters. Matching these parameters to the measured interim by an engineering solution is suggested. The method has been applied successfully to blockage calculations for a series of normal flat plates. Other experimental results, involving more typical wind tunnel models are also discussed. Author

N76-25236 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).
IMPROVED DISPLACEMENT CORRECTIONS FOR BULKY MODELS AND WITH GROUND SIMULATION IN SUBSONIC WIND TUNNELS
Gerhard Schulz *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 7 p refs (For availability see N76-25213 16-09)

Wind tunnel measurements have to be corrected owing to the finite dimensions of the test section. There are several kinds of corrections, namely: displacement or dynamic pressure corrections, downwash or direction corrections, and pressure gradient corrections. The numerous publications known on this subject do not state anything about the tolerable displacement up to which the corrections are still reasonable. This work presents quantitative and physically founded statements about this point. The decisive cognition is that, in the case of too large a blocking, the corrections take markedly different values for different parts of the model surface (inhomogeneity of dynamic pressure). The results may be summarized as follows: (1) big displacement has to be avoided, (2) bulky models produce in general considerably larger corrections than bodies of revolution of equal displacement, unless special cases are considered, (3) eccentric position of the model increases the corrections and the inhomogeneity, and (4) inhomogeneity cannot be corrected. Author

N76-25237 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
ACOUSTIC FLUCTUATIONS GENERATED BY THE VENTILATED WALLS OF A TRANSONIC WIND TUNNEL
Xavier Vaucheret *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 10 p refs In FRENCH; ENGLISH summary (For availability see N76-25213 16-09)

In order to reduce the noise level due to the acoustic perturbations generated by the wall perforations in the transonic test section, a classification of the noises emitted by several ventilated panels inserted in the test section was established. For this experimentation, the horizontal perforated walls are closed with adhesive tapes covering the holes. A solution consists of gluing, inside the test section, a plastic gauze with small mesh on the original walls. The advantage of this solution is the conservation of the original walls. It allows reducing the noise to a level similar to that measured for solid, i.e. closed, wall. Author

N76-25238 Boeing Commercial Airplane Co., Seattle, Wash.
NACELLE-AIRFRAME INTEGRATION MODEL TESTING FOR NACELLE SIMULATION AND MEASUREMENT ACCURACY
R. Decher, W. B. Gillette, and D. C. Tegeler *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 14 p refs (For availability see N76-25213 16-09)

Techniques necessary to achieve high accuracy in simulation and in force data for better subsonic airplane nacelle airframe integration are discussed. The selection of the appropriate nacelle simulation is covered together with experimental data obtained with flow, blown, and turbopowered nacelle models operated at wind tunnel flow conditions. The thrust calculation and the simulator calibration procedure are described. To guide test instrumentation and test procedures an error analysis is reported which shows that predicted error levels of under 1% of model airplane drag can be achieved in the wind tunnel. Data from an isolated and an installed test with flow, blown, and turbopowered simulator models of a high bypass engine nacelle on a four engined subsonic transport are shown to verify the validity of the test procedures. Author

N76-25239 British Aircraft Corp., Warton (England). Military Aircraft Div.
AIR DRIVEN EJECTOR UNITS FOR ENGINE SIMULATION IN WIND TUNNEL MODELS
R. Whitaker, A. W. Matthews, P. G. Knott, R. Angel, and D. J. Stewart *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 15 p refs (For availability see N76-25213 16-09)

The air driven ejector as a means of providing engine flow simulation is discussed. The characteristics of the ejector and its ability to simulate a wide range of engine types and flight conditions are outlined. It is shown that one dimensional theory with empirical loss factors now permits accurate performance predictions to be made. Recent experimental work has extended the scope of the empirical knowledge, demonstrated the merits of supersonic primary nozzle ejectors and improved the state of the art of ejector design. In low speed tunnel testing it has been demonstrated that for a high bypass ratio engine simulator good exit velocity profiles can be obtained and the installed performance well predicted under varying external conditions. Also, correct exhaust and intake momentum coefficients can be achieved at acceptable tunnel speeds even when using relatively low drive pressures. Author

N76-25240 Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
MEASUREMENT TECHNIQUES FOR JET INTERFERENCE EFFECTS
Jan VonDerDecken and Roland Joos *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 6 p (For availability see N76-25213 16-09)

Three methods are discussed: (1) the sum of jet thrust and aerodynamic forces including jet interference is measured, (2) the jet thrust itself is not weighed, only the aerodynamic forces working on the model including jet interference are measured, and (3) the thrust vector and the aerodynamic forces are weighed separately by two balances. For all three methods an example is presented. A special problem is the correct calibration of the different jet simulation systems under as realistic conditions as possible including the effects of onset flow. For the mentioned three cases, the calibration method is discussed. Author

N76-25241 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
INVESTIGATIONS ON A PLATE WITH UNIFORM BOUNDARY LAYER SUCTION FOR GROUND EFFECTS IN THE 3 m X 3 m LOW SPEED WIND TUNNEL OF DFVLR-AVA
R. Wulf *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 7 p refs (For availability see N76-25213 16-09)

A plate with uniform boundary layer suction for ground effects measurements is reported. For measurements with different model clearances the ground plate can be moved continuously through the test section. The velocity profile at various positions on the clean ground plate was measured with a total head pressure rake for different suction coefficients. A suction coefficient of C sub Q = 0.0055 is adequate to reach uniform flow with a boundary layer less than 10 mm thick. Depending on the suction coefficient, the flow in the vicinity of the plate is deflected towards the plate by an angle of C sub Q. In addition ground effect measurements have been performed on a VTOL model with an engine system of two tip turbine driven fans and cascades to deflect the jet by 90 deg. In a position close to the ground there is a remarkable influence of boundary layer suction. Hysteresis effects are reduced by boundary layer suction. Results from measurements with different bank angles of the ground plate are compared. Author

N76-25242 Air Force Aero Propulsion Lab., Wright-Patterson AFB, Ohio.
HIGH FREQUENCY GUST TUNNEL
Hermann Viets *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 8 p refs (For availability see N76-25213 16-09)

A mechanism is proposed employing unsteady fluidically controlled flapping jets for application to the production of variable frequency gusts in wind tunnels or in ambient air. The basic mechanism is an unsteady jet based on the simple fluidic element and controlled either by an acoustic feedback line between the control ports or by a pair of rotating valves simply constructed from slotted rods. Some advantages of the proposed system are (1) capable of high frequencies; (2) low torque motors required; (3) capable of producing transverse or streamwise gusts; (4) capable of producing nonsinusoidal wave forms; (5) capable of producing programmed transverse disturbance; (6) prescribed or random phase relationships among the various nozzles; (7) capable of producing uniform flow across the tunnel span; and (8) rotating valves are self cooling. Author

N76-25243 Salford Univ. (England). Dept. of Mechanical Engineering.
DESIGN AND OPERATION OF A LOW-SPEED GUST TUNNEL
R. A. Sawyer *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 7 p refs (For availability sue N76-25213 16-09)

The design of a low speed gust tunnel is described. The tunnel can produce sinusoidal, random or sharp edged vertical gust distributions in a horizontal airstream. The horizontal velocity range is 1.5 ms/1 to 18 ms/1 in an open jet of 0.7 m by 1.0 m cross section, and incidence variations are introduced by a linked array of air-foils across the upstream end of the open jet. The random and sinusoidal frequency range is 0 to 20 cs/1, and sharp edged gusts of thickness less than 0.1 m over the first meter of the working section may be produced. Four typical experiments conducted in the gust tunnel are described. These are concerned with unsteady pressure and force measurements, oscillatory vibrations, and response to simulated atmospheric gust spectra in the fields of wings, buildings and structures. The usefulness and limitations of the gust tunnel are assessed. Author

N76-25244 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
WEATHER HAZARD SIMULATION IN THE MODANE WIND TUNNELS
Guy Fasso, Guy Leclere, and Francois Charpin *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 8 p refs In FRENCH; ENGLISH summary (For availability see N76-25213 16-09)

Specially designed wind tunnel set-ups make it possible to simulate various weather hazards. The paper describes briefly the systems installed in the wind tunnels of Modane: (1) rain tests, at large scale and moderate speed, at S1-MA, or at great speed and smaller scale; (2) icing tests, at full or reduced scale, at S1-MA, on aircraft parts, on full aircraft models and on helicopter rotors; (3) and design of gust simulator. The main results obtained in the last ten years for rain and icing are presented. Author

N76-25245 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Luftstrahlantriebe.
A LASER-DUAL-FOCUS VELOCIMETER FOR WIND TUNNEL APPLICATIONS
R. School and H. B. Meyer *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 16 p refs (For availability see N76-25213 16-09)

The Laser Dual Focus (L2F) velocimeter measures the velocity of small particles as they are normally contained in every fluid. The basic idea is that two light beams are focused to two very small light spots in the measuring volume. Thus, the available laser power is concentrated to a very high light intensity inside the control volume. The result is that flow velocity measurements can be carried out in back scattering up to high velocities even in the proximity of surfaces normal to the optical axis. In wind tunnel applications, the L2F method is well appropriated to measure the velocity field around three dimensional models. Using back scattering allows the complete optical device to be built as one compact unit. By means of the L2F method the mean velocity, the mean flow angle, and the turbulence degree of the velocity components in a plane normal to the beam axis may be determined. The paper describes in detail the optical and electronic arrangements, the test procedure, and some tests in wind tunnels and turbomachines. Author

N76-25246 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Angewandte Gasdynamik
APPLICATION OF A LASER-DOPPLER-VELOCIMETER IN A TRANS AND SUPERSONIC BLOW-DOWN WIND TUNNEL
F. Maurer, J. C. Petersen, H. J. Pfeifer (ISL), and J. Haertig (ISL) *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 8 p refs (For availability see N76-25213 16-09)

To examine carefully the potential of a laser Doppler velocimeter for the application in trans- and supersonic blow-down wind tunnels, comparative measurements in turbulent supersonic boundary layers have been performed. Mean velocity profiles as well as turbulence distribution profiles in the wind tunnel boundary layer were measured traversing a crossed beam LDV system from free stream conditions to 0.1 mm distance to the wall. Results were compared to measurements of mean velocity profiles using a combined total pressure and temperature boundary layer probe, from which velocity informations could be derived. The agreement is mostly very good. Nevertheless there are some remaining discrepancies which are discussed. The measurements demonstrate the usefulness of the LDV instrument for transonic and supersonic wind tunnel application, the more so as its potential is still developing. Author

N76-25247 ARO, Inc., Arnold Air Force Station, Tenn.
INTERFEROMETRIC MEASUREMENT OF MODEL DEFORMATION
Ronald A. Belz, Winfried H. Goethert, and Bruce W. Bomar *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 7 p refs Sponsored by the AF (For availability see N76-25213 16-09)

Laser interferometry is proposed for measuring model orientation and deformation in a high Reynolds number wind tunnel. A multiple beam optical system and signal processing electronic systems are described which measure relative and absolute model motion (displacement and velocity) normal to the illumination wavefront. The method of determining rotation from the relative linear displacement measurements of two retroreflectors mounted flush with the surface is described and examples of reflector placement for model attitude and deformation are presented. The results of preliminary experiments using a two beam optical system are described to illustrate the measuring capabilities of this electro-optical instrument under laboratory conditions. Finally, errors associated with changes in the air density from no flow to full flow tunnel conditions and density fluctuations during the test are briefly discussed. Author

N76-25248 General Dynamics Corp., San Diego, Calif. Convair Div.
MODEL SYSTEMS AND THEIR IMPLICATIONS IN THE OPERATION OF PRESSURIZED WIND TUNNELS
Stanley A. Griffin *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 13 p refs (For availability see N76-25213 16-09)

The feasibility of designing multi-piece flow through models for high Reynolds number transonic wind tunnels is considered. Six component, high capacity balances are investigated, and a comparison is made of model aeroelastic characteristics in a pressurized tunnel in reference to the aeroelastic nature of the flight vehicle. Methods of matching model/airplane deformation are shown, together with a system for measuring model deformation in a wind tunnel. Selected configurations are reviewed with respect to model loads, distortions, and stress, and a summary of recommended fabrication materials is presented. Cost comparisons are made between models for testing in proposed high Reynolds number transonic wind tunnels and present day transonic wind tunnels. The study concludes that models and strain gaged balances capable of running in these facilities can be designed and fabricated at a reasonable cost with present techniques. The study also indicates that options are available to produce close similarity of the model/airplane wing deformation over a broad range of operating conditions. Author

N76-25249 Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
DESIGN AND CONSTRUCTION OF THE ALPHA JET FLUTTER MODEL
Peter Esch and Theo Windeck *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 9 p refs (For availability see N76-25213 16-09)

In order to prove flutter safety for the Alpha Jet, a flutter model (scale 1:8) was designed and constructed for experimental

investigations in the transonic wind tunnel For each component of the aircraft an adequate structural solution had to be found in order to fulfill the correct stiffness distribution The construction was carried out using advanced techniques, e g electron beam welding, chemical milling and bonding The static vibration tests of the complete model were in good agreement with the corresponding test results of the original aircraft Ahead of the main tests, preliminary tests with the wing and tail isolated were performed in a blowdown wind tunnel For the tests with the complete model a rigid wire suspension was used In the course of one year several configurations with and without external stores were investigated The experimental results agreed reasonably with the theoretical calculations Author

N76-25250* Virginia Univ., Charlottesville. Dept of Engineering Science and Systems.

MAGNETIC SUSPENSION TECHNIQUES FOR LARGE SCALE AERODYNAMIC TESTING

Ricardo N. Zapata *In* AGARD Wind Tunnel Design and Testing Tech Mar 1976 14 p refs (For availability see N76-25213 16-09)

(Grant NsG-1010)

The potential utility of magnetic suspension techniques is discussed in the context of current efforts towards realistic aerodynamic simulation in wind tunnels Design parameters are defined and problems of constructing large size facilities identified A three stage strategy towards realizing a truly large scale magnetic suspension and balance with full research capability is outlined Stage one, consisting of building and testing a prototype superconductor coil system to establish the feasibility of the concept has been completed successfully and its principal results are briefly described This proven feasibility of using superconductors for magnetic suspensions, together with the successful demonstration of the cryogenic wind tunnel concept, appear to have opened the way to clean tunnel, high-Re aerodynamic testing Results of a comparative analysis of scaling of several coil technologies for a specific magnetic suspension configuration, from the prototype size to a size compatible with the projected high Reynolds number cryogenic wind tunnel facility, are discussed in some detail Author

N76-25251 Von Karman Inst. for Fluid Dynamics, Rhode Saint-Genese (Belgium)

INTERFERENCE PROBLEMS IN V/STOL TESTING AT LOW SPEEDS

Mario Carbonaro *In* AGARD Wind Tunnel Design and Testing Tech Mar 1976 21 p refs (For availability see N76-25213 16-09)

When testing V/STOL models at low speeds several problems arise, in connection with the sharp downward deflection of the wake originating from the highly loaded lifting systems It is the purpose of this paper to define the various problems and to summarize and compare the obtained results First, the inclined wake may impinge on the wind tunnel floor and cause a breakdown in the wind tunnel flow uniformity The testing limitations associated with the occurrence of such phenomenon are discussed for the different cases of a rotor, a jet flap wing, or a single or multiple lifting jet configuration Wind tunnel boundary corrections account for the real behavior of the wake and an upper limit of their validity has to be assessed The various existing theories of wall corrections which take into account the deflection and eventually the curvature of the wake are summarized in the various cases of closed, open or ventilated test sections, and comparisons with existing experimental data are made The limits proposed in the literature for the validity of wall corrections are discussed Author

N76-25252 Westland Helicopters Ltd., Yeovil (England). Aerodynamics Research Dept

THE REMOVAL OF WIND TUNNEL PANELS TO PREVENT FLOW BREAKDOWN AT LOW SPEEDS

R E Hansford *In* AGARD Wind Tunnel Design and Testing Tech Mar 1976 8 p refs (For availability see N76-25213 16-09)

A model rotor was tested at low speed in a wind tunnel to study the problem of flow breakdown This condition arises from the wake impingement on tunnel floor and wall panels to induce a recirculatory flow upstream The phenomenon was first reproduced in the closed tunnel for various disc loadings and limiting operating conditions were established Panels were then selectively removed and it was subsequently shown that it was possible to obtain a representative tunnel flow, free from recirculatory interference, at lower advance ratios compared to closed tunnel operation By careful venting of a working section it is concluded that a substantial increase in maximum allowable downwash angle can be obtained Author

N76-25253 Hawker Siddeley Aviation Ltd., Hatfield (England). Wind Tunnel Dept

VSTOL WIND TUNNEL MODEL TESTING: AN EXPERIMENTAL ASSESSMENT OF FLOW BREAKDOWN USING A MULTIPLE FAN MODEL

M J Cull *In* AGARD Wind Tunnel Design and Testing Tech Mar 1976 8 p refs (For availability see N76-25213 16-09)

Tests have been made with a multifan VSTOL model in two different sized closed test section wind tunnels to investigate the problem of tunnel flow breakdown The boundary condition of incipient stagnation where the high energy jet exhaust first penetrates the tunnel wall boundary layer has been identified for a range of model conditions Correlation of results in both tunnels and with other work is good and the technique of establishing a flow breakdown boundary by investigating the behavior of the floor vortex, formed by the interaction of the model jet efflux and the tunnel mainstream flow, has been used successfully for a multifan configuration In addition model forces and moments are recorded in an attempt to estimate minimum testing conditions and to indicate the magnitude of wall constraint effect Direct comparisons are made of longitudinal forces and moments using results from both wind tunnels and a sample of results are presented Author

N76-25254 Aircraft Research Association Ltd., Bedford (England)

FURTHER EVIDENCE AND THOUGHTS ON SCALE EFFECTS AT HIGH SUBSONIC SPEEDS

A. B. Haines *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 12 p refs (For availability see N76-25213 16-09)

Recent evidence from tests at high subsonic speeds in existing tunnel facilities are reviewed to illustrate the difficulties in extrapolating the data to full scale. The uncertainties can be considerable even for wings currently being developed; the report stresses that these uncertainties affect not only the flow separation characteristics but also the drag in conditions where the flow is attached. None of the evidence detracts from the arguments which lead to the conclusion that there is a need in Europe for a new large pressurized transonic tunnel; but comments are also made as to whether the new theoretical tools, flight tests, further experimental research in existing facilities and modified experimental techniques could be partly used to offset the lack of such a facility in the next decade. Author

N76-25255 Tennessee Univ., Space Inst., Tullahoma.

ON TRANSONIC HIGH REYNOLDS NUMBER FLOW SEPARATION WITH SEVERE UPSTREAM DISTURBANCE

J. M. Wu, C. H. Chen, G. M. Elfstrom, L. Shen, and T. H. Moulden *In* AGARD Wind Tunnel Design and Testing Tech Mar. 1976 10 p refs (For availability see N76-25213 16-09)

(Contract F40600-74-C-0009)

Experimental studies on turbulent boundary layer separation were conducted at subsonic and lower transonic free stream conditions. The models used in these studies were shallow cavities of different depth to length ratio. The reattachment and relaxation of the flow over the back step and the subsequent re-separation at the forward facing step have been studied in detail. Emphasis in this paper is placed upon the surface pressure distributions and their relation to the flow relaxation process. The interaction between the separated wake and the main flow is also discussed. Author

N76-25256 National Aerospace Lab., Amsterdam (Netherlands)

THE CHARACTER OF FLOW UNSTEADINESS AND ITS INFLUENCE ON STEADY STATE TRANSONIC WIND TUNNEL MEASUREMENTS

R. Ross and P. B. Rohne *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 7 p refs (For availability see N76-25213 16-09)

Flow unsteadiness in wind tunnels has been separated into three modes: free stream turbulence convected by the flow, sound wave type disturbances travelling with the speed of sound with respect to the flow, and temperature spottiness convected with the flow. It was found, using the hot wire technique and microphones, that sound wave type disturbances are the most important type of unsteadiness in some transonic tunnels Tests carried out on a supercritical airfoil with noise levels of 0.35%

and 0.6% did not change trailing edge and shock induced separation. The additional noise caused transition to occur more forward by about 4% of the chord. Author

N76-25257* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
FLUID DYNAMIC RESEARCH AT NASA-AMES RESEARCH CENTER RELATED TO TRANSONIC WIND TUNNEL DESIGN AND TESTING TECHNIQUES
Lado Muhlstein, Jr. and Frank Steinle, Jr. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 8 p refs (For availability see N76-25213 16-09)
CSCL 20D

Fluid dynamic research with the objective of developing new and improved technology in both test facility concepts and test techniques is being reported. A summary of efforts and results thus far obtained in four areas is presented. The four area are: (1) the use of heavy gases to obtain high Reynolds numbers at transonic speeds, (2) high Reynolds number tests of the C-141A wing configuration; (3) performance and flow quality of the pilot injector driven wind tunnel; and (4) integration time required to extract accurate static and dynamic data from tests in transonic wind tunnels. Some of the principal conclusions relative to each of the four areas are: (1) initial attempts to apply analytical corrections to test results using gases with gamma other than 1.4 to simulate conditions in air show promise but need significant improvement; (2) for the C-141A configuration, no Reynolds number less than the full scale flight value provides an accurate simulation of the full scale flow; (3) high ratios of tunnel mass flow rate to injection mass flow rate and high flow quality can be obtained in an injector driven transonic wind tunnel; and (4) integration times of 0.5 to 1.0 sec may be required for static force and pressure tests, respectively, at some transonic test conditions in order to obtain the required data accuracy. Author

N76-25258 National Aeronautical Establishment, Ottawa (Ontario).
HIGH PITCH RATES FOR USE IN SHORT DURATION WIND TUNNELS
E. Atraghji and J. R. Digney. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 10 p refs (For availability see N76-25213 16-09)

The demand for high Reynolds numbers is being met at some existing pressurized blowdown wind tunnel facilities at the expense of reduced run time. One possible way of maintaining economical utilization of these short duration tunnels is to program the model for faster pitch rates. The influence of high pitch rates on the mean force, moment and pressure data measured on a typical sting mounted model at subsonic Mach numbers of 0.3 and 0.75 was studied. Results show that there is virtually no effect on these measurements at pitch rates as high as fifteen deg/sec. Author

N76-25259 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
SYSTEMATICAL INVESTIGATIONS OF THE INFLUENCE OF WIND TUNNEL TURBULENCE ON THE RESULTS OF MODEL FORCE-MEASUREMENTS
H. Otto. *In* AGARD Wind Tunnel Design and Testing Tech. Mar. 1976 9 p refs (For availability see N76-25213 16-09)

The influence of wind tunnel turbulence especially on the maximum lift of aircraft models, has been studied by systematical investigations in five low speed wind tunnels. In each wind tunnel the free stream turbulence was altered by two different grids which could be fixed at the nozzle exit. The test program included hot wire and sphere measurements to determine the free stream turbulence as well as force measurements on wind body models with different flap deflection angles. The results show that the maximum lift coefficient is not simply a function of the effective Reynolds number but depends also on the scale of the turbulence grid. This correlation is approximated by a simple formula. Author

N76-25266# Advisory Group for Aerospace Research and Development, Paris (France).
FLIGHT/GROUND TESTING FACILITIES CORRELATION
Apr. 1976 417 p refs Presented at 46th Meeting of the Flight Mech. Panel, Valloire, France, 9-13 Jun. 1975
(AGARD-CP-187, ISBN-92-835-0183-2) Avail: NTIS HC $11.00

The Symposium was organized around three subject areas: (1) correlation of basic wind tunnel techniques, (2) flight test techniques for correlation, and (3) wind tunnel/flight correlation. Papers were presented which treated specific studies designed to compare various two and three dimensional wind tunnel facilities, wind tunnel facilities designed to provide better Reynolds number matches with full scale, and techniques used to contain wall effects, measure dynamic characteristics and study noise. The state of the art with regard to parameter identification was summarized and the proceedings of the AGARD Flight Mechanics Panel Specialists' Meeting were reviewed. Also treated were methods of measuring aerodynamic characteristics, in flight, of wings, rotors, and special aircraft configured for the acquisition of data not normally available from flight tests. Correlation experience for a broad spectrum of aircraft types was reported. It was suggested that good correlation can be obtained if enough attention is given to ground tests. For individual titles, see N76-25267 through N76-25303.

N76-25267 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
COMPARATIVE TWO AND THREE DIMENSIONAL TRANSONIC TESTING IN VARIOUS TUNNELS
Xavier Vaucheret and Maurice Bazin. *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 14 p refs In FRENCH; ENGLISH summary (For availability see N76-25266 16-09)

Testing conditions at transonic speeds and the validity of the data obtained in various wind tunnels were studied. In two dimensional flow, two models of NACA 0012 and supercritical profiles were tested in ONERA S3 Modane and NAE 15x60 in. tunnels for Reynolds number 4 to 40 million, from Mach 0.3 to 0.9. Three homothetical profiles of NACA 0012 were also tested. Wind tunnel wall interferences were studied and recommendations on relative dimensions of models to test sections were made. In three dimensional flow, four homothetical models of a typical transport aircraft were tested in twelve transonic tunnels used for tests in various countries. The data were compared in a broad range of Reynolds number (0.3 to 7 million) between Mach number 0.7 and 0.96. Discrepancies can be reduced with corrections due to the free tunnel and wall interference. The effect of tripping the transition by grits was also analyzed, and comparisons were made with an axisymmetric body near Mach 1. Author

N76-25268 Aeronautical Research Inst. of Sweden, Bromma.
COMMENT ON RESULTS OBTAINED WITH THREE ONERA AIRPLANE CALIBRATION MODELS IN FFA TRANSONIC WIND TUNNELS
S. E. Gudmundson and S.-E. Nyberg. *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 7 p refs (For availability see N76-25266 16-09)

Some test results are presented from three-component measurements for three of the ONERA Airplane Calibration Models (designated M1, M2, M3). The tests were performed in the FFA transonic wind tunnels HT, S4 and TVM 500 in the Mach number range 0.7 to 0.96 and at Reynolds numbers, based on the mean chord of the wing, in the range 0.2 to 1.0 million. Comparisons are made for small angles of attack with results obtained with a small model (M1) in a large wind tunnel (ONERA S2MA in Modane). The agreement between the different tunnels is fairly good when the Reynolds number is the same. The Reynolds number effects are relatively large especially on the pitching moment in the lower Reynolds number range, which might mask some wind tunnel interference effects. Author

N76-25269* National Aeronautics and Space Administration Langley Research Center, Langley Station, Va.
RECENT PROGRESS ON NEW FACILITIES AT THE NASA LANGLEY RESEARCH CENTER
R. A. Kilgore and R. E. Kuhn. *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 16 p refs (For availability see N76-25266 16-09)
CSCL 14B

A new fan-driven high Reynolds number transonic cryogenic tunnel the National Transonic Facility is being planned for the United States. This tunnel will provide an order of magnitude increase in Reynolds number capability over existing tunnels. Theoretical studies and experience with the Langley 1/3 Meter Transonic Cryogenic Tunnel indicate that the cryogenic concept allows the attainment of full-scale Reynolds number at reasonable levels of dynamic pressure. The unique modes of operation which are available only in a cryogenic tunnel make possible the separation of Mach number, Reynolds number possible the separation of Mach number, Reynolds number, and aeroelastic effects. By reducing the drive power requirements to a level

where a conventional fan drive system may be used, the cryogenic concept makes possible a tunnel with high productivity and run times sufficiently long to allow for all types of tests at reduced capital costs and, reduced total energy consumption Author

N76-25270 ARO Inc., Arnold Air Force Station, Tenn
SPECIAL WIND TUNNEL TEST TECHNIQUES USED AT AEDC
T W Binion, Jr. *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 13 p refs (For availability see N76-25266 16-09) (Contract F40600-75-C-0001)

In recent years requirements have developed to investigate (1) captive loadings and trajectories of external stores, (2) maneuver and departure characteristics of aircraft and (3) static stability characteristics of missiles at angles of attack up to 180 deg Test techniques in use and being developed to satisfy these requirements are discussed Author

N76-25271* ARO, Inc., Arnold Air Force Station, Tenn
PREPARED COMMENT ON THE CONE TRANSITION REYNOLDS NUMBER DATA CORRELATION STUDY
N. S. Dougherty, Jr. *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 7 p Sponsored in part by NASA (For availability see N76-25266 16-09)

A sharp, smooth, 10-deg-included-angle cone was tested on twenty-one major wind tunnels of the United States and Western Europe to obtain correlation data on the effect of acoustic disturbances in wind tunnel flow on boundary layer transition Reynolds number. The cone is planned to be flight tested in order to obtain a basis of reference for the wind tunnel data over a nominal range of Mach numbers from 0.4 to approximately 2.0. Wind tunnel data obtained over a Mach number range from 0.2 to 4.6 are broadly characterized according to wind tunnel test section geometry and, in turn, to the types of acoustic disturbances associated with the geometry Author

N76-25272 National Aerospace Lab., Amsterdam (Netherlands)
THE PROPOSED LARGE EUROPEAN HIGH-REYNOLDS-NUMBER TRANSONIC WIND TUNNEL (LEHRT)
J. P Hartzuiker *In* AGARD Flight/Ground Testing Fac. Correlation Apr 1976 11 p refs (For availability see N76-25266 16-09)

This presentation sketches the background and the present-day activities in connection with the proposed European high Reynolds number transonic facility LEHRT, which could be operational around 1982 Author

N76-25273 ARO, Inc., Arnold Air Force Station, Tenn.
COMMENTS ON WALL INTERFERENCE-CONTROL AND CORRECTIONS
M. Pindzola, T. W Binion, Jr., and J. P. Chevallier (Office Natl d'Etudes et de Recherches Aerospatiales, Paris) *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 6 p refs (For availability see N76-25266 16-09)

A brief synopsis of meetings on the Design of Transonic Working Sections held under the auspices of the AGARD MiniLaWs Working Group of the Fluid Dynamics Panel is presented Author

N76-25274 Aeronautical Research Inst. of Sweden, Bromma
SOME RESULTS FROM AN INVESTIGATION OF THE SLOT FLOW IN A TRANSONIC SLOTTED TEST SECTION WALL, PREPARED COMMENT
S.-E Nyberg *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 4 p refs (For availability see N76-25266 16-09)

Some important features of slot flow were revealed by two-dimensional tests with a 6% thick circular arc profile in the FFA wind tunnel S3. Stagnation pressure in the slot, static pressure on the slat and a tentative flow model are presented deriving from tests at Mach number 0.903. Author

N76-25275 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany)
DYNAMIC SIMULATION IN WIND TUNNELS, PART 1
H Hoenlinger and O Sensburg *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 27 p refs (For availability see N76-25266 16-09)

Dynamic simulation techniques and wind tunnels used to investigate flutter characteristics and flutter suppression techniques are described Two cases where active flutter suppression was successfully applied are demonstrated One case deals with the flutter of a wing with a store and the other with an empennage flutter case Author

N76-25276* National Aeronautics and Space Administration Langley Research Center, Langley Station, Va
COMPARISONS OF FLIGHT MEASUREMENTS WITH PREDICTIONS FROM AEROELASTIC MODELS IN THE NASA LANGLEY TRANSONIC DYNAMICS TUNNEL
Wilmer H Reed, III *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 9 p refs (For availability see N76-25266 16-09)
CSCL 01A

The NASA Langley Transonic Dynamics Tunnel, which has a variable density Freon-12 (or air) test medium, was designed for the study of dynamics and aeroelastic problems of aerospace vehicles During the 15 years of operation of this facility there have been various opportunities to compare wind tunnel and flight test results Some of these opportunities arise from routine flight checks of the prototype, others from carefully designed comparative wind tunnel and flight experiments Data obtained from various sources is presented. The topics covered are: gust and buffet response, control surface effectiveness, flutter, and active control of aeroelastic effects Some benefits and shortcomings of Freon-12 as a test medium are also discussed Although areas of uncertainty are evident and there is a continuing need for improvements in model simulation and testing techniques, the results indicate that predictions from aeroelastic model tests are, in general, substantiated by full scale flight tests Author

N76-25277 National Aerospace Lab., Amsterdam (Netherlands)
COMMENTS ON MEASURING TECHNIQUES FOR UNSTEADY DERIVATIVES
J. W. C VanNumen *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 6 p refs (For availability see N76-25266 16-09)

In addition to the measuring procedures through which overall forces and moments are determined, the technique of measuring unsteady pressure distributions is discussed From such data, overall derivatives can be obtained by subsequent integration of the locally measured unsteady pressures Author

N76-25278 Royal Aircraft Establishment, Farnborough (England) Aerodynamics Dept
SOME AEROELASTIC DISTORTION EFFECTS ON AIRCRAFT AND WIND TUNNEL MODELS
G F Moss and D Pierce *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 11 p refs (For availability see N76-25266 16-09)

Aspects of the aeroelastic distortion of wings in flight and in the tunnel are discussed The effects of such distortion could be of prime importance when correlating flight and wind tunnel data, particularly when supercritical flows are present which tend to be comparatively sensitive to small geometric changes It is suggested, that as transonic facilities operating at higher stagnation pressures come into more general use as a means of achieving higher Reynolds numbers, better means of making allowances for the aeroelastic distortion of wind tunnel models will be necessary In flight the full benefits of advanced-wing technology will probably be achieved if similar improvements can be made to the techniques used by the aircraft designer In the long term, methods need to be found to control and use aeroelastic distortion to enhance aerodynamic performance in flight Reference is made experimental and theoretical data obtained with respect to these problems Author

N76-25279 United Technologies Research Center, East Hartford, Conn
DEVELOPMENT OF THE UNITED TECHNOLOGIES RESEARCH CENTER ACOUSTIC RESEARCH TUNNEL AND ASSOCIATED TEST TECHNIQUES
William M Foley and Robert W Paterson *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 10 p refs (For availability see N76-25266 16-09)

Design and development of an acoustic research tunnel is described Its operating experience is discussed relative to the design of new acoustic test facilities Experimental noise research programs conducted in the tunnel are described with attention given to the correlation of model studies with full-scale engine and helicopter rotor noise Author

N76-25280 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche (France)
CURRENT RESEARCH ON THE SIMULATION OF FLIGHT EFFECTS ON THE NOISE RADIATION OF AIRCRAFT ENGINES
Jean-Michael Fitremann and Mariano Perulli (Office Natl d'Etudes

et de Recherches Aerospatiales, Paris) *In* AGARD Flight/Ground Testing Fac Correlation Apr. 1976 3 p In FRENCH, ENGLISH summary (For availability see N76-25266 16-09)

Design problems related to the development of an anechoic wind tunnel in France were described. Typical results were presented, dealing with fundamental research on refraction, scattering and diffusion studies with the following goals: (1) to define an accurate method of transposing noise measurements made in an anechoic wind tunnel to real flight conditions, and (2) to understand the possibilities of full scale silencers from model tests analysis. Author

N76-25281 Royal Aircraft Establishment, Farnborough (England) Aerodynamics Dept

PROBLEMS OF NOISE TESTING IN GROUND-BASED FACILITIES WITH FORWARD-SPEED SIMULATION

John Williams *In* AGARD Flight/Ground Testing Fac. Correlation Apr 1976 14 p refs (For availability see N76-25266 16-09)

An overview of the design and operational problems associated with ground-based facilities for performing noise experiments with forward-speed simulation was presented. Various facilities were described. It was concluded that it is unlikely that one type of facility will be able to cater effectively for the whole range of simulated flight aero-acoustic measurements needed in aircraft noise R and D studies, towards the evolution of quieter military and civil aircraft without operational or economic penalties. Modified wind-tunnel type facilities are seen as providing the best approach for noise-model research work. The role of aircraft flight experiments was described, with the application of carefully controlled flight experiments using research-oriented modifications of small aircraft. The functions of large low-speed tunnels in noise testing was described, in relation to the development and exploitation of small acoustic tunnels. Author

N76-25282 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany)

STATUS OF METHODS FOR AIRCRAFT STATE AND PARAMETER IDENTIFICATION

P. G. Hamel *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 16 p refs (For availability see N76-25266 16-09)

The report of a meeting on aircraft system identification for flight test engineers and pilots, handling qualities and simulation experts, and aircraft and control system designers, was presented. It was shown that in recent years several identification procedures have evolved for obtaining aircraft parameters from inflight measurements. These approaches have been shown to have good success for conventional (winged) aircraft and have become practical to apply. The parameter identification problem becomes a much more complicated task for large and slender body aircraft where the elastic deformations at high dynamic pressure can no longer be neglected. For helicopters, simplifying assumptions are also, in general, considerably more difficult due to the strong coupling of the rigid body degrees-of-freedom, because of the different flexible motions introduced by the rotor blades, and because of the shortness of the test period which can be recorded due to the inherent instability of these vehicles. Author

N76-25283* National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif

PERSISTENCE AND DECAY OF WAKE VORTICITY

Leonard Roberts *In* AGARD Flight/Ground Testing Fac Correlation Apr. 1976 10 p (For availability see N76-25266 16-09)

CSCL 01A

Some recent research relating to the nature of the lift induced vortex wakes behind large aircraft was reviewed and the scaling laws that permit a comparison of results from ground facilities with those from flight test were provided. The maximum rotational velocities in the wake are shown to depend on a span loading shape parameter and on a characteristic length of persistence behind the aircraft. The effects of Reynolds number are also shown. Author

N76-25284 Royal Aircraft Establishment, Bedford (England)

FLIGHT MEASUREMENTS OF HELICOPTER ROTOR AEROFOIL CHARACTERISTICS AND SOME COMPARISONS WITH TWO-DIMENSIONAL WIND TUNNEL RESULTS

P. Brotherhood *In* AGARD Flight/Ground Testing Fac Correlation Apr. 1976 15 p refs (For availability see N76-25266 16-09)

The performance of airfoil sections designed specifically for helicopter rotor blades was investigated. These effect a better compromise of performance characteristics in the widely varying conditions of incidence and Mach number in which they operate. A technique of section comparison using appropriate airfoil fairings or 'gloves', each on opposing blades of a helicopter rotor, has been developed. In this way the helicopter is used as a test vehicle with the rotor providing the necessary environment for the airfoil tests. Results obtained in flight are compared with those from wind tunnel tests. The adverse effects of leading-edge roughness, simulating erosion, have also been investigated. Author

N76-25285 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany)

SOME INFORMAL COMMENTS ABOUT THE RESEARCH AIRCRAFT IN THE DFVLR

Hans-L. Meyer *In* AGARD Flight/Ground Testing Fac Correlation Apr. 1976 3 p (For availability see N76-25266 16-09)

An informal comment about the research aircraft of the DFVLR and some flight test systems was presented. The objective is to present an overview about the flight research activities at the DFVLR. The flight research activities of the DFVLR are concentrated at the Oberpfaffenhofen and Braunschweig research centers. Oberpfaffenhofen conducts activities in the field of electronics and physics of the atmosphere while Braunschweig is mainly concerned with flight mechanics and guidance and control. Presently, 12 aircraft are assigned at Oberpfaffenhofen and 6 at Braunschweig with which the divisions fly annually about 2,000 and 1,000 flight hours respectively. These research aircraft can be classified into the following groups: Jet: Canberra, HFB 320, T-33; 2-prop: 2 Do 28 D-1, 1 Queen Air, 1-prop: 5 Do 27, 2 P 149D, 1 C 207, 1 C 182, 3 powered gliders, gliders: 1 Ka-6 E, 1 Cirrus, 1 ASW 15. Author

N76-25286* National Aeronautics and Space Administration Langley Research Center, Langley Station, Va

ROTOR SYSTEMS RESEARCH AIRCRAFT (RSRA)

Gregory W. Condon and Robert Letchworth *In* AGARD Flight/Ground Testing Fac. Correlation Apr 1976 20 p ref (For availability see N76-25266 16-09)

CSCL 01C

A description of the Rotor Systems Research Aircraft (RSRA) was presented, with particular emphasis on the unique systems that provide the potential for good flight/ground test facility correlation. These flight research vehicles are designed specifically with the capabilities necessary for the effective and efficient in-flight test and verification of promising new rotor concepts and supporting technology developments. The research mission and unique features of the RSRA will provide the capability to measure and separate the flight loads of the airframe and rotor, thereby allowing direct flight/ground test facility correlation of rotors as well as correlation with analytical models. Author

N76-25287* National Aeronautics and Space Administration Flight Research Center, Edwards, Calif

A NEW EXPERIMENTAL FLIGHT RESEARCH TECHNIQUE: THE REMOTELY PILOTED AIRPLANE

Garrison P. Layton *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 7 p refs (For availability see N76-25266 16-09)

CSCL 01C

The results obtained so far with a remotely piloted research vehicle (RPRV) using a 3/8 scale model of an F-15 airplane, to determine the usefulness of the RPRV testing technique in high risk flight testing, including spin testing, were presented. The program showed that the RPRV technique, including the use of a digital control system, is a practical method for obtaining flight research data. The spin, stability, and control data obtained with the 3/8-scale model also showed that predictions based on wind-tunnel tests were generally reasonable. Author

N76-25288 Institut de Mecanique des Fluides de Lille (France)

FLIGHT SIMULATION USING FREE-FLIGHT LABORATORY SCALE MODELS [SIMULATION DE VOL PAR MAQUETTES DE VOL LIBRE EN LABORATOIRES]

Jean Gobeltz *In* AGARD Flight/Ground Testing Fac. Correlation Apr 1976 16 p refs In FRENCH, ENGLISH summary (For availability see N76-25266 16-09)

Two operating procedures related to the laboratory testing of free-flight models are defined: the 'direct similarity' testing

where tests have to predict directly the results of the flight tests of the full scale aircraft, and the indirect similarity' testing where tests are used first for analysis of the phenomena, secondly for its modelling which is later applied to the aircraft itself. Dynamic stall and spin results are given as examples of 'direct similarity" testing. Use of indirect similarity' is shown to be a broader and more scientifically fertile testing procedure. Examples quoted are relative to the longitudinal dynamic behavior and vertical atmospheric gust response of aircrafts. It is shown how, for phenomena modelling, both stationary aerodynamic characteristics and aerodynamic derivatives data of the model are extracted of purposely designed flights. These data are then used for computation. Piloting methods of the models are given. Other types of tests relative to landing or cross wind landing, ditching, transversal gusts and active controls are also mentioned. Author

N76-25289 Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost

EXPERIENCE IN PREDICTING SUBSONIC AIRCRAFT CHARACTERISTICS FROM WIND TUNNEL ANALYSIS

J H D Blom *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 15 p (For availability see N76-25266 16-09)

Some examples of experience gained in the field of subsonic aircraft characteristics using illustrative material from aircraft development experience in the Netherlands were presented. The accuracy in predicting aircraft characteristics from wind tunnel analysis not only depends on the quality of the wind tunnel facilities used, but also to a large extent on the experience of the aircraft designer in converting wind tunnel information into the appropriate conclusion for the full scale aircraft. Direct comparison of wind tunnel data with flight test results is useful in the interest of providing further insight into the interpretation and nature of the corrections to be applied to wind tunnel test data. Author

N76-25290 British Aircraft Corp., Weybridge (England) Commercial Aircraft Div

COMMENTS ON WIND TUNNEL/FLIGHT COMPARISONS AT HIGH ANGLES OF ATTACK BASED ON BAC ONE-ELEVEN AND VC10 EXPERIENCE

M W Salisbury *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 4 p (For availability see N76-25266 16-09)

The flight test and wind tunnel measurements made at high incidence on the BAC 111 have been used to find the effects of Reynolds number and Mach number on the maximum value of the lift coefficient. It is shown that the effect of Mach number changes in the range 0.18 to 0.27 are of the same order as the effect of the Reynolds number change between wind tunnel and flight. The flight/tunnel comparison on the VC10 is used to show the importance of representing the geometry of the slat and wing profile in great detail in order to achieve a satisfactory correlation. Examples are also given of the type of modification which has to be made to wind tunnel data in order to achieve agreement between flight and simulator handling characteristics at the stall, and of the use of a simple end plate model to investigate the effect on drag of detail configuration changes. Author

N76-25291 Bell Helicopter Co., Fort Worth, Tex

THE ART AND SCIENCE OF ROTARY WING DATA CORRELATION

Jan M Drees *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 11 p refs (For availability see N76-25266 16-09)

An overview of the correlation of helicopter rotor performance and loads data from various tests and analyses was presented. Information is included from free-flight full-scale tests in a 40 x 80 wind tunnel, one-fifth scale tests in a Transonic Dynamic Tunnel, and small scale tests of a rotor in air. These test data are compared with each other, where appropriate, and with calculated results. Typical examples illustrate the state of the art for correlation and indicate anomalies encountered. It is concluded that a procedure using theoretical analyses to aid in interpretation and evaluation of test results is essential to developing a science of correlation. Author

N76-25292* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

COMPARISON OF MODEL AND FLIGHT TEST DATA FOR AN AUGMENTOR-WING STOL RESEARCH AIRCRAFT

W L Cook and D C Whittley (De Havilland Aircraft Co., Ltd., Downsview, Ont.) *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 12 p refs (For availability see N76-25266 16-09)

CSCL 01C

The major areas of confidence derived from wind tunnel tests performed on the Augmentor-Wing jet-STOL research aircraft were delineated and it was shown that, for the most part, tunnel results compare favorably with flight experience. Since the model differs in some respects from the actual aircraft, precise correlation between tunnel and flight tests results were not expected. In some areas the model tests were known to be non representative so that a degree of uncertainty remained. These areas of greater uncertainty are identified and again discussed in the light of subsequent flight tests. Author

N76-25293* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

CORRELATION OF LOW SPEED WIND TUNNEL AND FLIGHT TEST DATA FOR V/STOL AIRCRAFT

Woodrow L. Cook and David H. Hickey *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 10 p refs (For availability see N76-25266 16-09)

CSCL 01C

The availability of wind tunnel test data for correlation purposes of the same V/STOL aircraft tested in flight is very limited. This is due in a large part to size limitations of wind tunnels and the number of wind tunnels available for testing of full-scale aircraft. Wind tunnel tests are described for two research aircraft - the XV-5B fan-in-wing aircraft and the YOV-10 BCF (rotating cylinder flap) aircraft - in the NASA Ames 40- by 80-foot wind tunnel. The tests were conducted specifically to provide for correlation between wind tunnel and in-flight aerodynamics and noise test data. Correlation between aerodynamic and noise data are presented and testing techniques that are related to the accuracy of the data, or that might affect the correlations, are discussed. The correlation of noise measurements made with a J-85 engine mounted on a F-108 aircraft during low altitude flyovers with the same J-85 engine mounted on a model and tested in the Ames 40- by 80-foot wind tunnel are also reported. Author

N76-25294 Royal Aircraft Establishment, Bedford (England)

A BRIEF FLIGHT-TUNNEL COMPARISON FOR THE HUNTING H 126 JET FLAP AIRCRAFT

D. N. Foster *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 7 p refs (For availability see N76-25266 16-09)

Flight measurements of the variation of lift with angle of incidence, for an aircraft with an internal-flow jet flap, were compared with results deduced from wind-tunnel tests of the aircraft itself, and of a one-seventh scale model of the aircraft. The correlation is shown to be unsatisfactory for large flap deflection and high values of the jet momentum. The effects of the wind-tunnel wall corrections, and of some uncertainties in the position error correction, were investigated in order to suggest areas where further work could lead to improvements in the flight-tunnel correlation. Author

N76-25295 Avions Marcel Dassault Breguet Aviation, Saint Cloud (France)

COMPARISON OF AERODYNAMIC COEFFICIENTS OBTAINED FROM THEORETICAL CALCULATIONS, WIND TUNNEL TESTS, AND FLIGHT TESTS DATA REDUCTION FOR THE ALPHA JET AIRCRAFT [COMPARAISON DES COEFFICIENTS AERODYNAMIQUES ISSUS DES CALCULS THEORIQUES, ESSAIS EN SOUFFLERIE ET DEPOUILLEMENTS D'ESSAIS EN VOL EFFECTUES SUR L'ALPHA JET]

Remi Guiot and Horst Wunnenberg *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 15 p refs In FRENCH (For availability see N76-25266 16-09)

The techniques used to obtain the aerodynamic coefficients for the Alpha jet aircraft by theoretical calculations, results from wind tunnel tests, and reduction from flight tests data, were described. Comparison of these various results was made and showed, in general, a good correlation between them.

Transl. by Y.J.A.

N76-25296 Royal Aircraft Establishment, Bedford (England).

FLIGHT MEASUREMENTS OF THE LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF A VECTORED THRUST AIRCRAFT (HS-P1127) THROUGHOUT THE TRANSITION

C. J. Thorpe and A. A. Woodfield *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 21 p refs (For availability see N76-25266 16-09)

At low speeds, the aerodynamic force and moment coefficients on a vectored thrust jet V/STOL aircraft are primarily functions of the three variables - incidence angle, thrust deflection angle and the ratio of free stream to jet momentum per unit area (effective velocity ratio). To obtain an indication of the influence of each variable and obtain data requiring a minimum of correlation for comparison with model results, quasi-static non-equilibrium flight test techniques were developed. The principles underlying aerodynamic lift, drag and pitching moment measurements on jet V/STOL aircraft are examined. Test and analysis procedures used for flight tests on the P1127 prototype at the RAE are described. Examples of results from the flight tests are used to illustrate the various test techniques. Author

N76-25297 Hawker Siddeley Aviation Ltd., Kingston upon Thames (England)

COMMENTS ON SOME WIND TUNNEL AND FLIGHT EXPERIENCE OF THE POST-BUFFET BEHAVIOUR OF THE HARRIER AIRCRAFT

S. F. Stapleton and B. V. Pegram *In* AGARD Flight/Ground Testing Fac Correlation Apr 1976 11 p (For availability see N76-25266 16-09)

The design background of the Harrier wing is briefly reviewed indicating the philosophy of design for controlled buffet penetration to achieve high usable lift. Some wind tunnel techniques for evaluation of high incidence behavior are described and problems of interpretation are discussed. Some results of flight trials concerned with establishing high incidence/Mach number limits of operation are discussed and comments are made on the difficulties of prediction of flight behavior from wind tunnel data on the basis of correlations on the Harrier. Author

N76-25298 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio

EFFECTS OF BUFFETING AND OTHER TRANSONIC PHENOMENA

William E. Lamar *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 32 p refs (For availability see N76-25266 16-09)

Buffeting and other transonic phenomena are viewed in the context of highly maneuvering fighter aircraft. The fighter combat problem is first discussed from the viewpoint of the pilot with emphasis on the effects of buffeting and stability and control problems which occur during highly maneuvering flight. The current state of knowledge and available data relating to the tolerance and performance of the pilot in this flight regime is then reviewed to sum up the assessment of buffeting effects on piloting capabilities. Basic transonic flow separation phenomena, structural dynamics, and relevant aspects of flight control are viewed from the standpoint of the technologists to provide understanding of the basic effects. Various aspects of buffeting are reviewed to aircraft design and development, and means of improving aircraft design to reduce buffeting and flight control problems. The situation regarding correlation of ground, wind tunnel and flight tests is reviewed and the need of improvements in such correlations is noted. Gaps in capabilities and needs for research and development are given emphasis. Author

N76-25299 Saab-Scania, Linkoping (Sweden) Aero-Space Div

SWEDISH EXPERIENCE ON CORRELATIONS OF FLIGHT RESULTS WITH GROUND TEST PREDICTIONS

Svein Teige, Gunnar Straeng, and Karl-Erik Staake *In* AGARD Flight/Ground Testing Fac. Correlation Apr 1976 10 p ref (For availability see N76-25266 16-09)

Some of the wind tunnel data and flight test data obtained during the development work on the SAAB 37 Viggen aircraft are compared. Three different areas of testing were selected: (1) spin tests, (2) inlet tests and (3) measurements of aerodynamic derivatives. The main spinning and recovery characteristics of the aircraft are in good agreement with those predicted from wind tunnel tests, one exception being that the inverted spin mode has not been found in flight tests. Generally, the agreement between uncorrected inlet scale model tests and full scale is fair, but with a tendency of model flow measurements to be a conservative prediction of the aircraft performance. By correcting the model data for Reynolds number effects and probe sizing influence, an almost perfect correlation was achieved. The aerodynamic derivatives measured in flight tests are in good agreement with data predicted from wind tunnel tests and calculations. No important Reynolds number effects have been found. Author

N76-25300 Hawker Siddeley Aviation Ltd., Brough (England)

FLIGHT/TUNNEL COMPARISON OF THE INSTALLED DRAG OF WING MOUNTED STORES

A. J. Grundy *In* AGARD Flight/Ground Testing Fac. Correlation Apr 1976 16 p refs (For availability see N76-25266 16-09)

Installed drags for a range of stores mounted on the outboard wing pylon (mid semi-span) of a Hawker Siddeley Buccaneer S. Mk 2 were measured in full scale flight and on a 1/12th scale wind tunnel full model. This initial comparison covers several types of stores including a simple tank, a rocket pod and twin side-by-side carriage of iron bombs up to 0.88 Mach number. The flight results were obtained using quasi-steady flight test techniques; excess thrust was derived from triple-axis accelerometer measurements and thrust from an altitude test facility, engine final nozzle calibration using jet pipe pressure. The comparison of incremental drag shows that agreement is satisfactory. 'Clean' stores show good agreement but 'dirty' stores generally have lower drag in flight. Data on changes in lift and pitching moment are also presented. Author

N76-25301 British Aircraft Corp., Preston (England) Aerodynamics Dept

COMMENTS ON MATHEMATICAL MODELLING OF EXTERNAL STORE RELEASE TRAJECTORIES INCLUDING COMPARISON WITH FLIGHT DATA

G. A. Cox and K. Carr *In* AGARD Flight/Ground Testing Fac. Correlation Apr. 1976 19 p (For availability see N76-25266 16-09)

The ability to reproduce wind tunnel and flight store jettison trajectories using a mathematical modelling technique is demonstrated. A correlation is shown between flight trajectories and predictions using mathematical models incorporating data from (1) matching of wind tunnel jettisons with corrections to full scale conditions (2) wind tunnel measurements of installed store loads and store free-air aerodynamic forces and moments. The potential of the mathematical modelling technique to minimize wind tunnel and flight store jettison programs is demonstrated. Author

N76-25302 Aeritalia, Turin (Italy). Wind-Tunnel Dept.

COMMENTS ON WIND TUNNEL/FLIGHT CORRELATIONS FOR EXTERNAL STORES JETTISON TESTS ON THE F 104 S AND G 91 Y AIRCRAFT

A. Garrone, G. Buoclantini, and E. Barbantini *In* AGARD Flight/Ground Testing Fac. Correlation Apr 1976 11 p ref (For availability see N76-25266 16-09)

Comparisons are shown of wind-tunnel/flight jettison test results for significant stores, on the aircraft F 104 S and G 91 Y. Relevant techniques of jettison tests are illustrated. Moreover a computer program is examined, for the theoretical estimation of the jettisoned stores trajectories, in support of wind-tunnel and/or flight tests. Author

N76-25303 Aerospatiale Usines de Toulouse (France)

ANALYSIS OF THE COMPARISON BETWEEN FLIGHT TESTS RESULTS AND WIND TUNNEL TESTS PREDICTIONS FOR SUBSONIC AND SUPERSONIC TRANSPORT AIRCRAFT [ANALYSE CRITIQUE DES COMPARAISONS DES RESULTATS DE VOL AUX PREVISIONS DE SOUFFLERIE POUR DES AVIONS DE TRANSPORT SUBSONIQUE ET SUPERSONIQUE]

C. Pelagatti, J. C. Pilon and J. Baldaud *In* AGARD Flight/Ground Testing Fac. Correlation Apr 1976 23 p refs In FRENCH (For availability see N76-25266 16-09)

The problems of comparing results obtained from wind tunnels with those derived from actual flight tests were discussed. It was pointed out that corrections must be made to relate these results directly, due to aeroelastic effects and the effect of Reynold's number differences. For instance, high aerodynamic loads may alter significantly the general aerodynamic shape of aircraft as compared to that of the corresponding scale models, corrections must then be made to the coefficients measured with wind tunnels, making predictions more difficult. In addition, certain problems arise in the measurement of aerodynamic coefficients over the transonic regime. Using results obtained with the Airbus and Concorde aircraft, an attempt was made to point out the accuracy that may be expected from aerodynamic

coefficients derived from wind tunnel measurements, and the parameters that effect that accuracy. Transl. by Y.J.A.

N76-29287# Advisory Group for Aerospace Research and Development, Paris (France)
FLIGHT SIMULATION/GUIDANCE SYSTEMS SIMULATION

Jun. 1976 380 p refs Presented at the Joint Flight Mech. Panel/Guidance and Control Panel Symp., The Hague, 20-23 Oct. 1975
(AGARD-CP-198) Copyright Avail: NTIS HC $10.75

Papers are presented dealing with the use of flight simulation techniques. Specific topics discussed include: (1) approach and blind landing, (2) aircraft design, and (3) military operations and missions such as air combat, weapon delivery, and mission training. The generation of motion, visual, and feel cues and turbulence models are also discussed. For individual titles, see N76-29288 through N76-29315.

N76-29288 British Aircraft Corp., Warton (England). Military Aircraft Div.
THE GROWING CONTRIBUTION OF FLIGHT SIMULATION TO AIRCRAFT STABILITY, CONTROL AND GUIDANCE PROBLEMS

A. G. Barnes *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 13 p refs (For availability see N76-29287 20-09)

The changing role and contribution of the research/development simulator is discussed. It is a field of activity where rapid progress is being made, and the reasons for such progress are considered. In particular the advances which developments in TV based displays have brought are noted. Examples are given of the increasing range of problems now addressed on simulators, and some of the future trends are indicated. Author

N76-29289 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Human Engineering Dept.
A METHOD FOR THE GUIDANCE AND CONTROL SYSTEM EVALUATION FROM THE OPERATIONAL POINT OF VIEW

H. Denkscherz and P. Hahn *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 7 p (For availability see N76-29287 20-09)

A method is described for human engineering assessment of avionic systems. The method is based on the use of human engineering criteria for which examples are given. The way these criteria lead to system evaluation and system optimization is shown by examples. Author

N76-29290 Centre d'Essais en Vol, Istres (France)
INVESTIGATION OF THE LANDING APPROACHES FOR A STOL AIRCRAFT USING A FLIGHT SIMULATOR [ETUDE AU SIMULATEUR DU PILOTAGE D'UN AVION STOL EN APPROCHE]

J. P. Petit and J. C. Raynal (ONERA, Modane) *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 15 p In FRENCH; ENGLISH summary (For availability see N76-29287 20-09)

The influence of instrumentation in the establishment of longitudinal handling qualities criteria for approach and flare was investigated. Velocity vector head-up display, IFR and VFR instrumentation were tested. Various types of STOL aircraft were defined by modification of the engine thrust static and dynamic characteristics and by modification of the lift coefficients, in order to give them various flight path margins and various flight path rates of change. The simulation methods used to define several STOL aircraft, the test program conducted, and the results obtained are described. Author

N76-29291 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugfuehrung
THE USE OF A FLIGHT SIMULATOR IN THE SYNTHESIS AND EVALUATION OF NEW COMMAND CONTROL CONCEPTS

R. Onken, V. Adam, and R. Dierke *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 16 p refs (For availability see N76-29287 20-09)

The introduction of digital electric flight control systems as well as new theoretical techniques in optimal control open new ways in overall design. In particular, the development of advanced command control systems offers great promise. A flight simulator is used as a design aid and as a means for exploratory and comparative investigations for the study of flight path command systems. Some results show the tracking performance achieved with an optimized control law and suitably modified pilot interfaces. Author

N76-29292 Naval Air Development Center, Warminster, Pa. Air Vehicle Technology Dept.
APPLICATION OF FLIGHT SIMULATION TO DEVELOP, TEST, AND EVALUATE THE F-14A AUTOMATIC CARRIER LANDING SYSTEM

Robert L. Fortenbaugh and James M. Rebel (NATC) *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 13 p refs (For availability see N76-29287 20-09)

In the development of a F-14A automatic carrier landing system, a moving-base simulator was utilized to replace portions of both computerized synthesis and flight test phases. The simulator proved to be a cost effective test and evaluation tool in that it was able to duplicate and predict flight test results, to receive pilot acceptance as a valid representation of the real airplane, and to provide significant increases and flexibility in the number of parameter combinations that could be examined by a pilot. Author

N76-29293 Societe Nationale Industrielle Aerospatiale, Toulouse (France). Dept. des Etudes de Qualites de Vol et de Pilotage.
SIMULATION TECHNIQUES AND METHODS USED FOR THE STUDY AND ADJUSTMENT OF THE AUTOMATIC LANDING SYSTEM ON THE CONCORDE SUPERSONIC TRANSPORT AIRCRAFT [MOYENS ET METHODES DE SIMULATION UTILISES POUR L'ETUDE ET LA MISE AU POINT DE L'ATTERRISSAGE AUTOMATIQUE DE L'AVION DE TRANSPORT SUPERSONIQUE CONCORDE]

Raymond Deque and Jean-Louis Bonafe *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 11 p In FRENCH (For availability see N76-29287 20-09)

After a brief presentation of flight simulation techniques, the utilization of the automatic landing system of the Concorde, breakdown consequences, and performance analysis are studied. A critical test of turbulence models is presented in the effective analysis of turbulences encountered in flight tests.
Transl. by B.B.

N76-29294 Boeing Aerospace Co., Seattle, Wash.
USE OF THE FLIGHT SIMULATOR IN YC-14 DESIGN

Robert E. Spitzer *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 14 p refs (For availability see N76-29287 20-09)

The twin-engine USAF/Boeing YC-14 STOL prototype is approaching the final stages of fabrication and assembly. With upper-surface-blowing powered lift, and triplex digital flight control system, the YC-14 represents a new generation of transport aircraft. The piloted flight simulator has served as an integral tool in the design process. The flight simulation work that supported and guided YC-14 development is described. Organization and features of the digital math model are discussed. The simulation includes powered-lift effects, engine bleed for leading edge BLC, mechanical and electrical flight control systems, aerial delivery modes, and a newly developed wind and turbulence model. The three main contributions of the simulator are covered: criteria development, control system definition, and validation of flying qualities. Criteria for engine-out STOL approach are discussed. Control laws were developed for conventional piloting techniques for STOL speed and flight path control. Satisfactory flying qualities were validated by Boeing, USAF, and NASA pilots for a wide range of flight conditions. It is concluded that the flight simulator is an invaluable tool in the design of advanced technology aircraft such as the YC-14. Author

N76-29295* Kansas Univ., Lawrence.
SIMULATION AND SIMULATOR DEVELOPMENT OF A SEPARATE SURFACE ATTITUDE COMMAND CONTROL SYSTEM FOR LIGHT AIRCRAFT

Jan Roskam *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 15 p refs Sponsored by NASA (For availability see N76-29287 20-09)
CSCL 14B

A detailed description is presented of the simulation philosophy and process used in the development of a Separate Surface Attitude Command control system (SSAC) for a Beech Model 99 Airliner. The intent of this system is to provide complete three axes stability augmentation at low cost and without the need for system redundancy. The system, although aimed at

the general aviation market, also has applications to certain military airplanes as well as to miniature submarines. Author

N76-29296 Messerschmitt-Boelkow-Blohm G m b H., Munich (West Germany)
BENEFITS OF FLIGHT SIMULATION WORK FOR THE DEFINITION, LAYOUT, AND VERIFICATION WITH HARDWARE IN THE LOOP, OF THE MRCA FLIGHT CONTROL SYSTEM
W. Burkhardt, E. Zehner, and W. Duerr *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 20 p (For availability see N76-29287 20-09)

Based on the description of the Primary Flight Control System of the MRCA the main system layout parameters are explained. The main benefits of software system simulation and layout are pointed out and their test results are illustrated. The subsequent hardware system integration work on a Flight Control Test Rig with open loop tests and closed loop tests combined with the computer aircraft simulation are demonstrated. Author

N76-29297 Air Force Flight Test Center, Edwards AFB, Calif.
SIMULATION IN SUPPORT OF FLIGHT TEST
Richard R. Hansen, Christopher J. Nagy, and Paul W. Kirsten *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 28 p (For availability see N76-29287 20-09)

The General Purpose Engineering Simulator (GPES) operated by the Air Force Test Center to support conventional aircraft and aerospace vehicle testing and developmental engineering is described. The GPES is a small simulator without motion or visual systems for somatic cueing. Two concurrent real-time man-in-the-loop simulations are provided by this system which includes hybrid and analog computers. This system is used in aircraft design modification, pilot familiarization, handling qualities investigations, and accident investigations among other engineering studies. A simple but accurate simulator such as the GPES has many advantages in an aircraft testing environment over more complex systems with motion and visual cues. Author

N76-29298 Naval Air Development Center, Warminster, Pa. Air Vehicle Technology Dept.
A JOINT PILOT/LANDING OFFICER SIMULATION PERFORMED TO DETERMINE AIRCRAFT WAVE-OFF PERFORMANCE REQUIREMENTS
Ronald L. Nave *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 10 p refs (For availability see N76-29287 20-09)

A combined pilot/landing signal officer simulation was performed at the Naval Air Development Center in order to develop requirements for the wave-off performance of Naval aircraft. The simulator was also used to investigate the dynamic interaction between the pilot and landing signal officer. Thrust/weight ratio and wing loading were identified as being the most important aircraft parameters influencing wave-off performance. A wave-off performance requirement was developed which specified minimum values of aircraft normal acceleration as a function of trim airspeed and time after initiation of the wave-off maneuver. A minimum thrust/weight ratio of .4 and a maximum power approach wing loading of 90 lb/sq ft were recommended based on pilot opinion gathered in the simulation. In a separate LSO experiment it was determined that the landing signal officer could detect aircraft altitude errors during approach as small as 5 feet at 1/4 mile range. Author

N76-29299 *Naval Air Test Center, Patuxent River, Md.*
ON IMPROVING THE FLIGHT FIDELITY OF OPERATIONAL FLIGHT/WEAPON SYSTEM TRAINERS
Marie D. Hewett and R. Thomas Galloway *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 13 p refs (For availability see N76-29287 20-09)

A team approach utilizing the complementary talents and expertise of Naval test pilots, flight test engineers, computer specialists, and simulator specialists from various Naval field activities is described. The approach is effective in improving the flight fidelity of existing Operational Flight Trainers and Weapon System Trainers and in guiding contractors in providing the best fidelity possible in new flight simulators. Results obtained in several programs are presented. Author

N76-29300 Le Material Telephonique, Trappes (France).
RADAR LANDMASS SIMULATOR
Michel Dachery *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 8 p (For availability see N76-29287 20-09)

The radar landmass simulator is used at all levels in the training of pilots and radar navigators: basic training, conversion training, continuation and improver training, and navigation exercises at high and low altitudes. The simulator has an operational use from its ability to provide radar prediction maps. The principle and organization of this type of simulator, its qualities of flexibility and accuracy, and its applications are described. Author

N76-29301 Ecole Nationale Superieure de l'Aeronautique et de l'Espace, Toulouse (France)
SIMULATION OF A VISUAL AID SYSTEM USED FOR THE PILOTING OF HELICOPTERS IN FORMATION FLYING
J. H. Llareus, A. J. Fossard, M. Clique (Centre d'Etudes et de Recherches, Toulouse), and N. Imbert (Centre d'Etudes et de Recherches, Toulouse) *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 14 p refs In FRENCH (For availability see N76-29287 20-09)

Real time simulation of a system used to aid the piloting of a helicopter, permitting it to fly in formation in hazardous weather conditions is presented. The leader arranges the navigation paths, the crew plots the distance and level of the preceding helicopter with the aid of a radar detection system. The simulation introduces the requirement of a human pilot who, with the help of a micromanipulator, provides orders of cyclic paths, longitudinal and lateral, determining the evolutions of a helicopter crew stationed at a digital computer. Transl. by B.B.

N76-29302 Forschungsinstitut fuer Anthropotechnik, Meckenheim (West Germany).
THE INFLUENCE OF VISUAL EXPERIENCE AND DEGREE OF STYLIZATION ON HEIGHT AND DISTANCE JUDGEMENT IN AIRCRAFT APPROACH SCENES
Gert Doerfel *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 9 p refs (For availability see N76-29287 20-09)

The technical development of the visual system of a flight simulator is considered. The basic problem is to determine to what extent the external scene might be simplified and stylized, while still presenting enough of the required information to the pilot for the landing approach. Experimental results which help to establish the human engineering visual requirements for the visual simulator being developed are given. Author

N76-29303 Royal Aircraft Establishment, Bedford (England).
DIGITALLY GENERATED OUTSIDE WORLD DISPLAY OF LIGHTING PATTERN USED IN CONJUNCTION WITH AN AIRCRAFT SIMULATOR
J. C. Penwill *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 12 p refs (For availability see N76-29287 20-09)

The main features are described of a digitally generated outside world display along with its uses as part of a flight simulation facility to support research programs concerned with all weather operations. The picture presented to the pilot is a view of airfield approach and runway lights as seen at night. The view is collimated to infinity by the use of a simple, low cost, concave mirror and can be seen by all crew members on the fixed base cockpit. The basis of the system is a digital computer used to generate the perspective picture and a specially developed television camera using a frame sequential technique which, together with a modified monochrome projector, presents a color display to the pilot. The system provides a very cost effective simulation of low visibility conditions. Author

N76-29304 National Aerospace Lab., Amsterdam (Netherlands).
DESIGN AND PERFORMANCE OF THE FOUR-DEGREE-OF-FREEDOM MOTION SYSTEM OF THE NLR RESEARCH FLIGHT SIMULATOR
W. P. Koopmans and C. J. Jansen *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 11 p (For availability see N76-29287 20-09)

The motion system of the NRL research flight simulator with freedom of motion in heave, roll, pitch and yaw is described. To give good motion cues, smooth operation without any jerks is required. To this end specific hydraulic jacks were developed in which stick-slip phenomena are eliminated by introducing hydrostatic bearing between the moving piston and rod and the fixed cylinder, resulting in an acceleration threshold level below 0.01 g. A mathematical model was prepared to simulate and study the behavior of the hydraulic jacks. Results are given of measurements on single jacks and the complete system.

comprising acceleration noise and threshold level, dynamic response and performance diagrams. Because of the required oil pressure for the hydrostatic bearing, special procedures have to be followed to start and stop the operation of the system. A description is given of the principles of the safety system applied. Author

N76-29305 Cranfield Inst. of Technology (England). Dept. of Electronic and Control Engineering.
FEEL FORCE SYSTEM WITH AN INERTIA REDUCTION CAPABILITY
J. M. Lipscombe and D. J. G. Lewis. *In* AGARD Flight Simulation/Guidance Systems Simulation. Jun. 1976. 13 p. refs. (For availability see N76-29287 20-09)

The design, construction, and test of a single and twin stick feel force system is described. The systems have the usual variable feel characteristics of stiffness, damping, backlash, Coulomb friction and breakout force, and also a variable inertia, so that the effective inertia can be increased to more than the stick inertia, or reduced to a small proportion of the stick inertia. Parameter plane design techniques are applied to a high order mathematical model of the system, and a digital computer and visual display unit are used in interactive mode, to evaluate and plot the locus of the parameters of the system for any desired pole and zero locations on the s-plane. The performance of the model is then compared to the performance of the system under test. Author

N76-29306 Royal Aircraft Establishment, Bedford (England). Flight Systems Dept.
DEVELOPMENTS IN THE SIMULATION OF ATMOSPHERIC TURBULENCE
B. N. Tomlinson. *In* AGARD Flight Simulation/Guidance Systems Simulation. Jun. 1976. 14 p. refs. (For availability see N76-29287 20-09)

In ground-based simulation of aircraft flight, inclusion of atmospheric turbulence is essential to the successful evaluation of handling and ride qualities, and to the creation of a realistic subjective environment and representative pilot workload. A new model of atmospheric turbulence capable of generating time-histories which reproduce the essential discrete-gust and non-Gaussian features of turbulence is described. A principal aim of the model is to reproduce the quality of 'intermittency' identified in real atmospheric turbulence from the non-Gaussian distributions of velocity differences. Qualitatively, intermittency appears in a turbulence record as relatively isolated large changes in gust velocity embedded in a background of low activity. Comparison with flight measurements of atmospheric turbulence shows that power spectra, intermittency, and discrete gust content are accurately reproduced by the model. A parameter in the model enables intermittency to be controlled explicitly and matched to a variety of weather conditions and terrain. Experiments in a simulator have shown acceptance by pilots, but credible simulation of turbulence and its effects requires a high quality motion system. The model exists as a FORTRAN computer program and as an analogue hardware device. Although orginally concerned with 'pilot-in-the-loop' simulation, the model of turbulence described has relevance and application in other areas, such as certification trials of automatic landing equipment. Author

N76-29307 Technische Hogeschool, Delft (Netherlands).
SIMULATION OF PATCHY ATMOSPHERIC TURBULENCE, BASED ON MEASUREMENTS OF ACTUAL TURBULENCE
G. A. J. VanDeMoesdijk. *In* AGARD Flight Simulation/Guidance Systems Simulation. Jun. 1976. 14 p. refs. (For availability see N76-29287 20-09)

Pilot dissatisfaction with the characteristics of Gaussian simulated turbulence in flight simulation stimulated a research program to determine the relevant non-Gaussian aspects of actual atmospheric turbulence needed in a realistic turbulence simulation. A model describing the so-called patchy characteristics of atmospheric turbulence as sensed by the pilot is developed in which the degree of patchiness is defined in mathematical terms. Results of actual measurements of patchy characteristics analyzed in a method indicated by the model are compared to the model characteristics. Finally a digital simulation of real-time patchy turbulence velocities is presented. Author

N76-29308* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
INTERACTIVE COMPUTERIZED AIR COMBAT OPPONENT
Walter W. Hankins, III. *In* AGARD Flight Simulation/Guidance Systems Simulation. Jun. 1976. 9 p. (For availability see N76-29287 20-09)
CSCL 01C

A computer program developed to fly interactive one-on-one simulated air combat maneuvers against human pilots is described. The program which is called Adaptive Maneuvering Logic (AML), is being used in the National Aeronautics and Space Administration (NASA) Langley Research Center's Differential Maneuvering Simulator. The basic control logic evaluates the relative states of the two aircraft and reacts by choosing the best of several elemental maneuvers. Pilot comments and results obtained when the computer was flown against combat-qualified fighter pilots indicate that the program performs realistic maneuvers and offers a very competitive standard pilot. Author

N76-29309 McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.
ANALYSIS OF AIR-TO-AIR MISSILE REQUIREMENTS AND WEAPONS SYSTEMS EFFECTIVENESS IN AN AIR-COMBAT MANEUVERING ENVIRONMENT
D. L. Glosseking, J. H. Simpson, and J. W. Oestreich (NWC). *In* AGARD Flight Simulation/Guidance Systems Simulation. Jun. 1976. 9 p. (For availability see N76-29287 20-09)

A simulation developed to aid in air-to-air missile system requirements analysis, missile subsystem design, and weapon system effectiveness is described. The air combat analysis (ACA) simulation was developed in support of advanced Navy air-to-air missile programs to offer improved design techniques for use with highly effective missiles. The ACA simulation brings added realism into the design process by introducing the combat environment as an independent input into the simulation. The combat environment is introduced by using mock combat aircraft trajectories (hassle) or manned cockpit simulation trajectories as initial conditions for missile firings. To illustrate the capability of the ACA simulation, sample analyses are discussed which demonstrate requirements analysis, subsystem design, and weapon system effectiveness. The preprocessing of the aircraft hassle data and the initialization of the missile simulation, the detail involved in the simulation itself, and the postprocessing of the simulation data to give intercept performance, failure summary, and terminal geometry, are described. Author

N76-29310 LTV Aerospace Corp., Dallas, Tex.
AIR COMBAT MANEUVERING TRAINING IN A SIMULATOR
Charles W. Mashiur and Gregory J. Butler (Tactical Air Command, Langley AFB, Va.). *In* AGARD Flight Simulation/Guidance Systems Simulation. Jun. 1976. 10 p. refs. (For availability see N76-29287 20-09)

The Tactical Air Command Aerial Combat Engagement Simulation (TAC ACES) is an attempt to use a fixed-base visual fighter simulator as a training device to improve combat skills. The program is structured to optimize the amount of training with simulation state of the art, such that it will enhance the flight syllabus, not replace it. The trainer configuration was developed from a review of U.S. industry and National Aeronautics and Space Administration (NASA) facilities. Instructional facilities were added to permit comprehensive monitoring of simulated combat with appropriate controls. In addition, a system of automated grading is provided, summarizing each student's performance through the use of a digital, computer-produced printout and finally, to teach the course, a flight training syllabus was developed for the simulator. Pilot skills, safety and potential savings are tangible assets, of course, but the more subjective opinions of pilots and instructors are sampled too. Author

N76-29311 McDonnell Aircraft Co., St. Louis, Mo.
APPLICATION OF MANNED AIR COMBAT SIMULATION IN THE DEVELOPMENT OF FLIGHT CONTROL REQUIREMENTS FOR WEAPON DELIVERY
J. B. Berger, R. P. Meyer, and David L. Carleton (AFFDL). *In* AGARD Flight Simulation/Guidance Systems Simulation. Jun. 1976. 20 p. refs. (For availability see N76-29287 20-09)
(Contract F33615-73-C-3122)

Manned air combat simulations were conducted to develop requirements for tactical advanced aircraft/weapon systems in which precision tracking and weapon delivery are optimized through flight control system design. The objectives were to (1) develop analytical pilot models that relate weapon delivery accuracy to the entire integrated aircraft/displays/sight/geometry system for air-to-air and air-to-ground weapon delivery tasks, (2) validate and incorporate these pilot models into the

Terminal Aerial Weapon Delivery Simulation (TAWDS) digital computer program, and (3) use the TAWDS program to determine how aircraft flying qualities affect air-to-air gunnery, and air-to-ground gunnery and bombing weapon delivery effectiveness. The TAWDS program enables a digital simulation to be performed on various closed loop weapon delivery systems under manual tracking control for predicting and evaluating weapon delivery accuracy. Tracking performance results, acquired from analytical pilot simulations, are compared with those obtained from the manned simulations, and the Tactical Weapon Delivery (TWeaD) flight test development programs. These results indicate that the judicious use of the all digital analytical weapon delivery program in conjunction with manned simulation studies provides a very cost effective approach in designing, developing, and optimizing advanced aircraft/weapon delivery systems. The evaluation of flying qualities for piloted advanced aircraft, performing air-to-ground weapon delivery tasks in terms of weapon system effectiveness, is shown to be feasible for determining and establishing flight control requirements. Author

N76-29312 Litton Systems, Inc., Woodland Hills, Calif.
DEVELOPMENT OF A SYSTEM FOR SCORING SIMULATED BOMBING RUNS
J. S. Ausman and F. J. Hellings (6585th Test Group) *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 19 p ref (For availability see N76-29287 20-09)

A Bomb Scoring System (BSS) to be used in evaluating radar bombing capabilities of F-111 and A6 aircraft was developed. The BSS consists of an inertial navigation system updated with precision range and range-rate measurements to a set of 2 to 4 ground transponders placed in close proximity to the target. A pod contains the airborne equipment (inertial navigation system and range/range-rate interrogator) and attaches to a standard weapon station on the aircraft. While the aircraft makes its (simulated) bombing run, the BSS pod continually monitors its position and velocity relative to the target. The aircraft's weapon delivery system sends its release pulse to the weapon station which holds the BSS pod. Subsequently, the computer predicts where the bomb would have landed if one had actually been released. Bomb impacts and other pertinent data are stored in memory for immediate readout when the airplane returns to base. Author

N76-29313 Dornier Werke G.m.b.H., Friedrichshafen (West Germany)
WASI: WEAPON AIMING TRAINING SIMULATOR INSTALLATION
Uwe Schulz *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 10 p (For availability see N76-29287 20-09)

An inflight training system for the squadron training of pilots is defined. The system provides realistic training in ground attack with simulated bombs, cannons, and rockets on a range or in tactical settings without the restrictions normally imposed by safety considerations, shortage of training ammunition, lack of availability of live firing ranges, etc. The system is self-contained within a standard modified drop-tank (WASI-POD), with the absolute minimum of mechanical and electrical interfaces. It provides an immediate indication to the pilot of miss distance and direction, while the most important parameters of the action are recorded on tape for subsequent play-back and analysis on the ground equipment. The WASI is suitable for basic training, refresher training, as well as continuous realistic tactical training. A detailed description of the system is given including some aspects concerning the future applications in the training for the air-air firing and dog fights. Author

N76-29314 Royal Netherlands Air Force, The Hague.
PROFICIENCY TRAINING OF PILOTS AND CONTROLLERS PARTICIPATING IN RNLAF MISSIONS BY THE USE OF A SIMULATOR
J. Alwon *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 4 p (For availability see N76-29287 20-09)

Simultaneous training of pilots and mission controllers by coupling a ground-based simulator with a radar control center is reported. The flight training simulator is briefly described. Results of pilot training and mission controller simulation are given. J.M.S.

N76-29315 Ministry of Defence, London (England)
RESEARCH INTO THE TRAINING EFFECTIVENESS OF A FULL MISSION FLIGHT SIMULATOR
Graham Shepherd *In* AGARD Flight Simulation/Guidance Systems Simulation Jun. 1976 17 p (For availability see N76-29287 20-09)

The training effectiveness of flight simulators is examined. An objective measure of aircrew performance is developed for use in long term streaming trails. Interim results for a number of flight profiles indicate the feasibility of deriving an objective measure of performance from recorded flight data and instructor assessments using linear multiple regression techniques. Author

N76-30236# Advisory Group for Aerospace Research and Development, Paris (France).
TECHNICAL EVALUATION REPORT ON THE FLUID DYNAMICS PANEL SYMPOSIUM ON WIND TUNNEL DESIGN AND TESTING TECHNIQUES
B. H. Goethert Aug. 1976 23 p Held at London, Oct. 1975 (AGARD-AR-97, AGARD-CP-174, ISBN-92-835-1222-7) Avail. NTIS

Advanced wind tunnel systems are discussed with emphasis on the impact of the cryogenic concept for high performance transonic wind tunnels. Topics covered include: cryogenic operation, adjustable walls, magnetic suspensions, and laser instrumentation. Author

N77-11070# Advisory Group for Aerospace Research and Development, Paris (France).
ON THE FLOW QUALITY NECESSARY FOR THE LARGE EUROPEAN HIGH-REYNOLDS-NUMBER TRANSONIC WINDTUNNEL LEHRT
J. P. Hartzuiker (National Aero- and Astronautical Res. Inst., Amsterdam), P. G. Pugh (Royal Aircraft Estab., Bedford, Engl.), W. Lorenz-Meyer (DFVLR, Goettingen, Germany), G. E. Fasso (ONERA, Chatillon sous Bagneux, France), and D. Kuechemann, ed. (Royal Aircraft Estab., Farnborough, Engl.) Mar. 1976 31 p refs
(AGARD-R-644; ISBN-92-835-1214-6) Avail: NTIS HC A03/MF A01

The Large European High Reynolds Number Transonic Windtunnel (LEHRT) is meant to provide aerodynamic data at high Reynolds numbers of high standard in a relatively short running time (dictated by economic reasons). This implies that the flow quality in LEHRT has to be excellent. Quantitative requirements for turbulence level as well as for pressure fluctuations have been developed in this report. Author

X77-72035 Advisory Group for Aerospace Research and Development, Paris (France)
RANGE INSTRUMENTATION, WEAPONS SYSTEMS TESTING AND RELATED TECHNIQUES
Mar. 1976 32 p
(AGARD-AG-219-Suppl, AGARDograph-219-Suppl) Avail: Advisory Group for Aerospace Research and Development, Paris, France NATO-Classified report

NOTICE: Available to U.S. Government Agencies

A classified supplement to AGARDograph 219 is presented. The two papers were prepared at the request of the Guidance and Control Panel of AGARD-NATO. The main unclassified AGARDograph contains 20 papers on weapon systems, test ranges, instruments, and test facilities. Author

20 SPACECRAFT PROPULSION AND POWER

Includes main propulsion systems and components, e.g., rocket engines; and spacecraft auxiliary power sources. For related information see also *07 Aircraft Propulsion and Power*, *28 Propellants and Fuels*, and *44 Energy Production and Conversion*

N76-24840# Advisory Group for Aerospace Research and Development, Paris (France).
RADIATION COOLING OF THRUST NOZZLES
J. J. Bernard (Paris Univ.) and J. Genot (ONERA) Mar. 1975 81 p refs
(AGARD-AG-184; AGARDograph-184) Avail: NTIS HC $4.75 CSCL 21H

Various heat transfers by radiation occur on the wall of a propulsion system, and the calculation of such heat transfers in axisymmetrical thrust nozzles is presented. The functions for exchanges between isothermal lines on the surface of revolution or plane cross-sections slightly inclined to the parallel lines are also shown. Numerical results are given in the form of universal functions of the geometrical parameters for the meridian. The diagrammatic configurations for the most usual type of nozzles, and the directly usable values of the transfer functions are quoted. Author

X77-72037 Advisory Group for Aerospace Research and Development, Paris (France).
SMALL SOLID PROPELLANT ROCKETS FOR FIELD USE
Oct. 1976 156 p Meeting held at Porz-Wahn, West Germany, 17-19 May 1976
(AGARD-CP-194-Suppl) Avail: Advisory Group for Aerospace Research and Development, Paris, France
NATO-Confidential report
NOTICE: Available to U.S. Government Agencies

The papers are divided into five sessions: requirements and systems specifications, development of small rocket motors, thrust vectoring and control, high performance solid propellants, qualification, testing and environmental effects Author

23 CHEMISTRY AND MATERIALS (GENERAL)

Includes biochemistry and organic chemistry

N76-11244# Advisory Group for Aerospace Research and Development, Paris (France).
HIGH TEMPERATURE CORROSION OF AEROSPACE ALLOYS
John F. Stringer (Liverpool Univ.) Aug. 1975 607 p refs (AGARD-AG-200; AGARDograph-200) Avail: NTIS HC $16.25

Information contained in various places in the technical literature, in government and other similar reports, and information not yet published was gathered for inclusion in a comprehensive publication. Summary information is presented on oxidation rates, diffusion, reaction kinetics, engineering information on practical alloys, and tests under simulated service conditions. Data on phase diagrams, diffusion information and thermodynamic information are included along with data on superalloys and refractory metals. For individual titles, see N76-11245 through N76-11250.

N76-11245 Advisory Group for Aerospace Research and Development, Paris (France).
BASIC DATA
In its High Temperature Corrosion of Aerospace Alloys Aug. 1975 p 1-26 refs (For availability see N76-11244 02-23)

Data, listed in tabular form for metal oxides and spinels, is presented. Specifically covered in the data are: (1) crystal structure; (2) melting and boiling points; (3) equilibrium pressures (ATM); (4) mechanical properties; (5) color descriptions, and (6) reaction kinetics. Also included is phase diagram information for metal-oxygen systems, metal sulphur systems, and systems involving oxides, chlorides, and sulphates. J.R.T.

N76-11246 Advisory Group for Aerospace Research and Development, Paris (France).
PREDOMINANCE DIAGRAMS
In its High Temperature Corrosion of Aerospace Alloys Aug. 1975 p 27-36 refs (For availability see N76-11244 02-23)

A number of predominance phase diagrams which show thermochemical information relating to the stability of phases in a convenient graphical representation are presented. Solid and liquid phases are assumed to be at unit activity. Author

N76-11247 Advisory Group for Aerospace Research and Development, Paris (France).
CONSTITUTION OF THE ATMOSPHERE IN THE GAS TURBINE
In its High Temperature Corrosion of Aerospace Alloys Aug. 1975 p 37-39 (For availability see N76-11244 02-23)

A typical marine diesel fuel was burned in the turbine. The SO3/SO2 ratio as a function of the fuel-to-air ratio (FAR) is shown; the air inlet temperature to the combustor was assumed to be 600 F. The equilibrium flame temperature, as a function of the FAR, for air inlet temperatures of 400 to 600 F is shown. The equilibrium composition of the flame gas, as a function of the FAR, is given. Actual analyses of the turbine exhausts indicated that the SO3 content was much less than that expected. The relative distribution of sulphur and sodium among their species as a function of temperature for the gas conditions is given. J.R.T.

N76-11248 Advisory Group for Aerospace Research and Development, Paris (France).
VAPOR PRESSURE AND CONDENSATION OF SODIUM SULPHATE
In its High Temperature Corrosion of Aerospace Alloys refs (For availability see N76-11244 02-23)

The corrosion deposits of sodium sulphate that occur on gas turbine metal alloy parts were studied. The chemical reactions occurring during high temperature corrosion are examined, and results are given for chemical analyses of various alloy specimens which were exposed to synthetic sea salt concentrations. Also included are diffusion data for various alloy combinations and the methods used to study high temperature corrosion for each alloy combination. The diffusing elements for different metallic oxides are also given. J.R.T.

N76-11249 Advisory Group for Aerospace Research and Development, Paris (France).
OXIDATION AND HOT CORROSION OF COMMERCIAL SUPERALLOYS
In its High Temperature Corrosion of Aerospace Alloys Aug. 1975 p 117-462 refs (For availability see N76-11244 02-23)

A summary of information on the oxidation and corrosion of 52 commercial nickel and cobalt base superalloys is presented. The composition of each alloy is given. The effects of the combustion of various sulphur-containing fuels and salt spray on alloy corrosion is examined. The results of weight analyses and chemical analyses of oxidized alloys are given. Photomicrographs of hot corrosion on turbine blades are shown. Results of thermal cycling tests are given. J.R.T.

N76-11250 Advisory Group for Aerospace Research and Development, Paris (France).
THE REFRACTORY METALS
In its High Temperature Corrosion of Aerospace Alloys Aug. 1975 p 463-602 refs (For availability see N76-11244 02-23)

The oxidation rates of the refractory metals, tantalum, niobium, molybdenum, and tungsten are examined. The composition of alloys of these metals is listed. The resistance of the alloys to oxidation at different temperatures, oxygen pressures, and time exposures is given. Weight changes, color changes, oxide scale thicknesses, and some mechanical properties of the alloys are given. The oxidation resistance of various alloy combinations is examined. The physical and chemical properties of molybdates are listed. J.R.T.

24 COMPOSITE MATERIALS

Includes laminates

N75-11034# Advisory Group for Aerospace Research and Development, Paris (France).
SPECIALISTS MEETING ON DIRECTIONALLY SOLIDIFIED IN-SITU COMPOSITES
E. R. Thompson, ed. and P. R. Sahm, ed. Aug. 1974 163 p refs Presented at the 38th Meeting of the Struct. and Mater. Panel, Washington, D. C., 23-24 Apr. 1974
(AGARD-CP-156) Avail: NTIS HC $6.25

Directionally solidified in-situ eutectic alloy composites and their use in fabricating aircraft parts were studied. Data cover microstructure, mechanical properties, and high temperature stability. Turbine blade design and fabrication and improvements observed in engines constructed from the composites are discussed. For individual titles, see N75-11035 through N75-11047.

N75-11035 General Electric Co., Cincinnati, Ohio.
REQUIREMENTS FOR AND CHARACTERISTICS DEMANDED OF HIGH TEMPERATURE GAS TURBINE COMPONENTS
L. P. Jahnke and C. A. Bruch *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 3-12 refs (For availability see N75-11034 02-24)

Composite structures consisting of high strength fibers or plates in ductile matrices with outstanding high temperature properties are achievable in directionally solidified eutectics. This new class of materials represents a major innovation in gas turbine blade technology. The advantages and limitations of the two more promising eutectic systems and the relationship of these properties to turbine blade design is discussed. Innovations in design and further property improvements will be required to successfully exploit these materials in engine hardware. It is concluded that the payoff offered by this technology fully justifies a major investment of resources to achieve a practical system.
Author

N75-11036 Toronto Univ. (Ontario). Dept. of Metallurgy and Materials Science.
THE STRUCTURE AND THERMAL STABILITY OF EUTECTIC ALLOYS
G. C. Weatherly *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 13-20 refs (For availability see N75-11034 02-24)

The factors that control the as-grown morphology, crystallography and thermal stability of uni-directionally solidified eutectic alloys are briefly reviewed. The crystallographic orientation relationships that are usually found in UDG alloys are considered only in their bearing on the thermal stability problem. The stability of rod morphologies and the possible coarsening mechanisms in faulted and perfect arrays of parallel rods are discussed for the extreme cases of diffusion and interface-controlled reactions. The coarsening mechanisms in lamellar eutectics are simpler and are controlled by the faults grown-in during solidification. The roles of lamellar terminations, sub-grains and discontinuous coarsening at migrating grain boundaries are considered. Finally, the problems encountered in phase stability of carbide reinforced nickel based superalloys during hot tensile deformation, are reviewed.
Author

N75-11037 Drexel Univ., Philadelphia, Pa. Dept. of Metallurgy Engineering.
THE MECHANICAL METALLURGY OF DIRECTIONALLY SOLIDIFIED COMPOSITES: STRENGTHENING FUNDAMENTALS, TENSILE, CREEP, FATIGUE AND TOUGHNESS PROPERTIES
Alan Lawley *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 21-33 refs Sponsored by the Navy (For availability see N75-11034 02-24)

A fundamental basis for the interpretation and prediction of the mechanical behavior of in-situ composites is developed by considering possible strengthening mechanisms and associated models. Experimental property data and structural observations are then discussed in light of these mechanisms. The general features of tensile, creep, fatigue, and impact loading are characterized and behavior interpreted from the viewpoint of structure. Where possible, observed and predicted response of in-situ composites are compared, as is the behavior of comparable synthetic composites. The various structure-mechanical property correlations allow for a rationalization of the major advantages and disadvantages of in-situ composites vis a vis synthetic composites and other advanced structural materials.
Author

N75-11038 Domaine Univ., Saint Martin d'Heres (France). Lab. de Thermodynamique et Physico-Chimie Metallurgiques
ORIENTATION SOLIDIFICATION OF BIPHASE COMPOSITES: CASE OF MULTICONSTITUENT SYSTEMS, LAMINAR AND POINT DEFECT PHASES [SOLIDIFICATION ORIENTEE DE COMPOSITES BIPHASE: CAS DES SYSTEMES MULTICONSTITUES, FAUTES LAMELLAIRES ET JOINTS DE PHASES]
Francis Durand *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 41-55 refs In FRENCH (For availability see N75-11034 02-24)

An evaluation was made of the solidification of biphase composites as a function of constituent alloys, and lamellar faults in relation to the structure in point phases. Data are included on theoretical ideas of equilibrium diagram limitations, solid composition analysis, and instability of the solid/liquid wall. Observations made of different mutual orientations, dislocations, and point orientation are included.
Transl. by E.H.W.

N75-11039 Michigan Technological Univ., Houghton. Dept. of Metallurgical Engineering.
CRYSTAL GROWTH METHODS FOR THE PRODUCTION OF ALIGNED COMPOSITES
A. Hellawell *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 57-66 refs (For availability see N75-11034 02-24)

Reactions which are suitable for the production of aligned composite materials are listed and their applications briefly considered. The requirements of a growth technique and a product are outlined as they affect thermal stability and control, directionality and perfection of structure, composition and orientation control and problems of contamination. The advantages of various techniques are then discussed in terms of their useful application to the control of different phase transformations.
Author

N75-11040 TRW, Inc., Cleveland, Ohio.
FORMING USEFUL DIRECTIONALLY SOLIDIFIED COMPOSITE SHAPES
J. A. Alexander and L. D. Graham *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 67-78 (For availability see N75-11034 02-24)

A selective review was conducted of available information relating to the fabrication of shapes from directionally solidified composites. The review is based upon information contained in the open literature in government contract reports. The summation of what was reported is augmented by discussions on what might be done to fabricate shapes from directionally solidified composites. An extensive study was made of the mechanical properties of the composites, and the potential for performance improvement in engine constructed from the materials.
Author

N75-11041 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (West Germany).
EUTECTIC PHASE EQUILIBRIA
E. Blank *In* AGARD Specialists Meeting Directionally Solidified In-Situ Composites Aug. 1974 p 81-92 refs (For availability see N75-11034 02-24)

Computational and experimental paths to the determination of phase diagrams are discussed which are not in common use: computer calculation, use of directional solidification, and use of diffusion techniques. Computer calculation of phase diagrams at present is confined to ternary systems. Although calculated phase boundaries often agree well with experimental values, the influence of the metallic solution models on the calculated results is not well understood. Generally, thermochemical data of the limiting binary systems are sufficient for the calculation of the ternary diagram. Ternary phases cannot be predicted a priori. Usually, they are limited to lines of specific stoichiometry. To lower costs computation should be carried out by a few specialists. Experimentally, the influence of all alloying elements on the shape of the liquidus and solidus surfaces may be allowed for by a directional solidification technique. Some diffusion techniques appropriate to solid state reactions are elucidated.
Author

N75-11042* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

DIRECTIONALLY SOLIDIFIED COMPOSITE SYSTEMS UNDER EVALUATION

Richard L. Ashbrook *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 93-115 refs (For availability see N75-11034 02-24)

Various types of high temperature in-situ composites were reviewed and attempts were made to determine which ones offer the most potential for future development. Some of the systems that were investigated according to the ductility of the component phases were categorized. The categories range from ductile-ductile to brittle-brittle. Examples in each category are considered with special emphasis on systems which look attractive for use in gas turbine engines. Data also touch on microstructure, mechanical properties, and process problems. Author

N75-11043 Pratt and Whitney Aircraft, East Hartford, Conn. Materials Engineering and Research Lab.

THERMAL STABILITY OF DIRECTIONALLY-SOLIDIFIED COMPOSITES

M. Gell *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 117-124 refs (For availability see N75-11034 02-24)

Microstructural and mechanical property stability under static and cyclic temperature exposure are two important requirements for turbine airfoil materials in advanced gas turbine engines. Under thermal cycling conditions, significant microstructural instability and mechanical property degradation was observed in a number of TaC-reinforced alloys, while the delta-reinforced alloys have exhibited greater stability. The physical and chemical properties of the eutectic promoting microstructural instability and the testing variables defining the severity of the thermal cycle are discussed. Author

N75-11044 Liverpool Univ. (England). Dept. of Metallurgy and Materials Science.

OXIDATION, HOT-CORROSION AND PROTECTION OF DIRECTIONALLY SOLIDIFIED EUTECTIC ALLOYS

John Stringer *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 131-140 refs (For availability see N75-11034 02-24)

The high temperature oxidation and corrosion behavior of directionally solidified eutectic alloys are discussed in general terms, and some simple models are presented of possible effects. Illustrations of these effects in real situations are shown. Author

N75-11045 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

PROSPECT OF DIRECTIONALLY SOLIDIFIED EUTECTIC SUPERALLOYS

Herve Bibring *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 141-155 refs In FRENCH; ENGLISH summary (For availability see N75-11034 02-24)

An evaluation was made of the possibilities offered by the utilization of more fully developed high temperature DS composites as aircraft blade materials. Two families of these materials are emphasized, namely: the lamellar intermetallic eutectics of the Ni3Al-Ni3Nb type recently broadened to the quaternary composition systems Co/Ni3Al-Ni3Nb with Cr additions, and the COTAC family of multicomponent fiber composites whose complex superalloy matrices are reinforced by in-situ aligned monocarbide whiskers. When compared to the best present day superalloys, both these families show an important gain in operational temperatures. Weak points, particularly noticeable in some of these new materials, such as lack of ductility poor corrosion resistance, and thermal cycling problems should be improved. Author

N75-11046 National Gas Turbine Establishment, Pyestock (England). Materials Science Dept.

COMPONENT DESIGN WITH DIRECTIONALLY SOLIDIFIED COMPOSITES

M. G. Cockcroft and P. H. Cowley *In* AGARD Specialists Meeting on Directionally Solidified In-Situ Composites Aug. 1974 p 157-162 refs (For availability see N75-11034 02-24)

Directionally solidified eutectic materials (in situ composites) are examined in general terms from the point of view of their use in turbine blades for aero gas turbines. The special characteristics that must be taken into account in the design of blades are outlined and attention is drawn to areas where further information is required. It is concluded that the materials might readily be used for uncooled or lightly cooled blades but production problems will need to be overcome before they are used in heavily-cooled blades. Author

N75-11047 Advisory Group for Aerospace Research and Development, Paris (France).

MEETING SUMMARY AND OUTLOOK

E. R. Thompson, P. Suhm, and M. C. Flemings *In its* Specialists Meeting Directionally Solidified In-Situ Composites Aug. 1974 p 165-166 (For availability see N75-11034 02-24)

A summary is made of the accomplishments, conclusions, and problem areas encountered in the study of composites used in turbine blade construction. The systems considered include the following families: (1) Co-Cr7C3, (2) Co-TaC, (3) Ni/Ni3Al-TaC, (4) Ni3Al-Ni3Cb. E.H.W.

N75-13034# Advisory Group for Aerospace Research and Development, Paris (France).

AVIONIC RADOME MATERIALS

R. H. Cary, ed. (Roy Radar Est.) Oct. 1974 243 p refs (AGARD-AR-75) Avail: NTIS HC $7.50

The electrical, mechanical, and thermal properties of materials are discussed for the wall, core, finish, and coating for radomes. These properties are presented for the following composite materials: polyesters, epoxy resins, polymides, silicone resins, and phenolic resins. F.O.S.

N75-15747# Advisory Group for Aerospace Research and Development, Paris (France).

TECHNICAL EVALUATION REPORT ON AGARD SPECIALISTS MEETING ON DIRECTIONALLY SOLIDIFIED IN-SITU COMPOSITES

E. R. Thompson (United Aircraft Corp., East Hartford, Conn.) Dec. 1974 9 p

(AGARD-AR-76) Avail: NTIS HC $3.25

Proceedings from this conference are reported as held to review the state of the art, identify gaps and difficulties in present knowledge and progress, and indicate approaches and goals for future efforts. The present state of developments of in-situ composites is evaluated, and several recommendations concerning directions of work considered necessary in this rapidly developing new field are presented. Increasing the temperature of turbine inlet gas in aircraft gas turbine engines promises to improve engine performance and economy. Directionally solidified eutectic alloys give indication of achieving high temperature strengths far exceeding those of the best current superalloys. Author

N75-23698# Advisory Group for Aerospace Research and Development, Paris (France).

SPECIALISTS MEETING ON FAILURE MODES OF COMPOSITE MATERIALS WITH ORGANIC MATRICES AND THEIR CONSEQUENCES ON DESIGN

Mar. 1975 162 p refs In ENGLISH; partly in FRENCH Presented at 39th Meeting of the Struct. and Mater. Panel, Munich, 13-19 Oct. 1974

(AGARD-CP-163) Avail: NTIS HC $6.25

The aerospace industry's constant search for structural materials which offer advantages of high strength, low density, high fatigue endurance and adaptability to the intended function, is reported. The understanding of the failure mechanism of an isotropic material like a metal, where fracture is essentially a single parameter problem, is still a difficult subject, but the quantitative analysis of the failure of anisotropic composites, where many parameters are involved, becomes infinitely more complex. This conference proceedings contains the text of twelve papers given at the AGARD Specialists Meeting organized to consider the problem. The latest developments in the study of failure of composite materials is contained in these papers. Included are analyses of the failure modes of these materials and presentation of methods to predict such failures. Included also are methodology and equipment for studying failures of composite materials, methods of testing composites to detect incipient failures, and suggestions of design criteria for the use of composites in order to achieve a safe-life design procedure for structures and components constructed of fiber-reinforced composite materials. For individual titles, see N75-23699 through N75-23710

N75-23699 Nottingham Univ. (England). Dept. of Mechanical Engineering.

PREDICTION OF STATIC AND FATIGUE DAMAGE AND CRACK PROPAGATION IN COMPOSITE MATERIALS

M J. Owen and P T Bishop *In* AGARD Specialists Meeting on Failure Modes of Composite Mater With Organic Matrices and Their Consequences on Design Mar 1975 12 p refs (For availability see N75-23698 15-24)

Finite element stress analysis was used to predict the stresses around a hole in finite width plates fabricated from various glass-fiber reinforced plastics The results were used to predict the initiation of damage at holes under static and fatigue loading and showed that they act as almost fully effective stress concentrators This approach leaves a number of important problems unsolved Firstly, for some materials there appears to be a substantial adverse size effect Secondly, in the life range from 1,000 to 1 million cycles the fatigue curve is nearly straight and attempts to extrapolate to long lives lead to the prediction of zero safe stress amplitude at finite lives Thirdly, the onset of transverse fiber damage is often an unacceptably severe criterion. Preliminary work on two of the GRP materials has shown that size effects can be represented through a fracture toughness approach and the problems of extrapolation to long lives and damage tolerance can be dealt with by means of a crack growth law (1) based on stress intensity factor range. Author

N75-23700 Washington Univ., St Louis, Mo.
FAILURE CRITERIA TO FRACTURE MODE ANALYSIS OF COMPOSITE LAMINATES
Edward M. Wu *In* AGARD Specialists Meeting on Failure Modes of Composite Mater With Organic Matrices and Their Consequences on Design Mar. 1975 11 p refs (For availability see N75-23698 15-24)
(Contract F33615-72-C-1514; Grant AF-AFOSR-74-2687)

Quantitative understanding of the parameters which control composite fracture is imperative to the implementation of fail safe design and inspection of critical load bearing structures. For isotropic materials, fracture is essentially controlled by a single parameter, e g , the fracture toughness or the stress intensity factor. This one dimensional nature lends itself to experimental quantification However, for anisotropic composites there are at least seven primary controlling parameters. (1) crack length; (2) crack orientation with respect to material axis of anisotropy, (3) nature of applied combined stresses, (4) lamination geometry, (5) deformational and strength responses of the constituent lamina, (6) three kinematically admissible modes of crack extension and (7) crack trajectory Because of this large number of parameters, experimental quantification by systematic permutation of the parameters must be realistically viewed as intractable This paper presents an analytical method of reducing these parameters from seven to two and furnishes experimental observations which lend support to the theoretical model Author

N75-23701 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (West Germany)
AN EXPERIMENTAL STUDY TO DETERMINE FAILURE ENVELOPE OF COMPOSITE MATERIALS WITH TUBULAR SPECIMENS UNDER COMBINED LOADS AND COMPARISON BETWEEN SEVERAL CLASSICAL CRITERIA
U Huetter, H Schelling, and H Krauss *In* AGARD Specialists Meeting on Failure Modes of Composite Mater With Organic Matrices and Their Consequences on Design Mar 1975 11 p refs (For availability see N75-23698 15-24)

For conventional isotropic materials failure hypotheses are known, which yield comparative failure stresses for combined load conditions. Such failure hypotheses may be described in three-dimensional failure envelopes, both, experimentally and analytically For fiber-reinforced composites, with the defined layerwise orthotropy of elastical and mechanical properties, a number of analytical approaches to failure hypotheses are known In order to determine these failure envelopes of fiber reinforced materials experimentally, a testing equipment was set up Using tubular specimens it was possible to find out the critical failure limits under general in-plane stress This report describes the installations required, the testing schedule, manufacturing and structural design of the specimens as well as the results found by extensive series of experiments. These results are compared with theoretical values of failure hypotheses available. Author

N75-23702 Institut Superieur des Materiaux et de la Construction Mecanique, Saint-Ouen (France) Lab de Rheologie
INELASTIC BEHAVIOUR OF COMPOSITES (PLASTIC PREDICTION BY LIMIT ANALYSIS) [ETUDES CRITIQUES DE DIVERS CRITERES DE PLASTICITE APPLICABLES AUX MATERIAUX COMPOSITES]
D Lenizerhy and T Vihn *In* AGARD Specialists Meeting on Failure Modes of Composite Mater With Organic Matrices and Their Consequences on Design Mar 1975 20 p refs In FRENCH (For availability see N75-23698 15-24)

The use of mathematical theories to study plastic properties, limit criteria, and anistropic yield in metal composites was examined Transl by E H W

N75-23703 Dornier Werke G m b H , Friedrichshafen (West Germany)
PRACTICAL FINITE ELEMENT METHOD OF FAILURE PREDICTION FOR COMPOSITE MATERIAL STRUCTURES
E Henze and S Roth *In* AGARD Specialists Meeting on Failure Modes of Composite Mater. With Organic Matrices and Their Consequences on Design Mar 1975 11 p refs (For availability see N75-23698 15-24)

A dimensioning procedure for anisotropic structures with the same resources already used to calculate and measure isotropic structures is examined The available means of calculation and measurements are the finite element method and the strain gage technique The necessary input data for the finite element method are: the elastic constants of the unidirectional lamina, the fiber orientation to a basic system and the contents of the different layers, characterized by the elastic constants and fiber angle, in the whole laminate The output of the used finite element program are the stresses in each lamina of the whole laminate in any structure These stresses are compared in a failure criteria with maximum stresses measured by simple test specimens The comparison of calculation and tests of several different specimens, using the procedure described, are presented Author

N75-23704 Centre d'Etude des Matiems Plastiques, Paris (France).
INFLUENCE OF FABRICATION PARAMETERS ON THE RUPTURE OF GLASS FIBER REINFORCED PLASTICS [INFLUENCE DES PARAMETRES DE FABRICATION SUR LA RUPTURE DES PLASTIQUES REINFORCES PAR DES FIBRES DE VERRE]
J Pabiot *In* AGARD Specialists Meeting on Failure Modes of Composite Mater. With Organic Matrices and Their Consequences on Design Mar. 1975 11 p refs In FRENCH (For availability see N75-23698 15-24)

A qualitative and quantative analysis was made of the marcoscopic rupture mechanism in glass fiber epoxy composites Measurements were made of rupture characteristics under tensile and bending stress in the orthotropic direction.
Transl. by E.H.W.

N75-23705 Technische Univ., Berlin (West Germany).
STRESS AND STRENGTH ANALYSIS OF REINFORCED PLASTIC WITH HOLES. CONSEQUENCES ON DESIGN
J. Wiedemann, H. Griese, and M. Glahn *In* AGARD Specialists Meeting on Failure Modes of Composite Mater. With Organic Matrices and Their Consequences on Design Mar. 1975 11 p refs (For availability see N75-23698 15-24)

Composites with cutouts strain distributions in biaxial reinforced specimens were measured and calculated according to the elastic theory. The tangential stress at the edge was compared with the orthotropic strength of the material. Thus failure position and ultimate load could be estimated. To improve strength, various possibilities are proposed: around holes, the woven reinforcement can be widened without cutting fibers, medium sized holes can be reinforced by patches, large cutouts should be shaped in a neutralizing way and stiffened by rovings. If patches are applied, failure occurs at the hole or in front of the patch or by delaminating Patches with elliptical shape prove advantageous for unidirectional loading according to theoretical and empirical investigations. In case of biaxial loading, a round neutralizing patch can be recommended. With respect to this case, calculations were made for isotropic and orthotropic materials. Also shear stiffness and stress of the adhesive are considered. Author

N75-23706 Royal Aircraft Establishment, Farnborough (England). Strength and Fracture Section.
FRACTURE BEHAVIOUR AND RESIDUAL STRENGTH OF CARBON FIBRE COMPOSITES SUBJECTED TO IMPACT LOADS
G. Dorey *In* AGARD Specialists Meeting on Failure Models of Composite Mater. With Organic Matrices and Their Consequences on Design Mar. 1975 12 p refs (For availability see N75-23698 15-24)

Carbon fiber reinforced plastic (CFRP) has properties such as high specific strength and stiffness which are attractive for

aerospace applications. However, it can be susceptible to impact damage at relatively low incident energies. Brittle fibers in a brittle matrix can absorb appreciable amounts of energy only by fracture processes. This paper describes a variety of such fracture processes by which CFRP laminates can fail under impact conditions. Which failure mode occurs in a particular situation is discussed in terms of material properties, component geometry and the kind of loading. Of particular interest to the designer are residual strengths and stiffnesses after impact and typical ... are illustrated for CFRP laminates subjected to dropweight and ball gun impact, from subcritical energies up to complete penetration. Material modifications, aimed at minimizing certain types of impact damage are described and examples given, such as hybrid composites and modified fiber arrangements, which show promise of improved impact resistance. Author

N75-23707 IIT Research Inst., Chicago, Ill. Stress Analysis Section.

OPTICAL METHODS FOR TESTING COMPOSITE MATERIALS

I. M. Daniel *In* AGARD Specialists Meeting on Failure Modes of Composite Mater. With Organic Matrices and Their Consequences on Design Mar. 1975 20 p refs (For availability see N75-23698 15-24)

Optical stress analysis techniques and their application to the study of deformation and fracture of composite materials are described and discussed. These include photoelastic coatings, moire grids, holographic interferometry, and liquid crystals. Photoelastic coatings are used to determine full-field surface strain distributions, strain concentrations around cracks and other discontinuities, and initiation, mode and propagation of fracture. Moire techniques yield full-field displacement and strain distributions. They have been applied to the detection of crack propagation and its associated failure modes, the determination of strain concentrations and the study of the interlaminar shear edge effect. The sensitivity of the method can be greatly enhanced by using fringe multiplication techniques. Holographic interferometry is most suitable for determining out-of-plane deformations. It is particularly useful in the study of flexure of plates, modes and amplitudes of vibration, and failure modes resulting in out-of-plane deformations, such as delaminations. The high sensitivity of liquid crystals to heat and their property of emitting visible radiation make them suitable for detecting local delaminations and fatigue fractures. All these techniques have different advantages and limitations. The selection of any one or more of these depends on each particular application. Author

N75-23708 Commissariat a l'Energie Atomique, Toulouse (France).

POSSIBLE UTILIZATION OF ELECTRON SCAN MICROSCOPE FOR THE STUDY OF COMPOSITE MATERIALS WITH ORGANIC MATRIX [POSSIBILITIES D'UTILISATION DU MICROSCOPE ELECTRONIQUE A BALAYGE POUR L'ETUDE DES MATERIAUX COMPOSITES A MATRICE ORGANIQUE]

J. Auvinet and J. Rouchon *In* AGARD Specialists Meeting on Failure Modes of Composite Mater. With Organic Matrices an Their Consequences on Design Mar. 1975 5 p refs In FRENCH (For availability see N75-23698 15-24)

The use of a scanning electron microscope to study rupture in metal matrix composites was discussed. Particular attention was given to evaluating the quality of composite impregnation under vacuum and fiber-matrix interfaces. The possibility of qualitative examining fiber corrosion in aged composites was discussed along with surface damage. Transl. by E.H.W.

N75-23709 Messerschmitt-Boelkow G m.b.H., Ottobrunn (West Germany).

DESIGN OF COMPOSITE STRUCTURE WITH RESPECT TO AVOID CRACK PROPAGATION

K Brunsche *In* AGARD Specialists Meeting on Failure Modes of Composite Mater. With Organic Matrices and Their Consequences on Design Mar. 1975 9 p ref (For availability see N75-23698 15-24)

Within the manifold of composite structures developed, rotary wings are the best known components. Several types of composite rotorblades have been developed, tested, and produced. The experience with fatigue testing many GFP, CFP and mixed modulus coupons and full scale blade sections is used to make some design recommendation how crack propagation might be avoided. Respect is given to both influence of fabrication and influence of environment. For some cases deformation limits up to which no damage propagation occurs are given. Author

N75-23710 McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.

CONSIDERATION OF FAILURE MODES IN THE DESIGN OF COMPOSITE STRUCTURES

L. B. Greszczuk *In* AGARD Specialists Meeting on Failure Modes of Composite Mater. With Organic Matrices and Their Consequences on Design Mar. 1975 24 p refs (For availability see N75-23698 15-24)

(Contracts N00019-72-C-0221, N00019-73-C-0405)

Pertinent equations are presented for predicting, from the properties of constituents and composite microstructure, the strength of unidirectional composites subjected to tensile, compressive, and shear loading in the fiber and transverse directions, the latter being normal to the fiber axis. Influence of fiber and matrix properties, voids, and ineffective or unbonded fibers on the strength and failure modes of composites are discussed. Typical examples are given on the application of results to the design of composite laminates and structures including: sensitivity of properties of multilayer, multidirectional composites to the aforementioned failure modes; reshaping of cutout shapes in composite plates to minimize the dependance of the plate's strength on a given material strength parameter; use of hybrid multiphase composites to improve strength properties and performance; and use of composite-reinforced metals for buckling critical applications and others. Author

N76-17212# Advisory Group for Aerospace Research and Development, Paris (France).

FAILURE MODES OF COMPOSITE MATERIALS WITH ORGANIC MATRICES AND THEIR CONSEQUENCES ON DESIGN

G. C. Leornand (Soc. Natl. Ind. Aerospatiale, Les Mureaux) Oct. 1975 8 p

(AGARD-AR-86) Avail: NTIS

Theoretical and experimental data on fracture mechanisms of composite materials with organic matrices are reported along with practical avoidance methods for designers. Data cover the following areas: propagation of cracks in composites, behavior of ply reinforced fabric, and behavior of assembly plies. Temperature and design effects and test equipment are also discussed. Author

N76-19235# Advisory Group for Aerospace Research and Development, Paris (France).

DESIGN OF STRUCTURES IN COMPOSITE MATERIALS (BASIC DATA AND INTERDISCIPLINARY ACTION)

Jan. 1976 23 p refs

(AGARD-R-639, ISBN-92-835-0152-7) Avail: NTIS HC $3.50

Quality control in the manufacturing of composite materials for use in aircraft structures is discussed. Also discussed are interdisciplinary approaches for materials and design engineers in the development of advanced composites. For individual titles, see N76-19236 through N76-19237

N76-19236 British Aircraft Corp., Warton (England).

GENERATION OF COMPOSITE MATERIAL DATA FOR DESIGN

I. C Taig *In* AGARD Design of Struct. in Composite Mater. (Basic Data and Interdisciplinary Action) Jan 1976 p 1-7 (For availability see N76-19235 10-24)

Quality control in the manufacturing of fiber composites (laminates) used in aircraft construction is discussed. Specifically considered is the availability of technical information on the mechanical and thermal properties of laminates. The availability of this information is presented in tabular form. A rating scale (lettered A to E) serves as a key to the tables and indicates either extensive technical information (i.e., letter A) or minimal technical information (i.e., letter E). Exposure of laminates to the manufacturing environment (e.g. humidity, solvents) is also considered. It is proposed that the burdensome requirement that every primary composite has its own development program can be eliminated if components are built in standardized ways from a finite family of layups using previously developed structural elements. J.R.T.

N76-19237 Grumman Aerospace Corp., Bethpage, N.Y.

COMPOSITE MATERIALS DESIGN FROM A MATERIALS AND DESIGN PERSPECTIVE

A August, R Hadcock, and S Dastin *In* AGARD Design of Struct. in Composite Mater. (Basic Data and Interdisciplinary Action) Jan. 1976 p 9-19 refs (For availability see N76-19235 10-24)

The aerospace industry in the United States has made significant strides in the development of advanced composite technology, for primary as well as for secondary structural applications. This technology has advanced to the point where the feasibility of using these materials is no longer questioned. Unfortunately, applications which can reap the benefits of the technology have not developed as fast as they should, since improvements in technical (know-how) education, and experience are required in a number of areas. One such area is the interface between the design engineer and the materials engineer. The significance of the design engineering/materials engineering interface in the development of advanced structures is examined. To achieve a smooth-working design/materials interface, long-term emphasis in three specific areas is suggested: (1) education (on the industrial level and also back to the colleges and universities), (2) interdisciplinary development of advanced composites, and (3) development of composites test standards. Author

N76-23367# Advisory Group for Aerospace Research and Development, Paris (France)

FATIGUE IN COMPOSITE MATERIALS

K. L. Reifsnider (Vir. Polytechnic Inst. and State Univ.) Feb. 1976 28 p refs

(AGARD-R-638) Avail. NTIS HC $4.00

A general overview of fatigue of composite materials is presented from the standpoint of basic characteristics and concepts, especially in the context of fatigue behavior of more familiar materials. Author

25 INORGANIC AND PHYSICAL CHEMISTRY

Includes chemical analysis, e.g., chromatography, combustion theory, electrochemistry, and photochemistry. For related information see also *77 Thermodynamics and Statistical Physics*.

N76-18252# Advisory Group for Aerospace Research and Development, Paris (France)

KINETIC ENERGY OF TURBULENCE IN FLAMES

K. N. C. Bray 1975 21 p refs Repr. from AGARD Conf. Proc. 164, Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, especially related to Combust., May 1975

(AGARD-CP-164-Paper-II-2) Avail: NTIS HC $3.50

The exact equations of turbulent, chemically reacting flow were used, together with an order of magnitude analysis, to derive an approximate form of the turbulence kinetic energy balance equation for premixed, two-dimensional, turbulent flames at low Mach number and high Reynolds number. Plausible closure hypotheses were then introduced, in order to obtain an equation which reduces to a familiar form of the turbulence kinetic energy equation, in the case of nonreacting flow of constant density. Additional terms, related to heat release and mass transport, become important in turbulent flames. Experimentally observed effects of turbulence on a variety of turbulent flame configurations are discussed in terms of this equation. Author

26 METALLIC MATERIALS

Includes physical, chemical, and mechanical properties of metals, e.g., corrosion, and metallurgy.

N76-17226# Advisory Group for Aerospace Research and Development, Paris (France)
MANUAL ON FATIGUE OF STRUCTURES. VOLUME 2: CAUSES AND PREVENTION OF STRUCTURAL DAMAGE. CHAPTER 6: FRETTING; CORROSION DAMAGE IN ALUMINIUM ALLOYS
William G. Barrois Nov. 1975 89 p refs
(AGARD-MAN-9-Vol-2) Avail: NTIS HC $5.00

The question of damage due to fatigue, fretting, corrosion, and stress corrosion is discussed in detail. The causes of failure are outlined, along with the characteristics of electrochemical corrosion. Prevention of and protection against stress corrosion and electrochemical corrosion were investigated. For individual titles, see N76-17227 through N76-17229.

N76-17227 Advisory Group for Aerospace Research and Development, Paris (France).
OUTLINE OF THE CAUSES OF FAILURE
In its Manual on Fatigue of Struct., Vol. 2, Chapter 6 Nov. 1975 p 1-25 (For availability see N76-17226 08-26)

The causes of failure are discussed; these include surface damage and low temperature brittleness. Remedies against wear, seizure, galling and fretting are presented along with the effects of fatigue, alloying elements, heat-treatments and ageing on low temperature brittleness. M.J.S.

N76-17228 Advisory Group for Aerospace Research and Development, Paris (France).
ELECTROCHEMICAL CORROSION
In its Manual on Fatigue of Struct., Vol. 2, Chapter 6 Nov. 1975 p 25-50 (For availability see N76-17226 08-26)

The theory of chemical corrosion was investigated in detail along with actual corrosion, protection against corrosion, and action against corrosion. M.J.S.

N76-17229 Advisory Group for Aerospace Research and Development, Paris (France).
STRESS CORROSION OF ALUMINUM ALLOYS
In its Manual on Fatigue of Struct., Vol. 2, Chapter 6 Nov. 1975 p 50-71 refs (For availability see N76-17226 08-26)

Intergranular corrosion and stress corrosion cracking were studied along with cracking mechanisms in aluminum alloys and data and tests relating to those alloys. Progress in stress corrosion testing is reported, and ways of preventing stress corrosion cracking are included. M.J.S.

N76-19268# Advisory Group for Aerospace Research and Development, Paris (France)
SPECIALISTS MEETING ON ALLOY DESIGN FOR FATIGUE AND FRACTURE RESISTANCE
Jan 1976 170 p refs In ENGLISH partly in FRENCH Presented at 40th Meeting of Struct. and Mater. Panel, Brussels, 13-19 Apr. 1975
(AGARD-CP-185, ISBN-92-835-0151-9) Avail: NTIS HC $6.75

The conference considering the microstructure of aerospace alloys and the associated effects on fatigue and fracture resistance is reported. Aluminum, titanium, and ferrous alloys were considered. For individual titles, see N76-19269 through N76-19274.

N76-19269 McMaster Univ., Hamilton (Ontario). Dept. of Metallurgy and Materials Science
BASIC MICROSTRUCTURAL ASPECTS OF ALUMINUM ALLOYS AND THEIR INFLUENCE ON FRACTURE BEHAVIOUR
J. D. Embury *In* AGARD Specialists Meeting on Alloy Design for Fatigue and Fracture Resistance Jan 1976 13 p refs Sponsored in part by Natl. Res. Council and Defence Res. Board (For availability see N76-19268 10-26)

Factors which determine the scale and distribution of precipitate particles in aluminum alloys and their effects on yield strength are discussed. The influence of coarse intermetallics on fracture, and intergranular fracture are analyzed in terms of strain hardening. F.O.S.

N76-19270 Aluminum Co. of America, Alcoa Center, Pa. Engineering Properties and Testing Div.
DESIGN OF ALUMINUM ALLOYS FOR HIGH TOUGHNESS AND HIGH FATIGUE STRENGTH
J. G. Kaufman *In* AGARD Specialists Meeting on Alloy Design for Fatigue and Fracture Resistance Jan 1976 26 p refs (For availability see N73-19268 10-26)

The basic concepts employed in designing fracture-resistant aluminum alloys are reviewed, and specific examples of the application of these concepts are presented in detail. The importance of consideration of strength and stress-corrosion resistance in addition to toughness and fatigue strength is emphasized, and it is pointed out that most successful applications of alloy design techniques have been in the areas of toughness and stress corrosion resistance, with little commercial success in the area of fatigue. The roles of interfaces and of various sizes and types of particles in initiating and propagating cracks is examined, and the steps necessary to control the size and spacing of insoluble constituents and precipitates as well as the grain morphology are discussed. Outstanding examples of the application of microstructural control are aluminum alloys 2048, 2124, 2419, 7050 and 7475, and the specific approaches to their development as well as data illustrating the commercial success are presented. Of the group, 7475 represents the optimum available in the toughness regime, while 7050 provides the best combination of strength, toughness and stress-corrosion resistance of the commercial alloys. Author

N76-19271 Royal Aircraft Establishment, Farnborough (England). Materials Dept.
METALLURGICAL ASPECTS OF FATIGUE AND FRACTURE IN TITANIUM ALLOYS
C. A. Stubbington *In* AGARD Specialists Meeting on Alloy Design for Fatigue and Fracture Resistance Jan. 1976 19 p refs (For availability see N76-19268 10-26)

The basic features of alpha-beta titanium alloys which result in property anisotropy are the elastic and plastic anistropy of the hexagonal alpha phase, and the sensitivity of their microstructures to thermomechanical processing. Mechanisms of fatigue crack initiation and microstructural requirements for resistance to initiation are discussed. The effect of crystallography on fatigue crack growth is described, and the apparent conflict in microstructural requirements for resistance to fatigue crack initiation and resistance to fatigue crack growth is indicated. It is concluded that in future work, microstructure and texture should be considered simultaneously in relation to fatigue properties, rather than separately, as has largely been the case hitherto. The relationships between microstructure, interstitial content and toughness in titanium alloys are discussed, and the importance of crystallography is highlighted. It is suggested that optimization and control of microstructure, interstitial content, and texture will be required for maximum toughness, and for maximum resistance to stress corrosion and sustained load cracking in alpha-beta alloys. It is also suggested that the approach to the texture parameter could either be to randomize it by heat treatment, or to control it and take advantage of the tough orientations. Maximum directional toughness will be obtained by a combination of microstructural optimization and textural toughening. Author

N76-19272 Rockwell International Corp., Thousand Oaks, Calif. Science Center
THE EFFECTS OF MICROSTRUCTURE ON THE FATIGUE AND FRACTURE OF COMMERCIAL TITANIUM ALLOYS
N. E. Paton, J. C. Williams, J. C. Chesnutt, and A. W. Thompson *In* AGARD Specialists Meeting on Alloy Design for Fatigue and Fracture Resistance Jan 1976 14 p refs (For availability see N76-19268 10-26)

The metallurgy of commercial alpha + beta titanium alloys permits a great variety of microstructures to be obtained. Equivalent strength levels can frequently be obtained in a given alloy with several different microstructures, making it possible to optimize properties other than strength and modulus by manipulation of microstructure. The effect is discussed of microstructure on fatigue and fracture behavior of two commercial Ti alloys, Ti-6Al-4V and Ti-6Al-2Sn-4Zr-6Mo. Emphasis is placed on fatigue crack growth rate (and corrosion fatigue) properties, and on fracture toughness. The influence of microstructure on secondary properties such as stress corrosion cracking is included where appropriate. In order to illustrate principles important to alloy design concepts, reference is made to work on the effects of microstructure and minor element additions (H and O) to single-phase model Ti alloys. Author

N76-19273 California Univ., Berkeley. Lawrence Berkeley Lab. Inorganic Materials Research Div.

FUNDAMENTAL CONSIDERATIONS IN THE DESIGN OF FERROUS ALLOYS

Victor F Zackay *In* AGARD Specialists Meeting on Alloy Design for Fatigue and Fracture Resistance Jan 1976 20 p refs Sponsored in part by ERDA, ONR, AFML and Army Mater and Mech Res Center (For availability see N76-19268 10-26)

The elements of defect structure and microstructure in ultrahigh strength steels that influence the plane strain fracture were studied with emphasis on the austenitizing phase in heat treatment The austenitizing temperature effects, and the fracture toughness of quenched and tempered steels are discussed along with carbon-free ferrous alloys F O S

N76-19274 Advisory Group for Aerospace Research and Development, Paris (France).

MECHANICAL PARAMETERS (FATIGUE AND TOUGHNESS) OF CERTAIN VERY HIGH STRENGTH STEEL ALLOYS [CARACTERISTIQUES D'EMPLOI (FATIGUE ET TENACITE) DE QUELQUES ACIERS A TRES HAUTE RESISTANCE]

P Rabbe and C. Amzallag *In its* Specialists Meeting on Alloy Design for Fatigue and Fracture Resistance Jan 1976 9 p refs In FRENCH (For availability see N76-19268 10-26)

Investigations were carried out on the following subjects related to certain steel alloys commonly used in aircraft structures. (1) study of the initiation of fatigue cracks, (2) endurance characteristics under tension/compression (Goodman diagram), (3) determination of the critical constraint intensity factor, and (4) graphs of crack propagation speeds The following specific steels were investigated 35NCD16, 15CDV6, and Z25NKDV 8-4. The results may be used to rank the various materials in relation to their intended use and also provide quantitative information on acceptable constraint values under service conditions Author

N76-28408# Advisory Group for Aerospace Research and Development, Paris (France) Structures and Materials Panel

REVIEW OF ADVANCED POWDER METALLURGICAL FABRICATION TECHNIQUES IN EUROPEAN NATO COUNTRIES

P W. Sutcliff (Atomic Energy Res Estab., Harwell, England) Jun 1976 12 p

(AGARD-R-641; ISBN-92-835-1220-0) Avail NTIS HC $3.50

Various hot consolidation techniques currently under investigation are described for the fabrication of titanium and nickel alloys for application in high-integrity, highly stressed aeroengine components. The present state of the art in this field is evaluated and recommendations made relevant to the preparation of the forthcoming specialists' meeting on Advanced Fabrication Techniques in Powder Metallurgy and their Economic Implications. Author

N76-33332# Advisory Group for Aerospace Research and Development, Paris (France)

THE THEORY, SIGNIFICANCE AND PREVENTION OF CORROSION IN AIRCRAFT

Sep 1976 158 p refs Presented as a lecture series, Wright-Patterson AFB, Ohio, 6-7 Oct. 1976, Delft, Netherlands, 11-12 Oct 1976, Lisbon, 14-15 Oct. 1976

(AGARD-LS-84) Avail NTIS HC $6.75

The significance, implications and economics of the various types of corrosion in aircraft were discussed, as well as the threats and preventive measures for the product life cycle, design, material selection, construction, maintenance and repair, inspection and test. The stress is placed on the need for greater application of known preventive methods, greater visibility of the problem, expanded engineering education, and better practical transfer of knowledge and technology For individual titles, see N76-33333 through N76-33340.

N76-33333 Promisel (N. E.), Silver Spring, Md.

INTRODUCTION: A SURVEY OF THE PROBLEM

N E. Promisel *In* AGARD The Theory, Significance and Prevent. of Corrosion in Aircraft Sep. 1976 5 p (For availability see N76-33332 24-26)

The overall situation and perspective of the corrosion problems in aircraft was reviewed A striking paradox is that, despite extensive research and knowledge in the field of corrosion and practical measures to combat it, aircraft corrosion damage is still being experienced that annually is costing many millions of dollars, as well as indirect penalties such as aborted missions, decreased aircraft usage factor, and even, occasionally, safety hazards to aircraft and personnel. It appears that there does not exist an adequate transfer of technology between scientists, engineers, designers, and users. The cost of corrosion should be determined by looking at a complete life cycle of a total system. Aircraft are subject to practically every type of corrosion pitting, intergranular, fatigue, stress-corrosion cracking, crevice, bacterial, embrittlement, fretting, galvanic, etc Easy access for in situ inspection should be a prime factor in aircraft design. Y.J A

N76-33334 Technische Hogeschool, Delft (Netherlands)

CORROSION THEORY AND PRACTICE

W A Schultze *In* AGARD The Theory, Significance and Prevent of Corrosion in Aircraft Sep. 1976 19 p refs (For availability see N76-33332 24-26)

A number of basic concepts and definitions related to corrosion were first reviewed, such as metallic corrosion, electrolytic corrosion, electrochemical reaction, electrode reaction. The thermodynamical concept of the equilibrium electrode potential was then introduced and applied to the various types of electrode reactions that could occur between metal and environment. The kinetic concepts of polarization and overpotential are treated and applied to the study of the rate of the reactions that are involved in corrosion processes. This is followed by a discussion of the mixed potential theory of electrochemical corrosion for a homogeneous metal. Some aspects of the types of corrosion that can occur when a metal consists of different phases, a combination of different metals is used, or a metal structure is exposed to an inhomogeneous environment or to stresses, are presented; these include pitting corrosion, crevice corrosion, intergranular corrosion, stress corrosion cracking, or corrosion fatigue. Y.J.A.

N76-33335 Ohio State Univ., Columbus. Dept. of Metallurgical Engineering.

ECONOMICS OF CORROSION

R W. Staehle *In* AGARD The Theory, Significance and Prevent. of Corrosion in Aircraft Sep. 1976 3 p (For availability see N76-33332 24-26)

The uncertainties related to the problems of defining the real costs of corrosion to military aircraft due to the complete lack of manipulable information were described. Various informed but informal estimates suggest that the costs directly associated with corrosion, including repair and inspection, are at least 25% of the maintenance costs, which are of the order of $1.5-2.0 billion per year Some general considerations which should serve as a reasonable basis for improving the understanding of not only corrosion economics but the general problem of maintenance economics are outlined Author

N76-33336 Naval Aircraft Materials Lab., Fleetlands (England).

CORROSION IN AIRFRAMES, POWER PLANTS AND ASSOCIATED AIRCRAFT EQUIPMENT

E J. Hammersley *In* AGARD The Theory, Significance and Prevent. of Corrosion in Aircraft Sep. 1976 16 p refs (For availability see N76-33332 24-26)

A review of corrosion problems in airframes, power plants, and aircraft equipment primarily found on naval and other aircraft operating in marine environments was presented. The following factors affecting the problem were first discussed: exposure (special nature of marine environment), initial standards (choice of materials, protection and inspection techniques, maintenance), feedback of information (between engineers, designers, and users), economics (original cost and operating cost), awareness of the problem (training of users). Specific corrosion problems encountered in the following aircraft components were then described: airframe structures (aluminum, magnesium, ferrous, titanium alloys; paint protective systems, geometric considerations, and the use of temporary or supplementary preservatives), engines, and aircraft equipment. Some comments on corrosion monitoring were also given. Y.J.A.

N76-33337 Messerschmitt-Boelkow-Blohm G.m.b H., Munich (West Germany). Aircraft Div.

CORROSION PREVENTION TECHNIQUES, MAINTENANCE AND REPAIR

Karl O. Sippel *In* AGARD The Theory, Significance and Prevent. of Corrosion in Aircraft Sep. 1976 15 p refs (For availability see N76-33332 24-26)

Possibilities which exist to increase the corrosion resistance of aircraft structures, mainly involving aluminum alloys, were described. Material selection and its treatment, application of suitable surface protections, and appropriate procedures during assembly were considered. Other materials, such as titanium and steel are also taken into consideration Special attention is drawn to those problems which arise during assembly and result

from incompatibility of protective coatings with structural materials or fasteners. Furthermore, a short description of a procedure used to determine inspection intervals by taking corrosive influence into account was given. As corrosion-preventive coatings on surfaces and fasteners are easily damaged, simple and inexpensive repair methods obtain great significance in practice. Therefore, methods in common practice in today's aircraft maintenance to repair corrosion-preventive coatings are described. Author

N76-33338 Societe Nationale Industrielle Aerospatiale, Suresnes (France). Lab. Central.

CORROSION: STUDY AND DETECTION

M. Brunin, G. Sertour, and C. Bezaud *In* AGARD The Theory, Significance and Prevent. of Corrosion in Aircraft Sep. 1976 16 p refs (For availability see N76-33332 24-26)

Two lines of approach to the study of corrosion phenomena are examined in parallel: corrosion reproduction and accelerated tests, and determination of corrosion rates. (1) Accelerated Corrosion Tests. Various types of test have been developed for the reproduction and acceleration of natural phenomena, such as salt spray, continuous and alternating immersion, and climatic cycle tests, together with exposure to marine and tropical environmental conditions. The development and utilization of these tests by a series of examples is demonstrated. (2) Measurement of Corrosion Rates. The rate of corrosion is obviously a valuable tool for forecasting damage resulting from this phenomenon, and its measurement is therefore amply justified. Methods used in this context, in particular the use of potentiostatic curves and measurement of impedance at low frequencies, are described. The application of these methods to the testing of anodizing is illustrated. In the context of stress corrosion cracking, the study of the kinetics of crack propagation likewise represents a powerful method of investigation and forecasting. Author

N76-33339 Ohio State Univ., Columbus. Dept. of Metallurgical Engineering.

DESIGNING FOR CORROSION PREVENTION

R. W. Staehle *In* AGARD The Theory, Significance and Prevent. of Corrosion in Aircraft Sep. 1976 26 p refs (For availability see N76-33332 24-26)

Approaches that may be used in aircraft design to prevent or minimize, in general, corrosion were discussed. These include: (1) simple preventive ideas, such as avoiding chlorides, high surface stresses, hydrogen in metals, etc., (2) point of view that aircraft must be designed on the basis of cyclic loading or fatigue, (3) the life cycle costs (capital and maintenance) must be kept as low as possible without compromising safety, reliability, or availability, (4) compromise must be made between the use of high strength, light weight, heterogeneous material systems and the chemical or mechanical instability of all engineering materials, with resulting problems of accelerated corrosion due to intimate juxtaposition. Applications were made to the B-1 program and to various alloys. Y.J.A

N76-33340 Advisory Group for Aerospace Research and Development, Paris (France).

PREVENTION AND COMBAT OF CORROSION IN AIRCRAFT STRUCTURES, BIBLIOGRAPHY

In its The Theory, Significance and Prevent. of Corrosion in Aircraft Sep. 1976 34 p refs (For availability see N76-33332 24-26)

A bibliography with abstracts dealing with aircraft corrosion was presented. The following areas were covered: high temperature corrosion, erosion and cavitation, manufacturing processes, non-destructive testing and inspection, failure analysis, fracture, fatigue, and stress corrosion cracking, wear, general and galvanic corrosion, exfoliation, localized corrosion, coatings, surface finish, and plating, power generation, fuels, and combustion, materials selection, testing, and evaluation. Author

N77-15152# Advisory Group for Aerospace Research and Development, Paris (France).

ADVANCED FABRICATION TECHNIQUES IN POWDER METALLURGY AND THEIR ECONOMIC IMPLICATIONS

Nov. 1976 240 p refs In ENGLISH partly in FRENCH Presented at the 42d Meeting of the AGARD Struct. and Mater. Panel, Ottawa, Can., 4-9 Apr. 1976

(AGARD-CP-200; ISBN-92-835-0171-3) Avail: NTIS HC A11/MF A01

The technological and economic achievements of powder metallurgy techniques are considered. The production of powders, the state-of-the-art of techniques for consolidation of titanium and superalloy powders to near net shapes, development of improved materials qualities, and cost reduction are emphasized. For individual titles, see N77-15153 through N77-15178

N77-15153# Air Force Materials Lab., Wright-Patterson AFB, Ohio.

TRENDS IN THE APPLICATION OF ADVANCED POWDER METALLURGY IN THE AEROSPACE INDUSTRY

G. P. Peterson *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 9 p (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

A variety of jet propulsion and airframe components were examined in terms of cost factors. It is shown that the dominant factor in increasing costs is metal removal or machining. Powder metallurgy is proposed as a means of reducing the costs of machining engine and aircraft components. Hot isostatic pressing, rotating electrode process, press and sinter, and extrusion are among the processes discussed. J.M.S.

N77-15154# Commissariat a l'Energie Atomique, Grenoble (France).

PRODUCTION OF POWDERS FROM TITANIUM ALLOYS BY VACUUM FUSION CENTRIFUGATION [PRODUCTION DE POUDRES D'ALLIAGES DE TITANE PAR FUSION-CENTRIFUGATION SOUS-VIDE]

Jacques Decours, Jacques Devillard, and Gerard Sainfort *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 13 p In FRENCH (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

A process is presented for fabricating powders of TA6V and TA625D alloys elaborated by fusion centrifugation under electron bombardment. An apparatus is described with a capacity for industrial production of metal powder. The properties of the powder thus fashioned are discussed. Large pieces of metal have been worked by frit and spinning at temperatures between 850 and 1100 C. The structural and mechanical properties of the products in the cold state are compared before and after heat treatment.

Transl. by A.H.

N77-15155# Nuclear Metals, Inc., West Concord, Mass.

PRODUCTION OF TITANIUM POWDER BY THE ROTATING ELECTRODE PROCESS

Gerald Friedman *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 5 p (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

The titanium alloy powder made by the rotating electrode process consists of closely-sized, high purity spherical particles within the range of 50-800 micrometers. Although earlier REP powders had been produced by a technique employing a tungsten cathode, this source of contamination was eliminated as a result of process modifications which make use of titanium cathodes, in either a consumable or nonconsumable mode.

Author

N77-15156# Leybold-Heraeus G.m.b.H., Hanau/Main (West Germany).

PRODUCTION OF HIGH PURITY METAL POWDER BY ELECTRON BEAM TECHNIQUE

H. Stephan *In* AGARD Advan. Fabric. Tech. in Powder Met and Their Econ. Implications Nov. 1976 6 p (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

Manufacturing of metal powders, especially of titanium and nickel-super-alloys of highest purity in the most econor. ical way is discussed. The powder can be of 100% spherical shape and of 50 - 600 micron diameter and of flake size of 20 - 400 mesh or a mixture of both. High purity is achieved by processing in high vacuum, melting with the programmed electron beam and atomizing with a water-cooled rotating disk This allows reduction of hydrogen from Ti-alloys and reduction of C, O2, H2 and N2 from Ni-super-alloys and avoids contamination of the metal powder from the environment, the heat source and the atomizing system. Author

N77-15157# Atomic Energy Research Establishment, Harwell (England). Chemistry Div.
TITANIUM POWDER PRODUCTION BY THE HARWELL CENTRIFUGAL SHOT CASTING PROCESS
P. W. Sutcliffe and P. H. Morton (Imperial Metal Ind. (Kynoch), Ltd., Birmingham, Engl.) *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 4 p refs (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

The centrifugal shot casting (CSC) process, which has particular relevance to the production of titanium alloy powders is briefly described. The process is one of several centrifugal atomization techniques being developed throughout the world which incorporates the mechanism of disintegration of molten titanium into discrete droplets. The melting of a titanium alloy electrode and the subsequent atomization as it takes place in the CSC process is illustrated. In addition, calculations of the time taken for pure titanium droplets of 50-500 micrometers diameter to solidify in flight are presented, as well as the distances traversed during solidification. The dependence of these parameters upon the nature and pressure of the inert gas environment is considered. Author

N77-15158# Allmanna Svenska Elektriska A. B., Robertsfors (Sweden).
PERFORMANCE AND ECONOMICS OF HIP EQUIPMENT IN INDUSTRIAL USES
Hans T. Larker *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 6 p (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

Hot isostatic pressing (HIP) is an established process within some segments of industry and ample experience has been gained from the use of ASEA QUINTUS(R) HIP equipment in production, both cold loaded for cemented carbide products and hot loaded for high speed tool steel. A design for the insulation system of HIP furnaces invented about ten years ago and then further developed has proven to give high reliability and low maintenance cost. Examples of HIP processing costs for a cold loaded unit and a hot loaded pressing line are given. The calculated costs ranging from some tens of cents to about a dollar per kg material being treated should enable a rapidly increasing use of the HIP process. Author

N77-15159# Autoclave Engineers, Inc., Erie, Pa.
PROCESS AND ECONOMIC CONSIDERATIONS FOR PRODUCTION SCALE HOT ISOSTATIC PRESSING EQUIPMENT
Charles W. Smith, Jr. *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 7 p (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

Equipment which makes the hot isostatic pressing process an economical and viable industrial process is now well developed. Hot and cold loading process systems are compared at a production rate of one cycle per eight hour day. Other comparisons of the two systems include equipment types, equipment costs, and the effect of material processed. Author

N77-15160# Conaway Pressure Systems, Inc., Columbus, Ohio.
NOTES ON SOME ECONOMIC ASPECTS OF HIP
R. M. Conaway *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 5 p (For primary document see N77-15152 06-26)
Avail: NTIS A11/MF A01

Two areas of interest involving hot isostatic processing are addressed. Some of the considerations involved in the concept of operation with respect to preheat are presented. Additionally, some of the results of a study intended to give indications of floor-to-floor processing costs are briefly presented Author

N77-15161# Wiggin (Henry) and Co. Ltd., Hereford (England).
NICKEL SUPERALLOY POWDER PRODUCTION AND FABRICATION TO TURBINE DISCS
C. H. Symonds and F. A. Thompson *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 14 p refs (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

One area of application has received more attention than any other, this being turbine disks where the requirement is not for the ultimate in high temperature resistance but for optimized mechanical properties at intermediate temperatures. These components lend themselves ideally to manufacture by the powder route since nearly all the advantages of powders over conventional routes can be utilized. An integrated powder production and compaction plant was installed aimed at the commercialization of this type of component. Work on the forging of disks from hot isostatically pressed (HIP) billet is reviewed along with indications of the potential for other techniques applicable to the production of powder disks, i.e. preforms plus forging, direct HIP to shape, isothermal forging, thermoplastic processing. Author

N77-15162# Pratt and Whitney Aircraft, East Hartford, Conn.
MANUFACTURE OF LOW COST P/M ASTROLOGY TURBINE DISKS
Dennis J. Evans *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 6 p (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

The use of powder metallurgy to produce components from difficult-to-forge alloys was demonstrated. However, as the costs of raw materials, labor, and processing increase rapidly, the stimulus for continued powder processing development shifts from performance to that of raw material conservation and cost reduction. It was the object of this program to demonstrate the reproducibility of the product obtained from the forging of annular preforms using a carbon modified Astrology powder and to establish production processes and specifications relevant to this product. The technical approach taken was to procure hot isostatically pressed low carbon Astrology forging preforms from two powder sources. One source utilized high pressure consolidation, the other low pressure consolidation. These as-HIP'ed preforms were hammer forged. Subsequent mechanical property evaluation verified the quality of these components and a disk for engine qualification was made available for testing. Author

N77-15163# Avco Lycoming Div., Stratford, Conn. Materials and Process Technology Labs.
ADVANCEMENTS IN SUPERALLOY POWDER PRODUCTION AND CONSOLIDATION
Louis J. Fiedler *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 9 p (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

A program was initiated to reduce the cost of fabricating superalloy turbine engine components through the utilization and improvement of powder metallurgical techniques. To date, investigations were conducted on both powder production and powder consolidation. Specifically, it was demonstrated that the cost of powder production could be significantly reduced at the expense of small property changes through the use of virgin materials and powder revert during melting, minimizing inert handling, and the use of coarser mesh fractions. Relative to consolidation, it was also shown that ceramic molds can be used to produce near net shaped parts by direct HIP or by sinter plus HIP techniques. The verification of these processes is currently in progress through the fabrication and evaluation of a full scale turbine disk with an integral stub shaft. Author

N77-15164# Pratt and Whitney Aircraft, West Palm Beach, Fla. Government Products Div.
ISO-FORGING OF POWDER METALLURGY SUPERALLOYS FOR ADVANCED TURBINE ENGINE APPLICATIONS
M. M. Allen *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 15 p (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

The Gatorizing forging process is a hot die isothermal technique used to produce complex configurations. This process utilizes the superplastic behavior imparted to advanced superalloys through prior processing and/or controlled forging parameters. This technique is currently being used in the production of all of the turbine disks and many of the compressor disks used in the F100 engine program. The Gatorizing technique has allowed production of a diverse array of precision forged net and near net shape superalloy components. Because the process uses hot dies and relatively low forming rates, the response of the as-Gatorized workpiece to subsequent heat treatment is remarkably uniform. Finally the Gatorizing process offers strong economic advantages over conventional forming techniques in applications which use expensive raw materials, require maximum material properties, or require complex component configuration. Author

N77-15165# Homogeneous Metals, Inc., Herkimer, N. Y.
METAL POWDER PRODUCTION BY VACUUM ATOMIZATION
J. M. Wentzell *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 6 p (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

The potential energy for atomization can be stored within the molten metal, which increases the efficiency. Also, the higher tap densities of vacuum-atomized powders, as compared with argon-atomized powders, is a distinct advantage. Alloy powders based on Ni, Co, Fe, Cu, Al, and misch metal were made successfully by this process. Powder metallurgy will play a significant role in this era of conservation and cost reduction, and vacuum atomization has shown that the unconventional approach may offer the most practical solutions to some of our current problems. Author

N77-15166# General Electric Co., Cincinnati, Ohio.
RENE 95 POWDER METALLURGY OPPORTUNITIES FOR GAS TURBINE APPLICATIONS
David B. Arnold *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 6 p (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

An intensive effort in powder metallurgy was initiated for Rene 95 when the powder metallurgy approach emerged as a viable technology through the combined development of powder production and hot isostatic pressing. The status of this effort is reviewed, and the major directions are indicated in which powder metallurgy Rene 95 is likely to make the most significant contributions. Author

N77-15167# Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
INVESTIGATIONS FOR MANUFACTURING TURBINE DISCS OF NI-BASE SUPERALLOYS BY POWDER METALLURGY METHODS
W. Betz, H. Huff, W. Track, M. Brandis, F. Schubert, and W. Spyra *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 19 p (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

The potential advantages arising from powder metallurgical production of turbine disks using different processing methods are discussed. Research work included the following production methods: (1) powder compressed by hot extrusion, disk shaping by forging in a conventional forging press; (2) Argon-atomized powder compressed by hot isostatic pressing (HIP), disk shaping by forging in a conventional forging press; and (3) Argon-atomized powder, compression and simultaneous disk shaping by HIP. The influence of different steps is discussed, e.g. HIP parameters, forging parameters and heat treatments on microstructure and results of tensile tests (from RT up to 800 C), creep rupture test (650 C and 730 C), and low cycle fatigue tests (test bars at RT and 600 C and spinned disks at RT). Parameters were found for HIP in combination with thermomechanical post treatment which produce a microstructure in which the previous particle grain boundaries are not densely covered by carbides. This microstructure leads to mechanical and technological properties which appear to be adequate for the use of these PH-materials for turbine disks. Author

N77-15168# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Corbeil (France)
INFLUENCE ON THE MECHANICAL PROPERTIES OF VARIOUS PROCESSING PARAMETERS APPLIED TO NICKEL BASE SUPERALLOYS POWDERS
Pierre Lescop, Michel Marty, and Andre Walder *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 12 p In FRENCH; ENGLISH summary (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

The characteristics of nickel-base alloys, fabricated from prealloyed powders, are influenced by each of the successive operations. The effect of the main parameters are shown, such as: (1) powder atomization process (rotative electrode, argon atomization), (2) powder granulometry, (3) carbon content of the alloy, (4) densification mode (extrusion, conventional isostatic compacting, fast isostatic compacting, pseudo-isostatic uniaxial compression), and (5) thermal treatments and forging conditions according to the temperature range considered for the application. The structures and the mechanical properties (tension, creep, low cycle fatigue) are examined on alloys fabricated at laboratory scale (IN 100, Astroloy) and on industrial products of various origins (Rene 95, Astroloy low carbon). Author

N77-15169# National Aeronautical Establishment, Ottawa (Ontario).
CONTROL OF GRAIN STRUCTURE DURING SUPERALLOY POWDER PROCESSING
W. Wallace, J-P. A. Immarigeon, J. M. Tronouth, and B. D. Powell *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 13 p refs (For primary document see N77-15152 06-26)
Avail: NTIS HC A11/MF A01

Factors which influence the control of grain structure during hot isostatic pressing of nickel-base superalloy powders are examined. The gamma precipitate can be used to control grain structure below the gamma solvus, while carbide precipitation on grain and particle boundaries controls the structure at higher temperatures. Carbon and sulphur are the main interstitials on particle boundaries. Flow properties, fracture behavior, and recrystallization during hot forging depend on temperature, strain, strain rate, and initial grain structure of the compact. The effects of these forging variables on final microstructure are examined. Author

N77-15170# Canadian Westinghouse Co., Ltd., Hamilton (Ontario). Turbine and Generator Div.

POWDER FABRICATION OF FIBRE-REINFORCED SUPERALLOY TURBINE BLADES

P. J. Mazzei, G. Vandrunen, and M. J. Hakim *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 16 p refs (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

A powder metallurgy process was developed to produce superalloy matrix-thoriated tungsten composite shapes. The continuous deposition of hafnium carbide and hafnium nitride diffusion barriers on tungsten wire by chemical vapor deposition was demonstrated. Coated fibers were combined with matrix alloy tape to produce composite plies. The plies can be stacked, outgassed and consolidated by hot isostatic pressing to near-net or possibly net composite shapes. Author

N77-15171# Centre de Recherches Metallurgiques, Liege (Belgium).

HIGH-STRENGTH POWDER-METALLURGY COBALT-BASE ALLOYS FOR USE UP TO 650 DEG C

J. M. Drapier, P. Viatour, D. Coutsouradis, and L. Habraken *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 14 p refs (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

The possibility of obtaining high strength levels at intermediate temperatures in experimental cobalt-base alloys prepared by powder metallurgy (P/M) techniques was investigated. The first part of the work concerned P/M grades containing (in wt.%) 10 to 15%Ni, 20%Cr, 10%Mo and up to 1.8%C, strengthened mainly by solid solution effects and precipitation of carbides. The second part dealt with P/M grades containing (in wt.%) 16%Cr, 3 to 5%Mo, 5%Ti and less than 0.1%C strengthened by solid solution effects and precipitation of the ordered f.c.c. gamma-Co3Ti intermetallic compound. Prealloyed powders sizing less than 500 microns were prepared by N2 atomization and, for some of the Ti-containing grades, by the rotating electrode process. After consolidation by hot extrusion of canned powders, the alloys were hot worked by rolling or swaging and subjected to a final aging treatment. Ultimate tensile strengths up to 1850 MN/sq. m at room temperature and 1350 MN/sq. m at 650 C (1200 F) were obtained in the gamma-Co3Ti strengthened alloys. Relationships between microstructures and mechanical properties are discussed in terms of the powder characteristics, and the extrusion and subsequent hot working and aging conditions. Author

N77-15172# Imperial Metal Industries (Kynoch) Ltd., Birmingham (England).

COMPARATIVE EVALUATION OF FORGED Ti-6Al-4V BAR MADE FROM SHOT PRODUCED BY THE REP AND C&C PROCESSES

R. F. Vaughan, P. A. Blenkinsop, and P. H. Morton *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 7 p refs (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

Ti-6Al-4V shot was obtained from two sources, the centrifugal shot casting process and the rotating electrode process. The chemistry and size distribution of the two types of shot were compared prior to an evaluation of the consolidated products. Alloy shot billets were produced by hot isostatic pressing (HIP) and the mechanical properties of as-HIP and as-HIP + forged/rolled material were compared. The two types of shot behaved in a similar manner and generally produced microstructures, tensile and fracture toughness properties similar to cast and wrought material. However, the low cycle fatigue behavior of the consolidated material was inferior to that observed in the conventional product. Internal fatigue origins were found to be associated with defects in the shot and in general the degree of scatter was higher and fatigue strengths were lower than in conventional material of a similar section size. Author

N77-15173# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Central Lab.

SOME COMMENTS ON THE MECHANICAL PROPERTIES OF HIP TITANIUM

Wolfgang Kelnath *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 12 p (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

The mechanical properties of HIP titanium TIAl6V4 produced under different conditions are discussed and the factors which influence the fatigue values are investigated. Author

N77-15174# General Electric Co., Evendale, Ohio.

HOT ISOSTATIC PRESSING OF Ti-6Al-4V POWDER FORGING PREFORMS

R. E. Peebles *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 6 p refs (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

Data are presented concerning powder characterization, hot isostatic pressing (HIP) parametric studies, producing and forging HIP preforms, and the determination of many mechanical properties from forgings as well as as-HIP material. The results of the mechanical property testing are compared to those of the conventional cast and wrought approach as well as to each other. The economics of forging powder preforms, and of using the alloy in the as-consolidated (by HIP) are discussed as well as current problems. Author

N77-15175# Air Force Materials Lab., Wright-Patterson AFB, Ohio.

WELDABILITY OF HOT ISOSTATICALLY PRESSED PREALLOYED TITANIUM 6Al-4V POWDERS

R. F. Geisendorfer, L. P. Clark, and M. A. Greenfield *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 5 p refs (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

The prealloyed Ti 6Al-4V powder shapes investigated included REP spherical powder and H/DH irregular powder. Both types were evaluated after three different time-temperature-pressure HIP combinations. In addition, a fourth HIP cycle above the beta transus was conducted with spherical powder only. Welding was conducted on as-compacted material using the bead-on-plate gas tungsten arc technique with full penetration and constant weld parameters. Weldments were evaluated by bend, tensile, and toughness testing in conjunction with radiographic and metallographic techniques. Author

N77-15176# Grumman Aerospace Corp., Bethpage, N.Y. Advanced Materials and Processes Development.

NEAR-NET POWDER METALLURGY AIRFRAME STRUCTURES

R. H. Witt *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 8 p refs (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

The use of powder metallurgy for the reduction or minimization of the acquisition cost of titanium alloy airframe parts is discussed. The results of studies regarding the following processes are presented: (1) cold isostatic pressing and sintering to produce high density preforms for subsequent hot forging to full-density, near-net shapes, (2) hot pressing of shapes, and (3) hot isostatic pressing to full-density, near-net shapes in a one-step operation. The primary titanium alloys investigated were Ti-6Al-4V and Ti-6Al-6V-2Sn. Advantages, disadvantages, technological and economic considerations are summarized for each approach and potential future airframe applications are presented. Author

N77-15177# Atomic Energy Research Establishment, Harwell (England). Chemistry Div.

POWDER PRODUCTION, PART 1 Final Summary

P. W. Sutcliffe *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 4 p (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

Methods for producing titanium alloy and nickel alloy powders are briefly reviewed. D.M.L.

N77-15178# Air Force Materials Lab., Wright-Patterson AFB, Ohio.

POWDER CONSOLIDATION, PART 2 Final Summary

Larry P. Clark *In* AGARD Advan. Fabric. Tech. in Powder Met. and Their Econ. Implications Nov. 1976 5 p (For primary document see N77-15152 06-26)

Avail: NTIS HC A11/MF A01

The state-of-the-art for powder consolidation and associated processing techniques is discussed. The sequence from the handling of powder, through consolidation and to evaluation of the final products is followed. Conclusions are drawn as to the state-of-the-art of powder consolidation into usable shapes and recommendations are made for future activities. Author

27 NONMETALLIC MATERIALS

Includes physical, chemical, and mechanical properties of plastics, elastomers, lubricants, polymers, textiles, adhesives, and ceramic materials.

N77-16182# Advisory Group for Aerospace Research and Development, Paris (France).
MECHANICAL PROPERTIES OF CERAMICS FOR HIGH TEMPERATURE APPLICATIONS
Dec 1976 61 p Presented at the 43d meeting of the Struct and Mater Panel of AGARD, Paris, Oct. 1976
(AGARD-R-651; ISBN-92-835-1232-5) Avail: NTIS HC A04/MF A01

Analytical techniques for the determination of localized stresses and strains and the application of fracture mechanics, proof testing, and life prediction techniques to ceramics are discussed. High temperature creep properties and design aspects of ceramic materials are also considered. For individual titles, see N77-16183 through N77-16185.

N77-16183# Karlsruhe Univ. (West Germany).
CREEP OF CERAMIC MATERIALS FOR GAS TURBINE APPLICATIONS
Fritz Thuemmler and Georg Grathwohl *In* AGARD Mech. Properties of Ceram. for High Temp. Appl. Dec. 1976 p 1-26 refs (For primary document see N77-16182 07-27)
Avail: NTIS HC A04/MF A01

The creep properties of silicon nitride and silicon carbide are important with respect to their possible application in gas turbines. General aspects of creep including common and unusual creep mechanisms are discussed along with testing procedures and evaluations. The creep of different types of Si3N4, Sialons, and of SiC is reviewed and compared, considering the important influences of purity, microstructure, and environment. Relations of creep to fatigue and to the delayed fracture phenomenon are mentioned. Open questions and future research requirements are discussed. Author

N77-16184# Durham Univ. (England). Dept. of Engineering Science.
FRACTURE MECHANICS OF HIGH TEMPERATURE CERAMICS
P. M. Braiden *In* AGARD Mech. Properties of Ceram. for High Temp. Appl. Dec. 1976 p 27-39 refs (For primary document see N77-16182 07-27)
Avail: NTIS HC A04/MF A01

The general concepts of fracture mechanics as applied to ceramics are discussed. The experimental techniques necessary for accurate measurement of fracture mechanics parameters are described. Some approaches to the characterization of the fracture properties of some engineering ceramics are discussed with particular attention to slow strain rate tests. Author

N77-16185# National Bureau of Standards, Washington, D.C. Inst. for Materials Research.
NEW DESIGN TECHNIQUES FOR BRITTLE MATERIALS
S. M. Wiederhorn, N. J. Tighe, and A. G. Evans (Rockwell Intern., Thousand Oaks, Calif.) *In* AGARD Mech. Properties of Ceram. for High Temp. Appl. Dec. 1976 p 41-55 refs (For primary document see N77-16182 07-27)
Avail: NTIS HC A04/MF A01

Methods of design for improving the reliability of ceramics in structural applications are described. Based on the science of fracture mechanics, these methods provide a rational basis for estimating the lifetime of structural components that are subjected to applied loads. Data obtained by standard strength or fracture mechanics techniques are used to develop design diagrams from which component performance is evaluated. Three types of diagrams are described, depending on whether the critical flaw size in a component is estimated by nondestructive evaluation, proof testing, or statistical evaluation. The validity of the theory was tested experimentally, and, on the whole, agreement between theory and experiment is satisfactory. However, additional experimentation is suggested to fully evaluate the limits of the theory. Author

28 PROPELLANTS AND FUELS

Includes rocket propellants, igniters, and oxidizers; storage and handling; and aircraft fuels. For related information see also *07 Aircraft Propulsion and Power*, *20 Spacecraft Propulsion and Power*, and *44 Energy Production and Conversion*.

N76-19295# Advisory Group for Aerospace Research and Development, Paris (France)
FUTURE FUELS FOR AVIATION
I. I. Pinkel (Pinkel, I. Irving, Consultant, Fairview Park, Ohio) Jan. 1976 41 p
(AGARD-AR-93; ISBN-92-835-1201-4) Avail: NTIS HC $4.00

The fuel supply outlook within the NATO nations is considered. Hydrocarbon fuels, alternate fuels as well as specification changes for fuels and changes in aircraft design and operation are discussed. Recommendations for future programs are included. Author

N77-11185# Advisory Group for Aerospace Research and Development, Paris (France).
SMALL SOLID PROPELLANT ROCKETS FOR FIELD USE
Sep. 1976 113 p refs Proceedings held at 47th Meeting of the AGARD Propulsion and Energetics Panel, Linder Hoehe, Germany, 17-19 May 1976
(AGARD-CP-194; ISBN-92-835-0174-8) Avail: NTIS HC A06/MF A01

Technological problems are discussed for propulsion systems of advanced small rocket motors for antitank, anti-aircraft, and light artillery rockets. The noise and shock effects of these weapons are explored. For individual titles, see N77-11186 through N77-11196.

N77-11186# Service Technique de l'Aeronautique, Paris (France). Section Armements Missiles.
MILITARY ROCKET AIRCRAFT: INHERENT CONSTRAINTS AND THEIR USES [LES ROQUETTES D'AVIATION: CONTRAINTES INHERENTES A LEUR UTILISATION]
Claude Sengeissen *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 7 p In FRENCH (For primary document see N77-11185 02-28)
Avail: NTIS HC A06/MF A01

The capabilities and disadvantages of aircraft launched, self-propelled rockets are discussed. Transl. by A.H.

N77-11187# Advisory Group for Aerospace Research and Development, Paris (France).
SPECIFICATIONS OF THE PROPULSION SYSTEMS FOR ANTI-TANK ROCKETS [SPECIFICATIONS DES SYSTEMS DE PROPULSION DES ROQUETTES ANTI-CHARS]
Alain Fournier *In its* Small Solid Propellant Rockets for Field Use Sep. 1976 4 p In FRENCH (For primary document see N77-11185 02-28)
Avail: NTIS HC A06/MF A01

An elevated operating pressure with a temperature coefficient acceptable for full-time use; high combustion speed; and a sensibility to erosive combustion are required for propulsion systems of future anti-tank type, single-stage rockets.
Transl. by A.H.

N77-11188# Dynamit Nobel A.G., Cologne (West Germany)
DEVELOPMENT OF A SMALL SOLID PROPELLANT ROCKET MOTOR FOR FLEXIBLE RANGE REQUIREMENTS
Walter Helmut Diesinger *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 13 p refs (For primary document see N77-11185 02-28)
Avail: NTIS HC A06/MF A01

Ballistic properties of the conventional German light artillery rocket LAR I are described. The ratio of minimum to maximum range must be smaller to meet military requirements in second generation systems. A solid propellant rocket motor having two propulsive charges and two independent thrust periods of equal thrust levels is proposed. The charges are ignited in sequence by an electronic timing circuit at a predetermined time of delay for optimum thrust for maximum range. A.H.

N77-11189# Institut fuer Chemie der Treib- und Explosivstoffe, Pfinztal (West Germany).
HIGH ENERGY COMPOSITE DOUBLE BASE SOLID PROPELLANTS
W. Kloehn *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 14 p (For primary document see N77-11185 Avail: NTIS HC A06/MF A01

Ammonium perchlorate is replaced by other oxidants as a constituent of composite double base solid propellants to prevent problems caused by hydrogen chloride in the combustion gases. Cyclic nitramines are substituted and tested. Fabrication techniques and properties of the propellants are discussed. A.H.

N77-11190# Centre de Recherches du Bouchet, Vert de Petit (France)
NEW PROPELLANTS FOR TACTICAL WEAPONS: SILANES [PROPERGOLS NOUVEAUX POUR ENGINS TACTIQUES: LES SILILANES]
G. Doriath *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 7 p In FRENCH (For primary document see N77-11185 02-28)
Avail: NTIS HC A06/MF A01

The fabrication process is described for composite propellants using silicon as a binder, ammonium perchlorate as an oxidant, and aluminum as the reducing agent. The mechanical properties of silanes are discussed and applied to ballistic weapons.
Transl. by A.H.

N77-11191# Centre de Recherches du Bouchet, Vert de Petit (France).
STRONG IMPACT PROPELLANTS OF LITTLE SPECIFIC ATTENUATION FOR RADIOELECTRIC WAVES [PROPERGOLS A FORTE IMPULSION SPECIFIQUE ATTENUANT PEU LES ONDES RADIOELECTRIQUES]
G. Prigent *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 7 p refs In FRENCH (For primary document see N77-11185 02-28)
Avail: NTIS HC A06/MF A01

Temperature rise caused by post-combustion provokes an increase in electromagnetic waves. Composite propellants were studied to determine the effect of anti-attenuant additives on impact and combustion rate. Transl. by A.H.

N77-11192# Cranfield Inst. of Technology (England).
THE MEASUREMENT OF IGNITER HEAT FLUX IN SOLID PROPELLANT ROCKET MOTORS
I. E. Smith and K. M. Siddiqui *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 13 p refs (For primary document see N77-11185 02-28)
Avail: NTIS HC A06/MF A01

Using platinum thin film gauges, the temporal and axial distribution of heat flux was measured from two different types of igniter compositions and two different igniter geometries. The parameters used were different igniter masses, tube lengths, and nozzle throat diameters. The size distribution of the particulate matter arising from combustion of pyrotechnic materials was investigated. Whereas radiation plays an insignificant part in the total heat transfer process, the 'point' heat flux due to particulate heat transfer was found to be an important mode of heat transport during igniter action. Author

N77-11193# Ballistic Research Labs., Aberdeen Proving Ground, Md.
AN INTERIOR BALLISTICS MODEL FOR A SPINNING ROCKET MOTOR
Carl W. Nelson *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 6 p refs (For primary document see N77-11185 02-28)
Avail: NTIS HC A06/MF A01

A computer model was developed for the spinning motor used in an artillery projectile. Lumped parameter equations for conservation of mass and energy are solved numerically. Gas properties were studied mixing the input from two different propellant grains. Gas dynamic effects due to the swirling of gases through a single central nozzle were investigated. A formula for radial burning rates was derived. Author

N77-11194# Institut fuer Chemie der Treib- und Explosivstoffe, Pfinztal (West Germany)
DETERMINING THE SHELFLIFE OF SOLID PROPELLANTS
F. Volk *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 17 p refs (For primary document see N77-11185 02-28)
Avail: NTIS HC A06/MF A01

While stored at various temperatures between 65 C and 90 C, several double base propellants with the same composition, differing only in the stabilizer, were aged artificially to the onset of autocatalytic decomposition. A correlation between the temperature and the storage period was established for the results obtained at the respective temperatures. The continuing aging

of the propellant gives rise to stabilizer reaction products which are characteristic of the respective aging condition. These reaction products may be used as a criterion for different stages of aging within the shelf life of solid propellants. Author

N77-11185# Technological Lab. RVO-TNO, Rijswijk (Netherlands). Rocket Section.

SIMPLE DETERMINATION OF THE MECHANICAL BEHAVIOR OF DOUBLE BASE ROCKET PROPELLANTS UNDER HIGH LOADING RATES

P. J. Greidanus *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 14 p refs (For primary document see N77-11185 02-28)

Avail: NTIS HC A06/MF A01

Two methods are discussed and evaluated for determining the mechanical behavior of double base rocket propellants. Uniaxial impact compression by an instrumented drop weight apparatus has advantages over tensile loading. Ultrasonic equipment is used to determine elastic properties and localize defects in propellant grains. Author

N77-11186# Institut Franco-Allemand de Recherches, St. Louis (France).

IMPULSIVE NOISE MEASUREMENT METHODS AND PHYSIOLOGICAL EFFECTS [METHODES DE MESURE DES BRUITS IMPULSIFS ET EFFETS PHYSIOLOGIQUES]

A. Dancer and M. Froboese *In* AGARD Small Solid Propellant Rockets for Field Use Sep. 1976 7 p refs In FRENCH (For primary document see N77-11185 02-28)

Avail: NTIS HC A06/MF A01

Exposure to complex impulse noise accompanying the firing of standard armaments results in headache, intense earache, and a sensation of deafness and may cause lesions to the inner and middle ear. Commercial pressure transducers were evaluated to determine reliability and used in determining precise measurements of the pressure pulses. Transl. by A.H.

31 ENGINEERING (GENERAL)

Includes vacuum technology; control engineering; display engineering; and cryogenics.

N75-22487# Advisory Group for Aerospace Research and Development, Paris (France)
SPECIALISTS MEETING ON FRETTING IN AIRCRAFT SYSTEMS
Jan. 1975 229 p refs In ENGLISH, partly in FRENCH Presented at 39th Meeting of the Struct and Mat. Panel, Munich, 6-12 Oct. 1974
(AGARD-CP-161) Avail. NTIS HC $7.50

The effects of fretting and wear on the reliability of aircraft structures and engines are examined. Various contact surfaces are categorized in terms of their role in the maintenance of flight profile and structural integrity along with several typical fretting situations. The occurrence of fretting on the fan, compressor, and turbine blades of jet engines is examined to include the effects on splines, rolling elements, bearing races, and secondary sealing elements of face type seals. The sequence of events which constitute the fretting mechanism is analyzed. For individual titles, see N75-22488 through N75-22503.

N75-22488 Missouri Univ., Columbia. Coll. of Engineering.
FRETTING OF AIRCRAFT CONTROL SURFACES
David W. Hoeppner *In* AGARD Specialists Meeting of Fretting in Aircraft Systems Jan. 1975 9 p Sponsored in part by ONR (For availability see N75-22487 14-31)

The occurrence of fretting and fretting fatigue in aircraft structures and components is discussed. The terminology and general conditions which produce fretting are defined. The two major elements of the fretting process are identified as: (1) relative displacement between surfaces in contact and (2) a normal load acting upon the surfaces. The conditions which lead to an acceleration of fretting and wear are analyzed. Illustrations of fretting fatigue and damage to representative aircraft components are provided. Author

N75-22489 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
FRETTING OF STRUCTURES FOR MODERN VG FIGHTERS
Volker Vontein and Peter E. Seibert *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 15 p refs (For availability see N75-22487 14-31)

The fretting phenomenon of structures for fighter aircraft and practical countermeasures to reduce fretting are discussed. Fretting problems caused by wing pivots are examined. The layout and design of the pivot lugs and bearings to avoid fretting are shown. A description of a wing carry-through box for fretting reduction is included. Author

N75-22490 Westland Helicopters, Ltd., Yeovil (England)
FRETTING IN HELICOPTERS
J. R. Lee *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 10 p (For availability see N75-22487 14-31)

The fretting problem in helicopters which is created by the high frequency of alternating loads is discussed. Examples are given of some of the more common cases of fretting. The most serious effect of fretting is stated to be reduction in fatigue strength. Methods for alleviating fretting by clamping pressure to prevent relative movement, improved lubrication, soft low strength interlayers, and hard wear resistant coatings are proposed. The author states that in many cases the only method for eliminating or reducing fretting is to redesign the component. Author

N75-22491 United Aircraft Corp., Stratford, Conn. Sikorsky Aircraft.
FRETTING FATIGUE IN TITANIUM HELICOPTER COMPONENTS
M. J. Salkind *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 6 p refs (For availability see N75-22487 14-31)

An analysis of the effects of fretting on the fatigue strength of titanium components used in helicopters is presented. Methods for reducing the effects of fretting consist of cold working of contact surfaces, silver plating, solid lubricants, and sacrificial metallic liners. Electron micrographs of main fracture surface for typical components are shown. The need for full scale testing to establish fretting characteristics is stressed since there are no representative small specimen tests which duplicate the fretting mechanism and the parameters controlling it. Author

N75-22492# National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio.
FRETTING IN AIRCRAFT TURBINE ENGINES
Robert L. Johnson and Robert C. Bill *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 17 p refs Prepared in cooperation with Army Air Mobility R and D Lab., Cleveland (For availability see N75-22487 14-31)

The problems created by fretting in turbine engines are discussed. The areas of greatest wear identified with the fan, compressor, and turbine blade mountings being the most critical items. Various methods for reducing or eliminating fretting in a turbine engine are described. Vacuum deposition of coatings by sputtering and ion plating are recommended as an economic method of applying thin films to inhibit fretting. Author

N75-22493 Societe Nationale d'Etudes et de Construction de Moteurs Aeronautiques, Corbeil (France).
COMMENT ON WEAR OF NON-LUBRICATED PIECES IN TURBOMACHINES [COMMENT REDUIRE L'USURE DES PIECES NON LUBRIFIEES DANS LES TURBOMACHINES]
J. Thiery and R. Spinat *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 14 p In FRENCH; ENGLISH summary (For availability see N75-22487 14-31)

The parts of a turbojet engine which may be damaged by fretting are identified. Fretting wear is investigated on an alternate friction test rig, up to high temperatures, for various solid materials and a number of anti-wear skins. From the results obtained, behavior principles for materials and skins are derived and used as guidelines to solve the main wear problems encountered. *Author*

N75-22494 Rolls-Royce, Ltd., Leavesden (England). Small Engine Div.
THE INFLUENCE OF FRETTING ON FATIGUE
W. J. Harris *In* AGARD Specialists Meeting of Fretting in Aircraft Systems Jan. 1975 12 p refs (For availability see N75-22487 14-31)

The fretting fatigue phenomena for various metals are discussed. Methods for reducing fretting in aluminum alloys are described. The use of epoxy resin matrix films for fretting reduction is recommended. The use of tungsten carbide-cobalt coats to reduce fretting of titanium alloys is proposed. The results of tests conducted with various types of fretting reduction coatings are analyzed. Author

N75-22495 Nottingham Univ. (England). Dept. of Metallurgy and Materials Science.
PHYSICS AND METALLURGY OF FRETTING
R. B. Waterhouse *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 17 p refs Sponsored by Min. of Def. and Sci. Res. Council (For availability see N75-22487 14-31)

Fretting corrosion and fretting fatigue are concerned with the oscillatory tangential relative movement of two contacting surfaces. In many contacts movement occurs over only part of the contact and fatigue cracks are frequently observed originating in the boundary between the slip and non-slip regions. Temperature rises in the contact zone can lead to thermoelectric effects between dissimilar metals but these are less important than metallurgical effects, particularly in heat-treatable materials. Work-hardened and age-hardened alloys are particularly susceptible to fretting damage. The volume of material affected by the stress system is of importance in fretting fatigue. Author

N75-22496 Metaalinstitut TNO, Apeldoorn (Netherlands).
SURFACE DISTRESS OF COPPER ALLOYS IN CONTACT WITH STEEL UNDER FRETTING CONDITIONS
A. Begelinger and A. W. J. DeGee *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 10 p refs (For availability see N75-22487 14-31)

Study of the fretting behavior of copper alloys against steel showed that, in the presence of a liquid lubricant, the wear process is purely adhesive by nature. Tests, performed under conditions of continuous lubricated sliding, show that such tests may be used to provide a first rough estimate of the behavior of materials under conditions of lubricated fretting, provided that the rate of energy production under sliding conditions equals that under fretting conditions. In the absence of a lubricant the

process is determined exclusively by the formation and subsequent behavior of oxides on the steel surface. Now, tests performed under conditions of continuous sliding give no indication whatever of the behavior of materials under fretting conditions. Author

N75-22497 Dow Corning G. m. b. H., Munich (West Germany)
LUBRICATION UNDER EXTREME PRESSURE [LA LUBRIFICATION EXTREME-PRESSION]
Paul Deyber and Maurice Godet *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 13 p refs In FRENCH (For availability see N75-22487 14-31)

Hydrodynamic action, film formation, and film elimination were studied during mixed lubrication under extreme pressure. Limits and hydrodynamic range were established for lubrication of the solid specimen studied. The gradual build up of a solid lubricating layer resulting from an additive reaction with steel was described. Finally, the competition between the formation of a film by reaction products from the chemical oil additives and the wear was observed. Transl. by E.H.W.

N75-22498 Rensselaer Polytechnic Inst., Troy, N.Y. Mechanics Div.
DESIGN OF PIVOTS FOR MINIMUM FRETTING
M. B. Peterson and F. F. Ling *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 22 p refs (For availability see N75-22487 14-31)

An analytical and experimental investigation has been conducted on the fretting of pivots. A test rig was set up which allowed fretting studies to be conducted under a wide range of conditions of frequency, load, amplitude, temperature, time, materials and geometries. It was found that rolling contacts performed much more satisfactorily than sliding contacts because of limited microslip. Dynamic loads, gross sliding, and changing of the contact area increase fretting substantially. Open contact geometries are less damage prone than more restrictive ones. Materials like tool steels and carbides are effective over a wide range of conditions when the microslip is limited. Designs are based on those contacts which give microslips less than 00004 in. and pressures less than 220,000 psi since these performed satisfactorily under long term tests. Since, microslips can be calculated for any given materials and designs research is needed to determine microslip damage limits of various materials. In studying fretting, it is important to clearly understand the motions and the nature of the damage processes. Author

N75-22499 Hydromecanique et Frottement, Andrezieux (France). Centre Stephanois de Recherches Mecaniques
NEW POSSIBILITIES OFFERED BY SURFACE TREATMENT IN CONTRAST TO CONTACT CORROSION [NOUVELLES POSSIBILITIES OFFERTES PAR LES TRAITEMENTS DE SURFACE DANS LA LUTTE CONTRE LA CORROSION DE CONTACT] c05
A. Gonin, A. Berger, and J. J. Caubet *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 16 p refs presence of one drop of medicinal white oil or a commercial lubricant, very small wear scars were produced in one hour. Oxidation of the oils increased wear slightly. The addition of tetralin hydroperoxide also increased wear. The greatest wear was produced with a mixture of oxidized oil and fine alpha Fe2O3 powder. Author

N75-22500* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EFFECT OF VARIOUS MATERIAL PROPERTIES ON THE ADHESIVE STAGE OF FRETTING
Donald H. Buckley *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 19 p refs (For availability see N75-22487 14-31)

Various properties of metals and alloys have been studied with respect to their effect on the initial stage of the fretting process, namely adhesion. Crystallographic orientation, crystal structure, interfacial binding energies of dissimilar metal, segregation of alloy constituents and the nature and structure of surface films have all been found to influence adhesion. High atomic density, low surface energy grain orientations exhibit lower adhesion than other orientations. Hexagonal metals in general manifest less adhesive wear than cubic metal. Knowledge of interfacial surface binding energies can assist in predicting adhesive transfer and wear. Selective surface segregation of alloy constituents can accomplish both a reduction in adhesion and improved surface oxidation characteristics. Equivalent surface coverages of various adsorbed species indicate that some are markedly more effective in inhibiting adhesion than others. Author

N75-22501 Fiat S.p.A., Turin (Italy).
SELF-LUBRICATING POLYMERS
Alfredo Franceschini *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 17 p refs (For availability see N75-22487 14-31)

Some polymers, either of the thermoplastic or the thermosetting type, are quite suitable as self-lubricating materials. Such bearings are useful whenever lubrication is impossible or impractical for temperature, weight, corrosion or other limitations. The most commonly used plastics in this field are the polytetrafluoroethylene, the polyamides, the polyacetals and the phenolics, these have been joined recently by a family of heat resistant materials, the polyimides. The significant material properties in tribology, in absence of lubrication, are the friction coefficient and the wear rate; to these are connected - in a more or less direct way - other physico-mechanical properties: thermal conductivity, hardness, and thermal expansion. With regard to running conditions the prominent parameters are temperature, load and sliding velocity; if they become more severe conventional polymers fail, and one must resort to more specialized materials, like PTFE sintered with bronze and lead, or members of a relatively new group of polymers: the polyimides. Author

N75-22502 Air Force Materials Lab., Wright-Patterson AFB, Ohio.
FRETTING WEAR BEHAVIOR OF A POLYSILOXANE BONDED SOLID LUBRICANT
R. J. Benzing and B. D. McConnell *In* AGARD Specialists Meeting on Fretting in Aircraft Systems Jan. 1975 6 p refs (For availability see N75-22487 14-31)

The development and characteristics of a polysiloxane bonded solid lubricant are discussed. The application of the lubricant to titanium engine compressor units to reduce fretting is described. The chemical properties of the lubricant are analyzed. The test equipment and the method for conducting fretting tests are reported. Author

N75-22503 Chevron Research Co., Richmond, Calif.
FRETTING WEAR OF STEEL IN LUBRICATING OILS c37
Douglas Godfrey *In* AGARD Specialist Meeting on Fretting in Aircraft Systems Jan. 1975 7 p refs (For availability see N75-22487 14-31)

Fretting wear experiments were conducted to determine the properties of mineral oil which inhibit or promote wear. The apparatus used caused a steel bearing ball to vibrate in contact with a steel block. Large wear scars and alpha Fe2O3 were produced in a few minutes with unlubricated specimens. In the presence of one drop of medicinal white oil or a commercial lubricant, very small wear scars were produced in one hour. Oxidation of the oils increased wear slightly. The addition of tetralin hydroperoxide also increased wear. The greatest wear was produced with a mixture of oxidized oil and fine alpha Fe2O3 powder. Author

N75-30359# Advisory Group for Aerospace Research and Development, Paris (France)
ANALYTICAL AND NUMERICAL METHODS FOR INVESTIGATION OF FLOW FIELD WITH CHEMICAL REACTIONS, ESPECIALLY RELATED TO COMBUSTION
May 1975 324 p refs In ENGLISH and FRENCH Conf held at Liege, 1-2 Apr. 1974
(AGARD-CP-164) Avail NTIS HC $9.25

Various methods used to study flows with chemical reactions and combustion are discussed. Major topic areas covered include: classical integration methods used to solve problems of laminar to turbulent (mean flow) combustion; calculation methods used to study turbulent flames, and methods applicable to combustors and their operation and to the analysis of pollutant formation. For individual titles, see N75-30360 through N75-30375.

N75-30360 Imperial Coll. of Science and Technology, London (England).
NUMERICAL COMPUTATION OF PRACTICAL COMBUSTION CHAMBER FLOWS
D. B. Spalding *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 24 p refs (For availability see N75-30359 21-31)

Numerical procedures for predicting combustion-chamber flows include mathematical models of physical processes, and computer programs for solving the resulting differential equations. The mathematical models for turbulence, radiation, chemical kinetics, and two-phase effects are briefly reviewed along with the fields of applicability of the computer programs PASS, EASI,

STABL and TRIC, all of which employ the SIMPLE algorithm. The ways in which the computer programs and the mathematical models can be used for practical purposes are illustrated by steady flame spread in a duct, the axisymmetrical combustor, unsteady flame spread in a duct, the inclined rocket exhaust, the annular-combustor sector, and the reaction region of a chemical laser. It is argued that the main current needs are for testing and exploitation of the numerical prediction procedures which recent research has made available. Author

N75-30361 Technische Hochschule, Aachen (West Germany).
THEORETICAL ANALYSIS OF NONEQUILIBRIUM HYDROGEN AIR REACTIONS BETWEEN TURBULENT SUPERSONIC COAXIAL STREAMS
H. Roentgen *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 10 p refs (For availability see N75-30359 21-31)

An analytical study is made of the free turbulent mixing and combustion taking place in the mixing layer between a cold supersonic central hydrogen jet and a preheated supersonic coaxial air stream. Finite difference approximations are developed that uncouple the governing equations by local linearization techniques together with iterative methods. Eddy viscosity models are used to describe the turbulent transport processes. Models are investigated for the prediction of the combustion process: (1) local chemical equilibrium and (2) steady state kinetics. Experimental investigations of the studied hydrogen-air flame are carried out. The numerical predictions are compared with the experimental results. Author

N75-30362 Societe Generale de Constructions Electriques et Mecaniques Alsthom, Grenoble (France).
THE SIMULATION OF TURBULENCE IN IRREPRESSIBLE MODELS [LA SIMULATION DE LA TURBULENCE DANS LES MODELES PETULA]
J. P. Huffenus *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 14 p refs In FRENCH; ENGLISH summary (For availability see N75-30359 21-31)

Mathematical models of turbulent flow are examined. It is shown that partial differential equations are not sufficient to solve the problem of determining turbulent flow characteristics in two parameter models. A model based on these findings is proposed for constant density flows and for flows with density differences, in which the force of gravity can modify the turbulence. Author

N75-30363 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NUMERICAL ANALYSIS OF THE INFLAMMATION PHASE IN A TURBULENT MIXING BOUNDARY LAYER [ANALYSE NUMERIQUE DE LA PHASE D'INFLAMMATION DANS UNE COUCHE DE MELANGE TURBULENTE]
Otto Leuchter *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 29 p refs In FRENCH, ENGLISH summary (For availability see N75-30359 21-31)

A numerical description is given of the inflammation process in the turbulent mixing region between a fuel jet (mixture of H2 and AR) and an external air stream, the two fluids being at the same temperature and of the same density. The initial conditions at the confluence are characterized by the velocity ratio and the initial boundary layer thicknesses. The description of the fields of mean quantities and second order correlations is performed by means of balance equations constructed from the general conservation theorems. Simplifying assumptions are introduced for the chemical kinetics, accounting for the particular behaviour of the hydrogen-oxygen chain reaction in the region of short ignition delay. The number of equations describing the chemical production and the effects of turbulence on it may thus be considerably reduced. The numerical solutions have revealed that the slowing effects of the turbulence are little affected by the initial conditions but depend essentially on the behaviour of the kinetics in the mixing layer, whenever the reduction of the inflammation length in the presence of boundary layers is due mainly to the distorsion of the mean velocity field. A simple criterion for the inflammability of jets is established taking into account these results. Author

N75-30364 California Univ., La Jolla. Dept. of Applied Mechanics and Engineering Sciences.
A REVIEW OF SOME THEORETICAL CONSIDERATIONS OF TURBULENT FLAME STRUCTURE
F. A. Williams *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 25 p (For availability see N75-30359 21-31)

The structure and motion of a laminar flame in a shear flow is considered. The strain rate is established as a key turbulent-flow factor influencing flame structure. It is concluded that premixed turbulent flames seldom are composed of an ensemble of sheared, premixed, laminar flames, while turbulent diffusion flames often are composed of a collection of laminar diffusion flames. A statistical description of premixed turbulent flame structure is outlined for turbulence of low intensity. The use of coupling functions is discussed for describing the structure of turbulent diffusion flames that consist of a statistical collection of laminar diffusion flames for which the flame-sheet approximation is applicable. It is shown how to obtain in a simple manner the average local volumetric production rate of nitric oxide in the turbulent diffusion flame, requiring as input only the local probability density function for the inert, evaluated at an inert concentration which corresponds to the flame-sheet position. Author

N75-30365 Southampton Univ. (England).
KINETIC ENERGY OF TURBULENCE IN FLAMES
K. N. C. Bray *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 20 p refs (For availability see N75-30359 21-31)

The exact equations of turbulent, reacting flow are used, together with an order of magnitude analysis, to derive an approximate form of the turbulence kinetic energy balance equation for premixed, two-dimensional, turbulent flames at low Mach number and high Reynolds number. Plausible closure hypotheses are then introduced, in order to obtain an equation which reduces to a familiar form of the turbulence kinetic energy equation, in the case of nonreacting flow of constant density. Additional terms, related to heat release and mass transport, become important in turbulent flames. Experimentally observed effects of turbulence on a variety of turbulent flame configurations are discussed in terms of this equation. Author

N75-30366 Aerospace Research Labs., Wright-Patterson AFB, Ohio.
A NUMERICAL SPECTROSCOPIC TECHNIQUE FOR ANALYZING COMBUSTOR FLOWFIELDS
Michael E. Neer *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 22 p refs (For availability see N75-30359 21-31)

A computer program which calculates the ultraviolet emission and absorption spectra of OH is presented for use in conjunction with numerical programs which predict combustor flow field properties. Spatial distributions of OH number density and temperature, resulting from analytical flow field calculations, are used as input data for calculating the absolute intensities of the spectra. Of particular interest is the ability to calculate the shapes of the intensity envelopes associated with the low resolution slit settings of a given spectrometer. Comparisons are made with actual spectral data obtained with various degrees of spectral resolution. The computer program is also used to generate graphical inversion techniques for analyzing experimental spectra. An example is given in which one such graphical technique is used to obtain average temperatures and number densities along the axis of an axisymmetric duct containing a supersonic diffusion flame. Another example is presented to demonstrate the manner in which a second inversion technique can be used to obtain radial profiles of temperature and OH number density from radial scanning of an axisymmetric combustor flow field. Two cases involving thermodynamic nonequilibrium are also discussed, one of which involves a hot vibrational band and the other an electronic nonequilibrium. Author

N75-30367 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
ANALYTICAL METHOD FOR PREDICTING CHEMICAL REACTION RATES IN THE PRESENCE OF INHOMOGENEOUS TURBULENCE (APPLICATION TO TURBULENT COMBUSTION) [METHODE ANALYTIQUE DE PREVISION DES TAUX DE REACTION CHIMIQUE EN PRESENCE D'UNE TURBULENCE NON HOMOGENE (APPLICATION A LA COMBUSTION TURBULENTE)]
Roland Borghi *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 28 p refs In FRENCH, ENGLISH summary (For availability see N75-30359 21-31)

A theoretical approach to the reciprocal influence between turbulence and chemical reactions is presented. The approach is based on a conventional method for studying turbulence in inhomogeneous, nonreactive flows, where the fluctuation evolution is followed and calculated by the evolution of their moments of order two. A quantitative calculation of the influence of turbulence on reaction rates is obtained by adding numerical calculation to analytical analysis. Author

N75-30368 California Univ., La Jolla. Dept. of Applied Mechanics and Engineering Sciences
STUDIES RELATED TO TURBULENT FLOWS INVOLVING FAST CHEMICAL REACTIONS
Paul A. Libby *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 18 p refs (For availability see N75-30359 21-31)

Turbulent flows involving chemical reactions in the simplest chemical system, fuel-oxidizer resulting in a single product are investigated. The conditions of the flow are assumed to be such that at a molecular level the reactions are infinitely fast. In this limiting case the properties of the turbulence determine the extent of chemical reaction. The physical picture of the chemical aspects of the flow which results from the assumption of fast chemistry and the experimental evidence to support this picture are emphasized. The mathematical consequences appropriate for the case of highly dilute reactions is then developed; it is shown that the crux of the problem of describing analytically the mean composition field resides in knowledge of rather detailed properties of a synthetic scalar quantity whose behavior can be related to that of a passive scalar in turbulent flows, for example, temperature or the concentration of helium in helium-air mixtures. In particular, it is shown that if at each point in the flow in question the probability density function of a synthetic scalar quantity is known, then the mean composition and the mean rate of creation of each species is determined. The results of calculations of a two-dimensional mixing layer with fuel in one stream and with oxidizer in the second stream are given. The results show the expected finite reaction zone. Author

N75-30369 Laboratoire d'Aerothermique du C.N.R.S., Meudon (France)
QUASI-EQUILIBRIUM METHOD FOR STUDY OF RELAXED FLOW [METHODE DE QUASI-EQUILIBRE POUR L'ETUDE DES ECOULEMENTS RELAXES]
R. Prudhomme *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 17 p refs In FRENCH; ENGLISH summary (For availability see N75-30359 21-31)

A quasi-equilibrium method which computes the evolution of a steady one dimensional relaxed flow is presented along with flow conservation equations written for a multireaction system. Numerical results are given for mixtures of H-H2 and H-H2-HF-F2. Other topics considered include integration stability, mass flow rate determination, and transonic zone. Author

N75-30370 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany) Space Div
CALCULATION OF THE EFFECT OF AFTERBURNING IN EXTERNAL SUPERSONIC FLOW BY MEANS OF A METHOD OF CHARACTERISTICS WITH HEAT ADDITION AND MIXING LAYER ANALYSIS
P. Mittelbach *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 16 p refs (For availability see N75-30359 21-31)

A method is described for the calculation of the effect of afterburning in supersonic flow in the vicinity of a base body on the pressure distribution along this body. The basis for it is a method of characteristics, where the heat addition is prescribed. Information on the distribution of heat sources is gained by an analysis of the turbulent reacting mixing layer applying the Patankar/Spalding boundary layer program. Examples showing the usefulness of this approach are given. Author

N75-30371* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
SUPERSONIC MIXING AND COMBUSTION IN PARALLEL INJECTION FLOW FIELDS
John S. Evans and Griffin Y. Anderson *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 8 p refs (For availability see N75-30359 21-31)
CSCL 20D

Adequate prediction techniques for supersonic, mixing, reacting flows are of great importance in the design and performance analysis of supersonic combustion ramjet (scramjet) engines. Analytical programs for parallel injection flow fields with chemical reaction and turbulent mixing are now available for both single and multiple-jet flows. The application of these analyses to simple flow geometries is discussed, and comparisons also are made with data on the more complex case of multiple-jet, reacting flows. A review is given of Langley investigations of parallel injection flow fields. Among these are single-jet studies of nonreacting, turbulent mixing (H2 in air and H2 in N2), and of reacting turbulent mixing (H2 in air) with both single and multiple jets. Implications of the results of the studies for scramjet fuel injector design are discussed. Author

N75-30372 Naples Univ. (Italy). Inst. of Aerodynamics
TURBULENT BOUNDARY LAYER IN HYBRID PROPELLANTS COMBUSTION
R. Monti *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 21 p refs (For availability see N75-30359 21-31)

Hybrid propellant combustion models (solid fuel and liquid oxidizer) are reviewed. The general equations for turbulent boundary layer combustion, together with the interface boundary conditions, are written. Combustion theories and working formula for solid fuel regression rates assume different orders of magnitude for the characteristic time ratios of the relevant processes (i.e. fuel vaporization, gas-phase chemical reactions, and oxidizer diffusion). It is shown that the models based on finite characteristic time for diffusion and chemical reaction explain the experimentally observed regression rate dependence on both mass flux and combustion pressure. Author

N75-30373 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (West Germany)
SOME PROBLEMS AND ASPECTS IN COMBUSTOR MODELLING
F. Suttrop *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 6 p (For availability see N75-30359 21-31)

Development of a theoretical combustor model that predicts CO and NO emissions and is applicable to industrial burners as well as gas turbines is described. Factors considered include: determination of the amount of NO formed in the flame front; selection of the correct rate constant for the reaction which controls NO formation; the temperature drop caused by radiation; and the effect of the initial amount of radicals on the NO formation. J.M.S.

N75-30374 Sheffield Univ. (England). Dept. of Chemical Engineering and Fuel Technology.
MEASUREMENT IN TURBULENT FLOWS WITH CHEMICAL REACTION
N. A. Chigier *In* AGARD Anal. and Numerical Methods for Invest. of Flow Fields with Chem. Reactions, Especially Related to Combust. May 1975 18 p refs (For availability see N75-30359 21-31)

Measurements in turbulent flows are considered particularly for their relevance to the prediction of flows with combustion. The relative accuracy of instruments used for the measurement of velocity, temperature, gas, and solid concentrations is discussed and examples are given of changes in the magnitudes of flame properties as measuring techniques have improved. The requirement of varying the time period for averaging according to the local conditions is stressed and it is shown that, under certain conditions, the averaging procedure can conceal the physical nature of the phenomena that is being measured. The disturbance to the flow and the errors introduced by using water-cooled pitot tubes for velocity, suction pyrometers for temperature, and relatively large water-cooled suction probes for particle and gas analysis are discussed. It is argued that future measurements in flames should be made with laser probes and that all measurements should be made optically, without the introduction of physical probes. Developments in laser anemometry and laser Raman spectroscopy are reviewed. Examples are given of measurement by laser probes of velocity in flames with swirl and of temperature and specie concentration in turbulent diffusion flames. The important role of accurate measurement in the formulation and testing of analytical and numerical prediction theories is stressed. Author

N75-30375 Technische Hogeschool, Delft (Netherlands). Dept. of Mechanical Engineering

SOME MEASUREMENTS AND NUMERICAL CALCULATIONS ON TURBULENT DIFFUSION FLAMES a24
Th. T. A. Paauw *In* AGARD Anal. and Numerical Methods for Invest. of Flow Field with Chem. Reactions, Especially Related to Combust. May 1975 11 p refs (For availability see N75-30359 21-31)

Measurements and the result of calculations are presented for the combustion flow field in a conical furnace, constructed so that boundary layer approximations are valid. Two types of flames are observed, an attached and a lifted flame. Measurements of temperature, velocity, and the mass fractions of N2, O2, CH4, and NO are obtained for the radial profiles at different distances along the cone. It is shown that the measured concentration of NO is sensitive to the flame type. Author

N76-11306# Advisory Group for Aerospace Research and Development, Paris (France).
LASER HAZARDS AND SAFETY IN THE MILITARY ENVIRONMENT
Aug. 1975 105 p refs Conf. held at Germany, 22-23 Sep. 1975, The Netherlands, 25-26 Sep. 1975, and Norway, 1-2 Oct. 1975; sponsored by the Aerospace Medical Panel and the Consultant and Exchange Panel of AGARD
(AGARD-LS-79) Avail: NTIS HC $5.50

A review of the theory, principles, and applications of laser systems was presented, with special emphasis on associated possible accidental injuries, safety precautions and codes, protective devices. For individual titles, see N76-11307 through N76-11316.

N76-11307 Western Ontario Univ., London. Dept. of Physics.
PROPERTIES OF ELECTROMAGNETIC RADIATION
J. Wm. McGowan *In* AGARD Laser Hazards and Safety in the Mil. Environ. Aug. 1975 9 p refs (For availability see N76-11306 02-31)

The basic principles dealing with electromagnetic radiation were discussed, particularly as they relate to the development of the Laser and insofar as life processes are affected by light. It was pointed out that, although the electromagnetic spectrum extends over more than thirty orders of magnitude, that portion of it now dominated by the Laser only includes four. It is through this range that all life processes are affected by light and, in particular, the eye can easily be damaged by it. Author

N76-11308 Western Ontario Univ., London. Dept. of Physics.
LASERS
J. Wm. McGowan *In* AGARD Laser Hazards and Safety in the Mil. Environ. Aug. 1975 12 p refs (For availability see N76-11306 02-31)

Principles and properties of the laser were discussed in some detail together with a description of the various types of lasers and their applications. Author

N76-11309 Army Environmental Hygiene Agency, Aberdeen Proving Ground, Md. Laser Microwave Div.
INSTRUMENTATION AND MEASUREMENT OF LASER RADIATION
David H. Sliney *In* AGARD Laser Hazards and Safety in the Mil. Environ. Aug. 1975 9 p refs (For availability see N76-11306 02-31)

New laser instruments and measurement techniques evolved during the past decade were reviewed. The measurements of primary interest in the evaluation of laser hazards are: output energy or power, pulse duration, beam profile and divergence, and pulse repetition frequency (PRF). The most useful types of detectors and beam profile methods were discussed. Short-cut check tests were also given. Author

N76-11310 Letterman Army Inst. of Research, San Francisco, Calif. Non-Ionizing Radiation Div.
OCULAR EFFECTS OF LASER RADIATION: CORNEA AND ANTERIOR CHAMBER
Edwin S. Beatrice and Bruce E. Stuck *In* AGARD Laser Hazards and Safety in the Mil. Environ. Aug. 1975 5 p refs (For availability see N76-11306 02-31)

The effects of infrared laser radiation on the cornea and skin of humans were considered. Three areas were discussed: normal anatomy and physiology of both tissues, summary of those laser systems which may interact with these tissues, and effects of these systems on tissues. It is pointed out that threshold damage to the eye from CO2 laser radiation is confined to the more superficial areas of the cornea. At above threshold levels, damage is observed to the entire thickness, and some changes in the anterior chamber are observed. Y.J.A.

N76-11311 Letterman Army Inst. of Research, San Francisco, Calif. Non-Ionizing Radiation Div.
OCULAR EFFECTS OF RADIATION: RETINA
Edwin S. Beatrice *In* AGARD Laser Hazards and Safety in the Mil. Environ. Aug. 1975 4 p refs (For availability see N76-11306 02-31)

A discussion of threshold levels associated with injuries to the primate retina from exposure to visible and near infrared laser radiation was given. It is explained that, while the retina is subdivided into ten identifiable layers, the absorption site of the visible and near infrared laser sources is limited to the melanin granules of the retinal pigment epithelium. The mechanism of injury at the above threshold exposed site is thermal. The endpoint for the determination of threshold levels can be subdivided into three areas: grossly observable retinal opacity level, light microscopic cellular alteration at the distal photoreceptor and pigment epithelial level, and subcellular change at the magnification power of the electron microscopic level. Y.J.A.

N76-11312 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
DETERMINATION OF SAFE EXPOSURE LEVELS: ENERGY CORRELATES OF OCULAR DAMAGE
R. G. Borland *In* AGARD Laser Hazards and Safety in the Mil. Environ. Aug. 1975 6 p refs (For availability see N76-11306 02-31)

Three techniques were used to define practical but safe criteria for use with laser systems. These are: inspection of the eye by optical means (ophthalmoscopy), fluorescein angiography, and microscopy (light and electron). The detection of damage is a form of quantal response and the determination of the threshold level is normally based on the energy or power which will result in a given probability of damage being detected. The energy correlates of damage depend on wavelength, pulse width or exposure time, repetition rate, tissue type and pigmentation, and ocular quality. This complex relationship necessarily limits experimental research to laser systems of special interest and so the interpolation of data to formulate overall safe exposure levels is necessary. Author

N76-11313 Army Environmental Hygiene Agency, Aberdeen Proving Ground, Md. Laser-Microwave Div.
DERIVATION OF SAFETY CODES. 1: USA EXPERIENCE
David H. Sliney *In* AGARD Laser Hazards and Safety in the Mil. Environ. Aug. 1975 13 p refs (For availability see N76-11306 02-31)

A review of the problems encountered in setting safety standards and the complementary laser system classification and field safety controls since 1965 was presented. Originally, only two or three limits were provided. However, since 1972, a sliding scale of limits varying with exposure duration, wavelength, and PRF have been in use, are now standardized throughout the USA, and are described in the paper. Author

N76-11314 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
DERIVATION OF SAFETY CODES. 2: UK EXPERIENCE
R. G. Borland *In* AGARD Laser Hazards and Safety in the Mil. Environ. Aug. 1975 6 p refs (For availability see N76-11306 02-31)

A review of laser safety codes in use in the United Kingdom since 1965 was presented. The initial codes were based on limited experimental data and so tended to be over-cautious. More recent studies have been related to the practical situation of ocular irradiation by parallel beams and have suggested that the retinal radiant exposure for damage increases with decreasing image size; it followed that a considerable relaxation of the recommendations published in 1972 was possible. The British Standards Institute (BSI) has since then recommended adoption of the American Conference of Governmental Industrial Hygienists (ACGIH) exposure levels. Author

N76-11315 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
OPTHALMOLOGICAL EXAMINATION OF LASER WORKERS AND INVESTIGATION OF LASER ACCIDENTS
D. H. Brennan *In* AGARD Laser Hazards and Safety in the Mil. Environ. Aug. 1975 11 p ref (For availability see N76-11306

Those aspects of ocular structure and function which are relevant to laser induced damage in man were discussed, including the transmission and absorption characteristics of ocular tissues and the natural protective mechanisms of the eye. A scheme for the ocular surveillance of laser workers was presented with an evaluation of the role of the field and other specialized examinations. The procedure to be followed in the event of a laser accident was discussed. It is recommended that this involves a biophysical assessment of the accident with particular reference to energy or power densities which may have been incident on the cornea, as well as a detailed ocular examination. This may include fluorescein angiography, which has been found to be a more sensitive technique for detection of damage than ophthalmoscopy in monkeys. Author

N76-11316 Army Environmental Hygiene Agency, Aberdeen Proving Ground, Md. Laser Microwave Div.
LASER PROTECTIVE DEVICES
David H. Sliney *In* AGARD Laser Hazards and Safety in the Mil. Environ. 1975 11 p refs (For availability see N76-11306 02-31)

The ideal characteristics of laser eye protective devices were presented and the present filter materials and goggle designs were compared with the ideal. Although the skin requires protection from lasers emitting in the ultraviolet and far-infrared regions at comparable exposure levels that may cause eye injuries, protection of the eye remains paramount. Author

N77-11221# Advisory Group for Aerospace Research and Development, Paris (France)
APPLICATIONS OF NON-INTRUSIVE INSTRUMENTATION IN FLUID FLOW RESEARCH
May 1976 309 p refs In ENGLISH, partly in FRENCH Presented at the Fluid Dynamics Panel Symp., Saint-Louis, France, 3-5 May 1976
(AGARD-CP-193, ISBN-92-835 0176 4) Avail NTIS HC A14/MF A01

The special and unique advantages of promising measuring concepts such as the Laser Doppler Velocimeter, electron beam, and Raman scattering are described. Emphasis is placed on measuring accuracies, limitations, corrections, and other problem areas. Techniques for measurement of velocity, thermodynamic properties, and other flow characteristics, in turbulent shear layers, flow fields, and combustion-mixing flows are included. For individual titles, see N77-11222 through N77-11248.

N77-11222# Institut Franco-Allemand de Recherches, St. Louis (France)
REVIEW ON HIGH SPEED APPLICATIONS OF LASER ANEMOMETRY IN FRANCE AND GERMANY
H. J. Pfeifer *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 18 p refs (For primary document see N77-11221 02-31)
Avail NTIS HC A14/MF A01

The development and use of laser anemometry in various French and German high-speed wind tunnels is discussed. In these studies the fringe type anemometer was used exclusively because it is insensitive to vibrations and high sound levels. Moreover, this type of anemometer is supposed to give the most accurate results with respect to mean flow velocity and turbulence intensity. This is especially true if electronic counters are used as data acquisition systems. Both the optical arrangements and electronic designs are described in detail. All the investigations described relied on the natural dust particles present in the flow as velocity indicators. As a result of binational cooperation it is shown that in the wind tunnels considered the size distribution of dust particles fulfils almost completely the requirements of negligible particles lag. With some applications in high speed tunnel testing it is proved that laser anemometry is a standard measuring procedure and that it yields results which may not be obtained by other methods. Author

N77-11223# Naval Surface Weapons Center, White Oak, Md.
APPLICATIONS OF THE LASER DOPPLER VELOCIMETER TO MEASURE SUBSONIC AND SUPERSONIC FLOWS
William J. Yanta and Benjamin J. Crapo *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 8 p refs (For primary document see N77-11221 02-31)
Avail NTIS HC A14/MF A01

Measurements with a Laser Doppler Velocimeter (LDV) using the differential Doppler or fringe type of optical system were made in a variety of subsonic and supersonic flows. The application of this instrument at the Naval Surface Weapons Center (NSWC) to determine aerosol size distributions, to measure turbulence properties in supersonic boundary layers, to measure the mixing characteristics of two supersonic flows, and to measure the three-dimensional flow field around an axially symmetric body at large angles of attack in subsonic flow is discussed. Results show that the LDV can be a very useful tool for making nonintrusive measurements. Results also show that since the LDV measurements require micron-size particles to be present in the flow, care must be taken to insure that the particles will follow the flow accurately. Author

N77-11224*# National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
LASER VELOCIMETRY APPLIED TO TRANSONIC AND SUPERSONIC AERODYNAMICS
D. A. Johnson, W. D. Bachalo, and D. Moddaress *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 12 p refs (For primary document see N77-11221 02-31)
Avail NTIS HC A14/MF A01

As a further demonstration of the capabilities of laser velocity in compressible aerodynamics, measurements obtained in a Mach 2.9 separated turbulent boundary layer and in the transonic flow past a two-dimensional airfoil section are presented and compared to data realized by conventional techniques. In the separated-flow study, the comparisons were made against pitot-static pressure data. Agreement in mean velocities was realized where the pressure measurements could be considered reliable, however in regions of instantaneous reverse velocities, the laser results were found to be consistent with the physics of the flow whereas the pressure data were not. The laser data obtained in regions of extremely high turbulence suggest that velocity biasing does not occur if the particle occurrence rate is low relative to the turbulent fluctuation rate. Streamwise turbulence intensities are also presented. In the transonic airfoil study, velocity measurements obtained immediately outside the upper surface boundary layer of a 6-inch chord MACA 64A010 airfoil are compared to edge velocities inferred from surface pressure measurements. For free-stream Mach numbers of 0.6 and 0.8, the agreement in results was very good. Dual scatter optical arrangements in conjunction with a single particle, counter-type signal processor were employed in these investigations. Half-micron-diameter polystyrene spheres and naturally occurring condensed oil vapor acted as light scatterers in the two respective flows. Bragg-cell frequency shifting was utilized in the separated flow study. Author

N77-11225# Arnold Engineering Development Center, Arnold Air Force Station, Tenn.
APPLICATION OF THE DUAL-SCATTER LASER VELOCIMETER IN TRANSONIC FLOW RESEARCH
V. A. Cline (ARO, Inc., Arnold AF Station, Tenn.) and C. F. Lo (ARO, Inc., Arnold AF Station, Tenn.) *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 12 p refs (For primary document see N77-11221 02-31)
Avail NTIS HC A14/MF A01

Topics, such as signal processing, signal-to-noise ratio, bandwidth, spatial resolution, and accuracy, are discussed in general for typical laser velocimeter (LV) systems. The particle lag problem and a data analysis scheme to minimize its effect are presented. Two experiments in a typical continuous aerodynamic transonic wind tunnel are discussed to demonstrate the technique. The data shown were taken with a two-component, dual-scatter, Bragg-cell type LV collecting back-scatter radiation from the ambient aerosol particles. The velocity field ahead of a hemisphere cylinder was measured at low supersonic Mach numbers in the first experiment. The boundary-layer velocity characteristics in the shock layer interaction region on a two-dimensional floor-mounted bump were also investigated. Both experiments pointed out the need for extreme care in data interpretation in certain flow regions. A new technique in data processing, designed to improve accuracy and increase data rate, is briefly introduced. Author

N77-11226# Royal Aircraft Establishment, Bedford (England).
THE APPLICATION OF A LASER ANEMOMETER TO THE INVESTIGATION OF SHOCK-WAVE BOUNDARY-LAYER INTERACTIONS
I. F. East *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 10 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

A detailed investigation of the interaction region of a normal shock wave and a two-dimensional turbulent boundary layer is described. The measurements were made with a two component

laser anemometer operating in the Doppler-difference mode and in backscatter. The details of the instrument and the method of analyzing the data are described. Shock wave boundary layer interactions with upstream Mach numbers of approximately 1.3, 1.4 and 1.64 were studied. The tests were made in the RAE 3ft x 3ft tunnel on the floor of the working section which was modified to be 915 mm wide by 762 mm high. The velocity and its direction were measured at about 1000 points. Both the complex inviscid interaction region of the flow as well as the boundary layer were investigated and an attempt was also made to make measurements in the separated flow. The emphasis is on demonstration of the capabilities of the laser anemometer rather than interpretation of the fluid mechanics. Author

N77-11227# Kent Univ., Canterbury (England). Physics Lab.
SUPERSONIC VELOCITY AND TURBULENCE MEASUREMENTS USING A FABRY-PEROT INTERFEROMETER
D. A. Jackson and P. L. Eggins *In* AGARD Appl. of Non Intrusive Instr. in Fluid Flow Res. May 1976 13 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

The laser Doppler technique in which the frequency shift is analyzed using a high resolution confocal Fabry-Perot interferometer is discussed. Details of typical optical arrangements are given together with the associated electronic instrumentation used for data collection and signal processing. Experimental results are given for measurements made in a wide variety of experimental situations including flows with interacting shock fronts, turbulence, and large velocity gradients. Author

N77-11228# Institut Franco-Allemand de Recherches, St. Louis (France)
RECENT APPLICATIONS OF ISL OF THE LASER VELOCIMETER MEASUREMENTS IN TURBULENT FLOWS [APPLICATIONS RECENTES, A L'ISL, DE LA VELOCIMETRIE LASER AUX MESURES DANS DES ECOULEMENTS TURBULENTS]
X. Bouis *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 12 p refs In FRENCH; ENGLISH summary (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

Introductory remarks deal with the accuracy and space/time resolution which can be attained with LDV systems in turbulent or high-velocity gradient flows. Some examples are given of the possibility of obtaining turbulent spectrum, autocorrelation, and simultaneous measurements of two velocity components. Already, these new methods give valuable information on transonic or heated flows. In the present phase however it is essential to strongly increase data rates and processing when time correlations are requested. Author

N77-11229# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium)
ANALYSIS OF THE OUPUT DATA OF A LASER DOPPLER VELOCIMETER
M. L. Riethmuller *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 11 p (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

Laser Doppler Velocimeter measurements in gas flows require as low a seeding as possible. Such conditions can only be accommodated by period counters. These instruments have to process a signal with low signal to noise ratios. The smaller the number of signals, the lower the SNR. These processors have built-in noise rejection devices. One of them is a comparator which allows a selection of signal on an amplitude criterion. The response of the period counter to variable comparator or trigger level is analyzed and a systematic procedure is proposed for its adjustment. Author

N77-11230# California Inst. of Tech., Pasadena. Dept. of Aeronautics
SINGLE SCATTERING PARTICLE LASER DOPPLER MEASUREMENTS OF TURBULENCE
Paul E. Dimotakis *In* AGARD Appl. of Non Instrusive Instr. in Fluid Flow Res. May 1976 14 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

Data reduction techniques are described to circumvent the problems of random, biased sampling of single scattering particle laser Doppler velocity measurements in turbulent flow. Two different methods are developed. For high mean data rates all statistical quantities are computed in an unbiased fashion through the use of time integrals. For low mean data rates statistical quantities can be computed in terms of ensemble averages where each event is weighed by the probability of its occurrence. The latter method will usually require a simultaneous measurement of at least two of the three velocity components of a single particle, and possibly all three depending on the shape of the local volume. These techniques allow reliable measurements to be extracted from the data in cases where the scattering particle number density is uncorrelated with the local velocity vector. Other topics discussed include (a) minimum sampling rate required if time integrals are used to compute averages and if no spectral information is desired; (b) frequency response of single scattering particle laser Doppler velocity; (c) apparent turbulence due to finite extent of measurement volume and curvature of velocity space correlation at the origin; and (d) flows for which laser Doppler velocimetry may not be a satisfactory measurement method. Author

N77-11231# Royal Aircraft Establishment, Farnborough (England).
DEVELOPMENT OF PHOTON CORRELATION ANEMOMETRY FOR APPLICATION TO SUPERSONIC FLOWS
J. B. Abbiss *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 11 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

The development is described of a laser anemometer based on a photon correlator for experimental applications in transonic and supersonic wind tunnels at the Royal Aircraft Establishment. The equipment was designed to operate with a differential Doppler optical system in the backscatter mode in order to minimize the problems associated with traversing and alignment. The light source is an argon-ion laser which can be operated simultaneously at several frequencies in the visible spectrum. After initial experiments with an unseeded laminar flow in a small test section at Mach numbers up to 2.5, two component measurements were made on the flow around a cone at zero incidence in a laminar supersonic airstream. For these experiments the strong lines at 488 and 514.5 nanometers in the laser output were used, together with two Doppler difference optical systems and separate detectors. Controlled seeding with micron-sized particles was provided by an oil mist generator. The results of these experiments, together with those obtained with the same arrangement in a turbulent supersonic boundary layer, are presented. The principles of the photon correlation method are discussed and consideration is given to the experimental criteria which should be met in order to facilitate interpretation of the autocorrelation function. Author

N77-11232# Edinburgh Univ. (Scotland)
MEASUREMENT OF PERIODIC FLOWS USING LASER DOPPLER CORRELATION TECHNIQUES
F. H. Barnes, Q. I. Daudpota, T. S. Durrani (Southhampton Univ., Engl.), I. Grant (Napier Coll. of Tech., Edinburgh, Scotland), and C. A. Greated *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 10 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

The application of photon correlation methods to the measurement of sinusoidally fluctuating flows is described. It is shown that with a laser Doppler optical configuration the correlation function for the Doppler signal is periodic with zero order Bessel function damping and that the amplitude of the velocity perturbation can easily be determined by locating the position of zeros of the Bessel function. For a two beam configuration, the cross correlation function is a distorted form of the velocity probability density function. Experiments were performed in a low turbulence wind tunnel in the wake of a circular cylinder using photon counting techniques for the Doppler signal analysis. The results of these experiments show the characteristic forms taken on by the correlation functions in the different locations. Measurements of velocity perturbation amplitudes obtained by visual inspection of the correlograms agree well with hot wire results. A curve fitting procedure for more accurate evaluation of the flow parameters is described. Author

N77-11233# George Washington Univ., Washington, D.C. School of Engineering and Applied Sciences
OPTICAL MEASUREMENTS OF THERMODYNAMIC PROPERTIES IN FLOW FIELDS. A REVIEW
R. Goulard *In* AGARD Appl. of Non Intrusive Instr. in Fluid Flow Res. May 1976 18 p refs (For primary document see

Avail: NTIS HC A14/MF A01

The state of the art in optical measurement techniques in high temperature flows is assessed. Several forums and workshops were held on the subject in 1974 and 1975. A number of review papers on specific techniques appeared also during this period. This review discusses the performance criteria of interest in gas dynamics and evaluates the various existing or proposed techniques in the context of their use in basic and applied configurations. Author

N77-11234# Office National d'Etudes et de Recherches Aerospatiales, Paris (France)

LASER RAMAN DIAGNOSTICS OF AERODYNAMIC FLOWS AND FLAMES

Sylvie Druet, Robert Sailly, Michel Pealat, and Jean-Pierre Taran *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 12 p refs In FRENCH; ENGLISH summary (For primary document see N77-11221 02-31)

Avail: NTIS HC A14/MF A01

Spontaneous Raman Scattering (SRS) is used for nonintrusive point concentration and temperature measurements in gas flows and reactive media. The main properties of the method and some of its typical achievements are reviewed. A second technique, coherent anti-Stokes Raman scattering (CARS) was developed and is found superior in the area of luminosity. An account of the limitations and of the field of applications of CARS is given. Author

N77-11235# Institut Franco-Allemand de Recherches, St. Louis (France).

LOCAL MEASUREMENT AND PROPORTIONAL DENSITY OF GASEOUS FLOW BY RAMAN ANTI-STOKES COHERENT SCATTERING [MESURE LOCALE ET CONTINUE DE LA DENSITE D'UN ECOULEMENT GAZEUX PAR DIFFUSION COHERENTE RAMAN ANTI-STOKES]

A. Hirth *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 7 p refs In FRENCH; ENGLISH summary (For primary document see N77-11221 02-31)

Avail: NTIS HC A14/MF A01

Coherent Raman scattering offers new possibilities for measuring concentrations and temperatures in gas flows. This technique was achieved by means of an original apparatus using two CW lasers as excitation sources. This allows the measurement of local density fluctuations in a flow. The experimental arrangement is described, its performances are analyzed (temporal and spatial resolution), limitations of the method are studied (the laser emission is disturbed when the flow is inside the cavity), and further improvements are proposed. The first results obtained with a N sub 2 flow are presented. Author

N77-11236# Princeton Univ., N.J. Gas Dynamics Lab.

THE ELECTRON BEAM FLUORESCENCE TECHNIQUE APPLIED TO HYPERSONIC TURBULENT FLOWS

Jerome A. Smith and James F. Driscoll (Michigan Univ.) *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 10 p refs (For primary document see N77-11221 02-31)

Avail: NTIS HC A14/MF A01

Several factors concerning the use of the electron beam fluorescence technique to make time resolved density and temperature measurements in relatively high density turbulent flows are discussed. Experience derived from a recent study of a M = 16.3 adiabatic tunnel wall boundary layer in helium is used to outline many difficulties to be encountered in the application of this broad bandwidth, nonintrusive technique to study hypersonic turbulent flows in general. Collision quenching, attenuation and other beam broadening effects are described. In addition, data analysis procedures often asymmetrically distributed about the mean fluctuations are discussed. For example, evidence is presented to show that mean intensity data does not provide mean flow property information in general. Primary emphasis is on results obtained in helium with recent work by others in air and nitrogen flows cited, especially where differences exist. Author

N77-11237# Massachusetts Inst. of Tech., Cambridge. Dept. of Mechanical Engineering.

QUALITATIVE AND QUANTITATIVE FLOW FIELD VISUALIZATION UTILIZING LASER-INDUCED FLUORESCENCE

C. Forbes Dewey, Jr. *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 7 p refs (For primary document see N77-11221 02-31)

Avail: NTIS HC A14/MF A01

Liquids or gases containing fluorescence molecules may be stimulated in a spatially controlled manner by the use of a laser. The resulting patterns of fluorescence may be analyzed to yield spatially resolved information on flow velocity, density, and mass transfer. Information may be recorded on TV tape, photographically, or monitored using focused optics and a photodiode detector. Several examples are described to illustrate the method, mass transfer between an external flow and a region of separation; visualization of axisymmetric starting vortices; location of turbulent reattachment points, and instability modes of confined jets. Author

N77-11238# Office National d'Etudes et de Recherches Aerospatiales, Paris (France)

CHARACTERIZATION OF NOISE SOURCES IN HOT JETS BY THE CROSSED BEAM TECHNIQUE [CARACTERISATION DES SOURCES DE BRUIT DANS LES JETS CHAUDS PAR LA TECHNIQUE DES FAISCEAUX CROISES]

Mariano Perulli, Jean-Francois DeBelleval, and Jean Maulard *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 11 p refs In FRENCH; ENGLISH summary (For primary document see N77-11221 02-31)

Avail: NTIS HC A14/MF A01

The sounding of simple or coaxial, cold or hot free jets by optical systems makes up a measuring means external to the medium investigated. More especially, the use of radiometers measuring infrared emissions gives access to spatio-temporal data that are tightly coupled to turbulence parameters. These data can be obtained by crossed beam techniques. The physical meaning of the signals issued from the radiometers, as well as their interpretation after processing, are discussed and compared with those obtained by other types diagnostic. In spite of the difficulties pertaining to the optical system and to the crossed beam measuring technique, it is shown, as a conclusion, that this methodology does, in some precise cases, reach its objective: to characterize noise sources. Author

N77-11239# Princeton Univ., N.J.

RESONANT DOPPLER VELOCIMETER

Richard B. Miles *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 8 p refs (For primary document see N77-11221 02-31)

Avail: NTIS HC A14/MF A01

Resonance fluorescence is a potentially useful tool for studying hypersonic flowing gases. This paper discusses the measurement of velocities and demonstrates visualization techniques using sodium seeded into helium flows. A narrow linewidth dye laser is tuned onto the sodium resonance line. The Doppler shift of the absorption frequency yields the velocity profile, and the fluorescence provides direct flow visualization. Other flow properties such as the turbulence frequency, temperature, etc. may also be measured. Author

N77-11240# Purdue Univ., Lafayette, Ind. Applied Optics Lab.

FRINGE MODE FLUORESCENCE VELOCIMETRY

Warren H. Stevenson, Reginaldo DosSantos, and Stephen C. Mettler *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 9 p refs (For primary document see N77-11221 02-31)

Avail: NTIS HC A14/MF A01

A modified technique in which the standing electromagnetic field induces a time varying fluorescent emission from liquid droplets doped with a suitable organic dye is described. The fluorescence consists of a band of wavelengths not including the incident laser light and therefore can be passed by a filter which blocks the laser wavelength. This can significantly improve the signal to noise ratio or allow signal detection only from those particles deliberately added to the flow. An extensive study was carried out to determine factors which influence the quality of the fluorescence signal. The effect of dye concentration in the solvent and other environmental factors were investigated. Data obtained to date indicate that the fluorescence signal is of the same order of magnitude as the scattered light signal only in the case of a backscatter system. Author

N77-11241# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt e.V., Linder Hoehe (West Germany).

THE LASER-DUAL-FOCUS FLOW VELOCIMETER

R. School *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 9 p refs (For primary document see N77-11221 02-31)

Avail: NTIS HC A14/MF A01

The use of a low cost rotating radial diffraction grating as a beam splitting frequency shifter for operation in laser Doppler

velocimeter systems is discussed. A high efficiency phase grating is used that can be exposed to high power laser beams. A compact optical design is described having a grating disc with a diameter of 35 mm and a line density of 166 line pairs per mm. Several optical arrangements, operating as well in the fringe mode as in the reference beam mode, are studied. The advantages of these arrangements are the simple set-up and the ease of optical alignment, which become significant for the two and three component systems. Author

N77-11242# Technisch Physisch Dienst TNO-TH, Delft (Netherlands)
THE USE OF ROTATING RADIAL DIFFRACTION GRATINGS IN LASER DOPPLER VELOCIMETRY
J. Oldengarm *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 6 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

The use of a low cost rotating radial diffraction grating as a beam splitting frequency shifter for operation in laser Doppler velocimeter system is considered. A high efficiency phase grating is used that can be exposed to high power laser beams. A compact optical design is described having a grating disc with a diameter of 35 mm and a line density of 166 line pairs per mm. Several optical arrangements, operating as well in the fringe mode as in the reference mode, are discussed. The advantages of these arrangements are the simple set-up and the ease of optical alignment which become significant for the two and three component systems. Author

N77-11243# Atomic Energy Commission Research Establishment, Risø (Denmark). Electronics Dept.
THE TIME-OF-FLIGHT LASER ANEMOMETER
L. Lading *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 20 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

The time of flight laser anemometer is based on measuring the time of flight between two small volumes in space by correlation techniques. It is shown that this anemometer can generally give the same kind of information as can be obtained with a laser Doppler anemometer, and that in some specific cases the space time resolution is even better than for the laser Doppler anemometer. The uncertainties on the measured values are discussed in relation to the statistical properties of the measuring system and signal processing. The effects of spatial and temporal velocity fluctuations are analyzed. With the anemometer it is possible to obtain a particle size versus particle velocity spectrum, provided that the particles are larger than the focal beam diameters in the flow direction. The anemometer was used for measurements in a two phase flow surrounding a simulated fuel rod. The configuration was also used under extremely low light level conditions (an average number of photon counts less than one per transit through one spot) to measure gas velocity. Author

N77-11244# Ruhr Univ., Bochum (West Germany).
CURRENT PROBLEMS OF OPTICAL INTERFEROMETRY USED IN EXPERIMENTAL GAS DYNAMICS
Wolfgang Merzkirch *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 11 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

Optical interferometry is surveyed for its role to deliver quantitative values of gas density and concentration when applied to gas dynamic measurements. It is shown that optical interferometers can be classified into two groups, according to their ability to measure either the density directly or the density gradient. Emphasis is placed on two major problems: the evaluation of interferograms taken of three dimensional test fields, and the correction for light refraction in fields with strong refractive index gradient. Author

N77-11245# Politecnico di Milano (Italy)
FLOW FIELD IN THE WAKE OF A BLUNT BODY BY LASER DOPPLER ANEMOMETRY
F. Cignoli, A. Coghe, U. Ghezzi, and S. Pasini *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 11 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

The flow field in the wake of a blunt body was investigated by laser Doppler anemometry. The cold flow and the flow with chemical reactions was considered in order to determine directly the combustion influence on the flow field. Premixed methane-air flame was obtained with a 20 mm inner diameter tube burner. A disc of the same external diameter was positioned, coaxially, 30 mm higher on the burner mouth. Both the situations, where the blunt body is only an obstacle generating a wake and where it acts as a flame stabilizer, were analyzed. Flame front crossing, in laminar premixed flames, was also carefully analyzed. Experiments were carried out by means of different LDA signal processors and in different conditions of scattering particles. Both the mean and fluctuating velocities were measured in the axial and radial directions. The analysis of results was not intended to a flame structure discussion, but rather to a critical examination of LDA measurements in connection with some specific problems: particle behavior, turbulence effects, resolution of turbulence fluctuations, minimum particle concentration, performances of different LDA signal processor. Author

N77-11246# National Gas Turbine Establishment, Pyestock (England).
INVESTIGATION OF A V-GUTTER STABILIZED FLAME BY LASER ANEMOMETRY AND SCHLIEREN PHOTOGRAPHY
H. Clare, D. F. G. Durao (Imperial College, London), A. Melling (Imperial College, London), and J. H. Whitelaw (Imperial College, London) *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 10 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

Laser Doppler anemometry was used to study premixed propane air flames stabilized on a V gutter, both in smooth combustion and in buzz. Axial velocity measurements in the wake of the gutter were made in an isothermal flow and in a combusting flow to examine the influence of combustion on the velocity distribution and the recirculation zone length. Velocities outside the wake in a moderate buzz condition were measured, but velocity pulsations corresponding to the regular fluctuations in static pressure observed by means of a pressure transducer mounted in the duct wall could not be detected by the technique used. A separate study using high speed cine schlieren photography, has revealed cyclic variations in the flame structure at the same frequency as the observed pressure pulsations. Author

N77-11247# United Technologies Research Center, East Hartford, Conn.
SIMULTANEOUS LASER MEASUREMENTS OF INSTANTANEOUS VELOCITY AND CONCENTRATION IN TURBULENT MIXING FLOWS
F. K. Owen *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 7 p refs (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

A nonperturbing capability for the simultaneous, local measurement of instantaneous velocity and concentration was developed and is described. The technique is being used in the study of turbulent mixing flow fields and its application is illustrated by measurements obtained in the initial mixing region of two confined coaxial jets. Author

N77-11248# Brown Univ., Providence, R. I.
A THREE-COMPONENT LASER-DOPPLER-VELOCIMETER
T. Gunnar Johansson (Chalmers Univ. of Tech., Sweden), Lars F. Jernqvist (Chalmers Univ. of Tech., Sweden), Sture K. F. Karlsson, and Nils Froessling (Chalmers Univ. of Tech., Sweden) *In* AGARD Appl. of Non-Intrusive Instr. in Fluid Flow Res. May 1976 4 p (For primary document see N77-11221 02-31)
Avail: NTIS HC A14/MF A01

The development of a three component laser Doppler velocimeter is described. It utilizes four incoming beams which are all frequency shifted. Three of the beam propagate in one plane and form three dual beam arrangements. Two of these are used to measure two independent velocity components in this plane. The fourth beam propagates outside this plane and forms together with one of the first three beams a third dual beam arrangement, which measures a velocity component in a direction out of the plane formed by the first three beams. The frequency shifts are chosen so that three signals can be identified corresponding to three independent directions. The system is to be tended to measurements in five points simultaneously. The signal is fed into three phase locked loops and the frequencies generated by their local oscillators are counted, sampled digitally and stored on magnetic tape for later processing on a digital computer. Author

32 COMMUNICATIONS

Includes land and global communications, communications theory; and optical communications. For related information see also *04 Aircraft Communications and Navigation* and *17 Spacecraft Communications, Command and Tracking*.

N74-20889# Advisory Group for Aerospace Research and Development, Paris (France).
STANDARDIZATION OF THE PRINCIPAL ELECTROMAGNETIC SYMBOLS
P. Halley (Centre Natl. d'Etudes des Telecomun., Issy-les-Moulineaux) Feb. 1974 30 p in ENGLISH and FRENCH Revised
(AGARD-R-576-Rev-1) Avail: NTIS HC $4.50

Standard notations, symbols, and units used to express dimensionless values or numbers which pertain to electromagnetism are listed. E.H.W.

N74-31812# Advisory Group for Aerospace Research and Development, Paris (France).
NONLINEAR EFFECTS IN ELECTROMAGNETIC WAVE PROPAGATION
May 1974 397 p refs Presented at Electromagnetic Wave Propagation Panel Symp., Edinburgh, 12-15 Nov. 1973
(AGARD-CP-138) Avail: NTIS HC $23.00

The excitation of parametric instabilities in the ionosphere and their effects on radio wave propagation are considered. For individual titles, see N74-31813 through N74-31844.

N74-31813 Raytheon Co., Sudbury, Mass.
INTRODUCTORY SURVEY: POTENTIAL APPLICATIONS OF IONOSPHERIC MODIFICATION TO AERONOMY
Gerald Meltz *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 26 p refs (For availability see N74-31812 21-13)

Ionospheric heating by powerful radio waves holds promise for establishing new techniques in the aeronomy of D, E and F-regions. This survey reviews the observed phenomena associated with absorption of HF waves in the context of present theoretical understanding of plasma temperature and density changes, enhanced visible airglow emission and parametric excitation of plasma waves. Cooling rates and electron thermal conductivity are attainable from optical and incoherent scatter, measurements of the spatial and temporal changes in electron temperature. Cross modulation experiments or partial reflection techniques could be used to simultaneously measure these changes from which the ambient effective recombination rate and its electron temperature dependence could be inferred. The decay of enhanced airglow yields an estimate of the quenching coefficient and hence the neutral density provided the interaction is a local one. The decay of enhanced plasma waves measures the electron-ion collision frequency at night and the photoelectron flux during the day. Superthermal plasma wave intensities also act as a tracer of density irregularities and plasma drift since parametric pumping acts over a very narrow range of altitudes. Author

N74-31814 Institute for Telecommunication Sciences, Boulder, Colo.
INTRODUCTORY SURVEY: A SURVEY OF IONOSPHERIC MODIFICATION EFFECTS PRODUCED BY HIGH POWER HF RADIO WAVES
William F. Utlaut *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 17 p refs (For availability see N74-31812 21-13)

Experiments with high power, high frequency radio waves have proved the feasibility of temporarily altering the ionosphere's properties. Many different radio and photometric effects have been observed as a result of the ionospheric modification. A survey is given of some of the effects observed near Boulder, Colorado which are produced at times when a 2 MW facility is used to illuminate the overhead ionosphere. Effects to be discussed include artificial generation of spread F, sky mapping of the perturbed ionosphere, wideband attenuation of diagnostic o-mode waves, 6300 A and 5577 A photometric changes and D-region cross modulation phenomena. Author

N74-31815 Rice Univ., Houston, Tex.
PARAMETRIC INSTABILITIES IN THE IONOSPHERE EXCITED BY POWERFUL RADIO WAVES OBSERVED OVER ARECIBO
W. E. Gordon and H. C. Carlson (Arecibo Obs.) *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 17 p refs (For availability see N74-31812 21-13)

Enhancements of various features of the incoherent scatter spectrum are observed when the ionosphere is illuminated with powerful, high frequency radio waves. The radio waves excite plasma instabilities producing lines or more complex spectral features near the local plasma frequency, at the local ion-acoustic frequency, near the local gyrofrequency and twice the gyrofrequency. The enhancements occur in a thin slab as observed by the incoherent scatter radar and at both upshifted and downshifted frequencies with respect to the probing radar frequency. The enhancements are observed to vary with time when the high frequency transmitter that produces the radio wave excitation is held at constant power, and to vary with time as the high frequency transmitter is turned on or off. Author

N74-31816* Norges Tekniske Hoegskole, Trondheim.
OBSERVATIONS OF ENHANCED ION LINE FREQUENCY SPECTRUM DURING ARECIBO IONOSPHERIC MODIFICATION EXPERIMENT
T. Hagfors and C. J. Zamlutti *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 13 p refs Sponsored in part by NASA (For availability see N74-31812 21-13)

The Arecibo 430 MHz incoherent scatter radar (ISR) was used to monitor the effects of modifying the ionosphere by a high power HF transmitter feeding the 305 m reflector antenna. When in the ordinary magnetoionic mode parametric instabilities develop in the ionosphere near the reflection level. Manifestations of these instabilities are the strong enhancement of Langmuir oscillations in the direction of the ISR beam at a wavelength of 35 cm and the simultaneous much weaker enhancement of ion oscillations in that direction. The spectral analysis of the enhanced peak with a height resolution of 2.4 km shows that the ionic mode enhancement most often has a double humped frequency spectrum corresponding to up- and down-going ion acoustic waves. The shape of the frequency spectrum is interpreted in terms of a stable oscillation which is driven by a secondary electrostatic field caused by nonlinear interaction of Langmuir waves within a cone centered on the magnetic field and by the scattering of the pump field on stable Langmuir waves travelling along the direction of the ISR. Author

N74-31817 National Oceanic and Atmospheric Administration, Boulder, Colo. Environmental Research Labs.
ONSET, GROWTH AND MOTIONS OF IONOSPHERIC DISTURBANCES CAUSED BY HIGH INTENSITY ELECTROMAGNETIC HEATING
J. W. Wright *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 17 p refs (For availability see N74-31812 21-13)

At an observing location 46 km from the Platteville (Colorado) high intensity RF transmitter, multifrequency spaced antenna digitized observations are made of the complex amplitude variations of ionospheric echoes antenna digitized observations are made of the complex amplitude variations of ionospheric echoes of pulsed transmissions by the Kinesonde. Characteristically, all measurable and derivable quantities of the echo signals develop marked changes with altitude dependent delays following E sub P turn-on. Transient phenomena resulting from brief E sub P transmissions are illustrated, as are some ionospheric motions which appear to develop in response to E sub P. Several of the diagnostic techniques demonstrate a desirable high sensitivity to the ionospheric modifications which occurs, but their interpretation is sometime far from straightforward. Author

N74-31818 Stevens Inst. of Tech., Hoboken, N.J.
INTRODUCTORY SURVEY TO SESSION ON PARAMETRIC INSTABILITIES, LABORATORY EXPERIMENTS AND THEORY
George Schmidt *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 5 p refs Sponsored in part by AEC (For availability see N74-31812 21-13)

Parametric instabilities produced by electromagnetic waves propagating in a magnetic field free plasma are reviewed. The discussion is based on the use of the ponderomotive force as the basic physical mechanism responsible for these instabilities. If the plasma is bounded the threshold power is non-zero even

in the absence of damping, and may be the dominant factor in determining threshold and growth rate values. The threshold for stimulated Raman scattering increases in the presence of plasma density gradients, while temperature gradients have a similar effect on simulated Brillouin scattering. The finite cross section of the pump wave determines the undamped threshold for the filamentation instability. In a nonuniform plasma stimulated Raman backscattering becomes very strong in the neighborhood of the point where the pump frequency is twice the local plasma frequency. Author

N74-31819 Princeton Univ., N.J. Plasma Physics Lab.
LABORATORY EXPERIMENTS ON PARAMETRIC INSTABILITIES AND PLASMA HEATING IN A MAGNETIC FIELD

M. Porkolab, V. Arunasalam, and N. C. Luhmann, Jr. *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 16 p refs (For availability see N74-31812 21-13)
(Contract AT(11-1)-3073)

Experimental studies on parametric instabilities and associated plasma heating in a magnetic field are reported. The following parametric decay processes are observed: (1) For pump frequencies omega sub o greater than omega sub u, (where omega sub u is the electron cyclotron frequency) the parametric excitation of Bernstein waves, lower hybrid waves, and ion acoustic waves is observed; (2) for frequencies omega sub o smaller than omega sub ce, omega sub o smaller than omega sub pe externally launched Trivelpiece-Gould modes and whistler-waves have been observed to decay parametrically into electron plasma waves, and ion acoustic waves; (3) for omega sub o approximately omega sub pe, parametric decay into ion acoustic waves and electron plasma waves of the ordinary mode of electromagnetic wave propagation is observed. Fast plasma heating follows the occurance of all the foregoing instabilities. Heating of the main body of plasma particles, as well as tail formation on the distribution function is observed. A comparison between the various regimes is given. Author

N74-31820 TRW Systems Group, Redondo Beach, Calif.
MODELING OF IONOSPHERIC PARAMETRIC INTERACTIONS IN THE QUIPS DEVICE

R. L. Stenzel, A. Y. Wong, D. Arnush, B. D. Fried, and C. F. Kennel *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 18 p refs (For availability see N74-31812 21-13)
(Contract F30602-72-C-0304)

A large quiescent steady state plasma device has been constructed for experiments on parametric mode coupling instabilities produced by an S-band electromagnetic pump matched to the local plasma frequency in a weak, controllable plasma density gradient. One purpose of this experiment is to study the linear instabilities, and their nonlinear saturation, produced by HF excitation irradiation of the F-region. In that vicinity linear conversion from the incident electromagnetic waves (EMW) to electrostatic waves (ESW) at pump frequency is observed. When the pump intensity exceeds a certain threshold lower frequency ESW and ion acoustic waves are parametrically generated which are polarized along the density gradient and which, within measurement accuracy, satisfy frequency and wave vector matching conditions. Amplification by the pump of launched ion acoustic waves along with the simultaneous appearance of a parametrically matched ESW has been observed. Inserting two pump frequencies, separated by the ion acoustic frequency, has been observed to create double resonance excitation. The relevance of these to ionospheric observations are discussed. Author

N74-31821 National Oceanic and Atmospheric Administration, Boulder, Colo. Aeronomy Lab.
MODIFIED ELECTRON DISTRIBUTION FUNCTION DURING PARAMETRIC INSTABILITIES

Jerome Weinstock and Bandel Bezzerides *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 6 p refs (For availability see N74-31812 21-13)

A calculation is made of the heating of electrons by parametrically excited Langmuir wave turbulence in a homogeneous plasma. The number of hot electrons is determined by a kinetic equation in which the effects of turbulence are described by a stochastic wave diffusion tensor. Both resonant and resonant broadened wave-particle interactions, as well as the angular distribution of Langmuir waves, are important. The kinetic equation is solved for a steady state by balancing the turbulent diffusion with a relaxation collision term. It is predicted that suprathermal electrons exist to velocities as large as the fastest growing phase velocity. Author

N74-31822* Max-Planck-Institut fuer Physik und Astrophysik, Munich (West Germany). Inst. fuer Extraterrestrische Physik.
THE SATURATION SPECTRUM OF PARAMETRIC INSTABILITIES

J. A. Fejer and Yu-Yun Kuo (Calif. Univ., La Jolla) *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 10p (For availability see N74-31812 21-13)
(Grants NGR-05-009-078; NSF GA-30828)

Recent calculations on the nonlinear saturation spectrum of the parametric decay instability are described. The initial calculations did not use the correct expression for the spontaneous emission term and were aimed at obtaining the distribution of spectral energy in the unstable part of wave vector space. Results of those initial calculations are combined here with the correct expression for the spontaneous emission term to obtain the distribution of spectral energy in the stable part of wave vector space. These latter calculations are believed to be relevant to the interpretation of the so called plasma line spectra obtained in ionospheric heating experiments at Arecibo, Puerto Rico. Author

N74-31823 TRW Systems Group, Redondo Beach, Calif.
THEORY OF DOUBLE RESONANCE PARAMETRIC EXCITATION IN THE IONOSPHERE

D. Arnush (Hiroshima Univ.), K. Nishikawa, B. D. Fried, C. F. Kennel, and A. Y. Wong *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 7 p refs (For availability see N74-31812 21-13)
(Contracts AT(04-3)-34; F44620-73-C-0007)

Reviewed is a general theory of the parametric instabilities in a plasma driven by a long wavelength electric field with two pump frequencies which lie near the resonant frequency for Langmuir oscillations. A general dispersion relation in terms of linear susceptibilities, is derived by retaining, on a selective basis, terms of fourth order in the pump amplitudes. Illustrative calculations, appropriate to the ionosphere, are carried out using resonant approximations. A lowering of the net power threshold for instability is found in both cases for E-layer parameters, i.e., when the linear damping rate of the electronic wave is large compared to omega. In addition, in both the E- and F-layers, a coupling between the decay and oscillating two stream instabilities occurs when delta is approximately equal to omega. It is suggested that since the oscillating two stream is an absolute instability which is ordinarily not generated because of its high threshold, double resonance stimulation of this mode may enhance saturated wave amplitudes. Author

N74-31824* Max-Planck-Institut fuer Physik und Astrophysik, Munich (West Germany). Inst. fuer Extraterrestrische Physik.
GENERATION OF LARGE SCALE FIELD-ALIGNED DENSITY IRREGULARITIES IN IONOSPHERIC HEATING EXPERIMENTS

J. A. Fejer *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 7 p refs (For availability see N74-31812 21-13)
(Grant NGR-05-009-076, Contract DAHC04-72-C-0037; Grant NSF GA-30828)

Threshold and growth rate for stimulated Brillouin scattering are calculated for a uniform magnetoplasma. These are then compared with the threshold and growth rate of a new thermal instability in which the nonlinear Lorentz force felt by the electrons at the beat frequency of the two electromagnetic waves is replaced by a pressure force due to differential heating in the interference pattern of the pump wave and the generated electromagnetic wave. This thermal instability, which is still essentially stimulated Brillouin scattering, has a threshold which is especially low when the propagation vector of the beat wave is almost normal to the magnetic field. The threshold is then considerably lower than the threshold for normal stimulated Brillouin scattering and therefore this new instability is probably responsible for the generation of large scale field aligned irregularities and ionospheric spread F. Author

N74-31825 Bell Telephone Labs., Inc., Murray Hill, N.J.
INSTABILITIES AND NONLINEAR PROCESSES IN GEOPHYSICS AND ASTROPHYSICS
Akira Hasegawa *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 13 p refs (For availability see N74-31812 21-13)

A review of plasma instabilities and some of their nonlinear effects on geophysical and astrophysical plasmas is presented. The nonlinear effects cover: (1) quasilinear diffusion; (2) anomalous resistivity; (3) wave-wave, wave-particle interactions; and (4) modulational instability and formation of wave packet. Author

N74-31826 TRW Systems Group, Redondo Beach, Calif.
TYPE 1 IRREGULARITIES IN THE AURORAL AND EQUATORIAL ELECTROJETS
C. F. Kennel and D. Arnush *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 24 p refs (For availability see N74-31812 21-13)
(Contract N00014-69-A-0200-4060)

Theoretical knowledge concerning irregularities in the equatorial and auroral electrojets is considered with particular emphasis upon Type I irregularities. A simple model of equatorial electrojet polarization is reported. The evidence that discrete auroral arc electrojets flow at the poleward edge of the auroral oval and a diffuse electrojet at the equatorward edge is discussed. A simple model of the diffuse electrojet is formulated, and the linear theory of electrojet instabilities is reviewed. A new fluid theory dispersion relation for the two-stream instability, valid even at the Pedersen conduction maximum is presented, despite drastic differences in electrojet geometry, the similarities between the Doppler spectra, particularly for Type I irregularities, suggest that the nonlinear saturation mechanisms are similar in both electrojets. Author

N74-31827 Kernforschungsanlage, Juelich (West Germany). Inst. fuer Plasma Physik.
NONLINEAR THEORY OF INSTABILITIES IN THE EQUATORIAL ELECTROJET
Andre Rogister *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 13 p refs (For availability see N74-31812 21-13)

It is suggested that the stabilization of Type I irregularities has two aspects: in a first step the turbulence inhibits the formation of large currents and maintains the plasma in a state relatively close to marginal stability; in a second step, energy is transfered by two-dimensional nonlinear wave coupling processes from the linearly growing modes propagating mainly in the direction of the electron drift velocity to linearly damped ones propagating in other directions. This transfer process open the aperture of the cone containing the directions of propagation of suprathermal waves. It is also suggested that stabilization of Type II irregularities mainly occurs via one-dimensional wave-wave scattering processes which transfer the energy from large wave-lengths, where it is generated, to small wavelengths, where it is absorbed by diffusion; the process extends toward larger wavenumbers the spectrum of suprathermal waves. Most of the observed features of Type I and Type II irregularities can be explained by these theories. Author

N74-31828 Oxford Univ. (England). Dept. of Theoretical Physics.
PLASMA MECHANISMS FOR PULSAR EMISSION
J. W. Buckee, S. Grounds, L. C. M. Miranda, and D. TerHaar *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 8 p refs (For availability see N74-31812 21-13)

A partial analysis is presented of the nonlinear processes occurring in a strongly magnetized plasma through which a beam of relativistic particles is passing. The conversion of longitudinal plasmons into transverse waves through Compton scattering is considered and it is found that the frequency of these waves lies close to the plasma frequency which lies in the radio band for the plasma. Radio waves beamed at right angles to the magnetic field are linearly polarized. These characteristics can be shown to be conserved in the propagation of the transverse waves through the magnetosphere and are in good agreement with observational pulsar data. The processes considered can produce the observed large radio brightness of pulsars. Author

N74-31829 King's Coll., London (England). Dept of Mathematics.
A SELF CONSISTENT THEORY OF TRIGGERED VLF EMISSIONS
D. Nunn and M. J. Rycroft (Southampton Univ., England) *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 15 p refs (For availability see N74-31812 21-13)

The nonlinear interaction of cyclotron resonant electrons with VLF radio waves is used to explain the phenomenon of VLF emissions triggered by whistler mode signals propagating in the earth's magnetosphere. It is found that in an inhomogeneous medium resonant particles become stably trapped in the wave and make a dominant contribution to the nonlinear resonant particle current. This current continuously modifies the wave field and effectively causes the emission. This simplifying feature makes possible a fully self consistent simulation of the triggering process. The computer model described in this paper successfully produces rising and falling tones similar to those observed experimentally. Sideband stability and the origin of spectral structuring in banded chorus are also discussed. Author

N74-31830 Comissao de Estudos de Energia Nuclear, Lisbon (Portugal). Inst. Superior Tecnico.
WHISTLER TRIGGERED EMISSIONS
A. L. Brinca *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 11 p refs (For availability see N74-31812 21-13)

The electromagnetic radiation from energetic particles evolving in the geomagnetic mirror is used to describe the main phase of emissions artificially stimulated by signals propagating in the whistler mode. Those particles are in a cyclotron resonance with the triggering whistler of arbitrary obliquity in the vicinity of the equator (onset region); their velocity distribution becomes unstable to the whistler mode through the nonlinear evolution of the wave-particle interaction. The obtained spectral shapes reproduce most of the forms observed in triggered emissions of short duration. Author

N74-31831 Newcastle-upon-Tyne Univ. (England). Dept. of Engineering Mathematics.
NONLINEAR WAVE MODULATION OF WHISTLER WAVES
Masayoshi Tajiri *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 11 p refs (For availability see N74-31812 21-13)

Nonlinear modulation of the electromagnetic waves propagating parallel to a magnetic field is investigated by means of a modification of the reductive perturbation method developed by Taniuti and Yajima. The Vlasov equation is reduced to a modified nonlinear Schrodinger equation which includes additional nonlinear terms. It is conjectured that these terms arise from the weak but continuous resonant action that takes place between the wave and particle velocity. Author

N74-31832 Istituto Nazionale di Geofisica, Rome (Italy). Ionospheric Dept.
NONLINEAR MAGNETOIONIC EFFECTS IN THE MAGNETOGUIDING OF WHISTLERS
P. Dominici *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 3 p refs (For availability see N74-31812 21-13)

The complete basic equations of the magnetoionic theory in the Q.L. approximation are examined in order to explain the magnetoguided propagation of whistlers; the principal result is briefly discussed, namely the existence of nonlinear terms of current, related to self trapping magnetoionic components both in lower and upper ionosphere. Author

N74-31833 Norwegian Inst. for Air Research, Kjeller.
INTRODUCTORY SURVEY: NONLINEAR EFFECTS IN PLASMA RESONANCES AND ION SHEATH
Kristen Folkstad *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 8 p refs (For availability see N74-31812 21-13)

Some nonlinear properties observed in ionospheric topside soundings are considered and particle generated emissions in the near space environment are discussed. The energy transfer which takes place between interacting waves in a plasma is determined by their phase relationship. Criteria for distinguishing between the cases of strong and weak coupling in three wave interactions are described. A useful quantum mechanical analogy pertaining to weakly interacting random waves is mentioned. The possible role of the ion sheath as a source for nonlinear signal generation is evaluated. Author

N74-31834 Communications Research Centre, Ottawa (Ontario). Dept. of Communications.
NARROWBAND RADIO NOISE IN THE TOPSIDE IONOSPHERE
H. G. James, E. L. Hagg, and D. L. P. Strange *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 18 p refs (For availability see N74-31812 21-13)

Strong narrow bands of radio noise at frequencies near 2 and 4 MHz are occasionally observed by the ISIS satellites at auroral latitudes. A characteristic smooth peak in amplitude is often observed at the upper frequency limit of the lower frequency noise band. A self consistent interpretation for this part of the spectrum is proposed involving waves propagating upward from below the spacecraft. Ray tracing has been applied to the spatial geometry of the noise region to find the point source height for that part of the spectrum exhibiting the smooth peak. This source is located at altitude where the upper hybrid frequency, f sub T equals twice the electron gyrofrequency, 2 f sub H. Furthermore the observed peak frequency, f, satisfies the relation f = f sub T = 2f sub H. The condition f sub T = 2f sub H is important because, according to the hot-plasma wave dispersion theoryit defines an ionospheric height above which electrostatic-to-electromagnetic-o-mode wave conversion is more probable than below it. There is some evidence that the noise band near 4 MHz originates from the same source is the smooth peak component. Author

N74-31835 Norwegian Inst. for Air Research, Kjeller.
RESONANCE PHENOMENA OBSERVED ON MOTHER-DAUGHTER ROCKET FLIGHTS IN THE AURORAL IONOSPHERE
K. Folkestad and J. Troim *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 15 p refs (For availability see N74-31812 21-13)

Swept frequency transmissions in the HF band on mother/daughter rocket flights have revealed certain resonance frequencies where the transmitted stimulus evidently excites nonlinear mechanisms somewhere along the propagation path. The nonlinear effects are disclosed by notable signals being detected in receivers whose pass bands differ from the frequencies of the generating signals. It appears that major experimental features may be explained in terms of the theory of resonance cones in an anisotropic propagation medium. For the plasma parameters of the lower ionosphere such resonances may exist in the lower branch for frequencies below the electron gyrofrequency, and in the upper branch for frequencies between the plasma frequency and the upper hybrid frequency. Graphs of the admittance measured at the terminal of the transmitting antenna show a very pronounced dependence upon the level of the driving voltage. Author

N74-31836 Institut fuer Physikalische Weltraumforshung, Freiburg (West Germany).
MODIFICATION OF THE PLASMA IMPEDANCE OF AN ANTENNA DUE TO ION SHEATH INDUCED NONLINEARITIES
H. Thiemann, R. Kist, E. Neske, and K. Rebstock *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 9 p refs (For availability see N74-31812 21-13)

Measurements with a cylindrical sensor in a laboratory plasma applying large RF voltages showed specific modification of the impedance around series resonance. The purpose of the work presented here is to understand this modification in terms of sheath induced nonlinearities. A nonlinear differential equation derived from a network representing the sheath-plasma-system has been solved numerically in a general way. A corresponding computer program determined the voltage drop across the ion sheath, the Fourier Spectrum of the RF current through the system and its resulting impedance. Numerical results show that scattering of RF energy into higher harmonics of the frequency applied is not important around series resonance. The measured impedance modification when varying the RF voltage can be understood using the concept of an effective sheath resistor, defined by integration of the differential resistor of the sheath's current-voltage characteristic over one period of the voltage drop across the sheath. Author

N74-31837 SIGMA Association, Hamburg (West Germany).
RESONANCE FREQUENCY OF AN IONIZED LAYER IN DEPENDENCE ON LAYER THICKNESS
C. Fengler *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 6 p refs (For availability see N74-31812 21-13)

An ionized symmetric layer gets excited by an electromagnetic pulse. The evaluation of the pulse response yields a resonance frequency in dependence on layer thickness. The oscillation occurs above a minimum thickness of the layer only. At large layer thickness the frequency of oscillation asymptotically approaches the plasma frequency. Author

N74-31838 Office of Naval Research, London (England).
INTRODUCTORY SURVEY: WAVE INTERACTION IN THE LOWER IONOSPHERE: A SURVEY
A. H. Waynick *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 8 p refs (For availability see N74-31812 21-13)

A summarization of the reviews to date on the field of wave interaction in the lower ionosphere is attempted. This covers the study of the interaction process and the determination of electron density, electron-neutral collisional frequency, and height distribution in D-region. The current status of the use of this technique in synoptic profile procurement and the role of this work in investigations on the physics and chemistry of this region are outlined. Author

N74-31839 New England Univ., Armidale (Australia).
ELECTRON HEATING IN THE IONOSPHERE BY POWERFUL GYRO-WAVES
R. A. Smith and R. G. Loch (Warrnambool Inst. of Advanced Education, Victoria, Australia) *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 14 p refs (For availability see N74-31812 21-13)

Pulse wave interaction experiments using disturbing gyro-waves radiated by an aerial array of 40 dipoles are described. Steady state and transient changes in the amplitudes and phases of 1.78 and 2.12 MHz wanted pulses have been measured for transmitted powers at the gyro-frequency (1.515 MHz) in the range 0.7 - 500 kW. The wave interaction effects have been computed using a model of the behavior of slow electrons in air which links properties for the thermal energy known from ionospheric wave interaction experiments to properties for energies well above the thermal known from laboratory experiments. Excellent agreement with the experimentally measured amplitude and phase changes is obtained over the entire power range. The effects of night-to-night variability of the lower E region on the temperature rise and the factors which limit it, are discussed. Author

N74-31840 Pennsylvania State Univ., University Park. Ionosphere Research Lab.
WAVE INTERACTION USING A PARTIALLY REFLECTED PROBING WAVE
W. A. Kissick and A. J. Ferraro *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 9 p refs (For availability see N74-31812 21-13)
(Contract N00014-67-A-0385-0014; Grant NSF GA-13885)

A proposed new form for the wave interaction experiment is reported which utilizes a partially reflected echo of the probing wave that originates in the heated region. Digital computer simulation shows that the amplitude interaction coefficient can be as high as 0.1 for certain conditions. The effects of self-heating are calculated by using the probing wave parameters and geometry. A significant change in the measured A sub x/A sub o ratio occurs when the self-heating effect is included. Author

N74-31841 Cornell Univ., Ithaca, N.Y. Center for Radiophysics and Space Research.
DOUBLE CROSS MODULATION IN THE D-REGION
G. C. Rumi *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 15 p refs (For availability see N74-31812 21-13)
(Grant NSF GP-5452)

An experiment of cross modulation in the lower D-region that made use of 2 relatively high frequencies is described. Its peculiarity was that the received wanted wave - on account of its relatively high frequency - contained a relatively strong extraordinary component together with the ordinary component. Such an echo was received alternatively by means of circularly and linearly polarized antennas, so that both amplitude cross modulation and cross modulation of the plane of polarization were detected. The discrimination between these two kinds of cross modulation was obtained just by shifting from one kind of antenna to the other. Since the experiment produced two pieces of information analytically related to the two knowns of the ionosphere at a specific height, namely the electron density, and its collision frequency, both of them were determined for heights ranging between 70 and 40 km. Author

N74-31842 Leicester Univ. (England). Dept. of Physics.
MODIFICATION EFFECTS IN THE IONOSPHERIC D-REGION
Tudor B. Jones *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 6 p refs (For availability see N74-31812 21-13)

Nonlinear effects are observed during D region heating experiments using the high power transmitter at Platteville, Colorado. The first experiments, in which the power and frequency of the modifying transmitter were varied, indicate that the electron temperature changes are greater than perturbation magnitude. Experimental results are in good agreement with cooling due to the excitation of the rotational bands of molecular nitrogen. Later experiments, in which two frequencies are transmitted simultaneously, indicate that nonlinear frequency mixing may occur when the frequency difference is equal to the gyro-frequency. Author

N74-31843 Camerino Univ. (Italy).
NUMERICAL SOLUTION OF A PROBLEM OF NONLINEAR WAVE PROPAGATION THROUGH PLASMAS
L. M. DeSocio and G. Gaffuri *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 10 p refs (For availability see N74-31812 21-13)

The self-interaction of an electromagnetic wave propagating through a plasma layer has been considered as a typical example of nonlinear effect in the ionosphere. For the plasma, the indicative values of the physical characteristics of the D region have been considered. Quasi-longitudinal and non derivative propagation have been assumed and the electron heating is supposed to be described by Bailey's equation. The problem of determining the changes of the modulation index, the second harmonic distortion and the total absorption of both the ordinary and extraordinary waves has been solved numerically in an extensive range of values of the characteristic parameters. Author

N74-31844 Naples Univ. (Italy). Centro Studi di Radiopropagazioni.
THE IONOSPHERIC PROPAGATION OF THE MODULATED WAVES WITH CARRIER FREQUENCIES FAR FROM AND VARYING AROUND THE GYROFREQUENCY
M. Cutolo, P. DiMaio, G. Gaffuri, G. Agnelli (Osservatorio Astronomico di Rome, Italy), F. Fabbri (Osservatorio Astronomico di Rome, Italy), M. Iannello (Osservatorio Astronomico di Rome, Italy), R. Flagg (Florida Univ.), and W. Greenman (Florida Univ.) *In* AGARD Nonlinear Effects in Electromagnetic Wave Propagation May 1974 13 p refs (For availability see N74-31812 21-13)

The self modulation phenomenon has been studied with oblique and with vertical incidence and with C.W. and pulse techniques. The C.W. experiments to demonstrated that the phenomenon clearly depends on the power emitted by the radio transmitting station. While the transmissions with C.W. were made with a carrier frequency far from the local gyrofrequency, the pulse transmissions were made with a carrier frequency varying around the gyrofrequency. The experiments have shown that it is possible to have demodulation or overmodulation and a resonance curve when the carrier frequency varies around the local gyrofrequency. The experiments made during the total solar eclipse of 7th March 1970 are also discussed. Author

N76-16256# Advisory Group for Aerospace Research and Development, Paris (France)
ELECTROMAGNETIC NOISE INTERFERENCE AND COMPATIBILITY
Nov. 1975 585 p refs In ENGLISH and FRENCH Presented at the Joint Avionics/Electromagnetic Wave Propagation Panels Symp., Paris, 21-25 Oct. 1974
(AGARD-CP-159) Avail: NTIS HC $13.75

Electromagnetic interference and compatibility studies on avionics equipment and subsystems are presented. For individual titles, see N76-16257 through N76-16297.

N76-16257 Stanford Research Inst., Arlington, Va.
DEFINITIONS AND FUNDAMENTALS OF ELECTROMAGNETIC NOISE, INTERFERENCE, AND COMPATIBILITY
G. H. Hagn *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 24 p refs (For availability see N76-16256 07-32)

The terms electromagnetic noise, interference, and compatibility are defined, and some of the different definitions for these terms in current usage are discussed with emphasis on international definitions. For this paper, noise is defined as all electromagnetic energy except that associated with the desired signal for a specific system of interest. Interference is considered to be an undesirable effect of electromagnetic noise upon a system or subsystem rather than as a cause or source of noise. Electromagnetic compatibility is the condition that prevails when telecommunications equipment is collectively performing its individually assigned functions in a common electromagnetic environment without causing or suffering unacceptable interference. Selected aspects of the fundamentals of noise, interference, and compatibility are discussed. Author

N76-16258 Lightning and Transients Research Inst., Melbourne, Fla.
ATMOSPHERIC DISCHARGES AND NOISE (AND COMMUNICATIONS SYSTEMS INTERFERENCE REDUCTION)
M. M. Newman and J. D. Robb *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 22 p refs (For availability see N76-16256 07-32)

Most studies of atmospherics in the past have dealt with the subject on the basis of the frequency domain as a linear phenomenon. From the special point of view of working to improve communications systems performance, there are advantages to be derived in viewing the problem in the time domain. Considered are broadband measurements, up to 200 megahertz, of the fine structure of radiation from individual discharges, as well as longer consecutive records of the character and spacing of pulse components of branching streamers and repeated discharges, which have hitherto been unavailable. Direct lightning interception studies are discussed in relation to discharge noise characteristics. Research on artificial lightning discharge noise propagation and reception at various distances is presented as a unique tool for atmospherics propagation studies. Author

N76-16259 Stanford Research Inst., Arlington, Va.
MAN-MADE ELECTROMAGNETIC NOISE FROM UNINTENTIONAL RADIATORS: A SUMMARY
G. H. Hagn and R. A. Shepherd *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 24 p refs (For availability see N76-16256 07-32)

Considered is the noise from electrical and electromechanical devices that are not designed as intentional radiators but that produce electromagnetic energy as a by-product. The emphasis here is on description of the noise from electrical power transmission and distribution lines and from vehicle ignition systems; these two sources are known to be important below and above 20 MHz, respectively. Other sources are mentioned, and prediction of the composite environment due to unintentional radiators is considered. Author

N76-16260 Observatoire de Paris-Meudon (France).
COSMIC NOISE [LES BRUITS COSMIQUES]
A. Boischot *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 12 p refs In FRENCH (For availability see N76-16256 07-32)

A description of the various natural sources of electromagnetic radio noise was given, including the nature of the various types of noise generated. Some of these have a very broad, continuous spectrum (such as the noise from galaxies or radio sources), while others have intermittent, irregular spectra (such as the noise from solar or Jovian flares, pulsars). The average characteristics of the various parts of the spectra generated by these sources were given, including their perturbing effects on ground communication. Transl. by Y.J.A.

N76-16261 Science Research Council, Slough (England). Appleton Lab.
LAND, SEA AND ATMOSPHERIC THERMAL NOISE
P. G. Davies *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 15 p refs (For availability see N76-16256 07-32)

Thermal emission is reviewed for the natural environment within the microwave, far infrared and medium infrared bands of the E-M spectrum down to a wavelength of about 3 micron where reflection of solar radiation begins to predominate. The emphasis is primarily on the fundamental aspects of the emissive properties of the atmosphere and various surfaces and the relationship of this thermal emission to the thermal, absorptive and scattering properties of the atmosphere in slant path propagation. A nomogram technique for determining the noise signal at a point in the atmosphere is considered and a bibliography of recent work on thermal emission is included. Author

N76-16262* Stanford Research Inst., Menlo Park, Calif. Radio Physics Lab.
IONOSPHERIC AND TROPOSPHERIC SCINTILLATION AS A FORM OF NOISE
E. J. Fremouw and C. L. Rino *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 13 p refs (For availability see N76-16256 07-32)
(Contracts NAS5-21551; NAS5-21891; DASA01-68-C-0104; DNA001-74-C-0255; F30602-74-C-0279)

Recent tests of signals observed through the ionosphere, the solar wind, and a laboratory plasma have revealed a surprising consistency in parameters describing the first order statistics of a signal caused to scintillate by a randomly structured plasma. This paper describes a means for exploiting these new findings in a transionospheric communication channel model. Author

N76-16263 SIGMA Association, Hamburg (West Germany).
THE INFLUENCE OF PARTICULAR WEATHER CONDITIONS ON RADIO INTERFERENCE
C. Fengler *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 10 p refs (For availability see N76-16256 07-32)

The various propagation properties of the atmosphere are associated to the variation of the refractive index. A stratified atmosphere shows due to the meteorological parameters a strong change which corresponds for example to variations of parameters as k-factor or radio horizon and noise temperature. The case of an atmosphere with embedded discontinuities is illustrated by experimental results, which were obtained on line-of-sight ground links, links with a distance near the radio horizon, transhorizon links as well as earth-space links. It concludes that most radio interference is to be expected during days with strong radiation and the influence of cold fronts. Author

N76-16264 SEFTIM, Paris (France).
ELECTROSTATIC CHARGES AND THEIR PERTURBING EFFECTS ON RADIO COMMUNICATION [LES CHARGES ELECTROSTATIQUES ET LES PERTURBATIONS QU'ELLES ENTRAINENT DANS LES LIAISONS RADIOELECTHIQUES]
Charles Fevrot *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 4 p In FRENCH (For availability see N76-16256 07-32)

The following areas related to the effect of electrostatic charges on aircraft radio communication were discussed: (1) electrostatic charges and potential distribution on the surface of aircraft, (2) generation of these charges, (3) jamming effects, (4) suggested solutions. High electrostatic potential differences may exist between the metallic surface of aircraft and the surrounding air, or between two neighboring points of an insulating surface, although metallic surfaces may be assumed to be equipotential. Such charges may be generated by phenomena linked to the surrounding atmosphere, the aircraft itself, or other special situations (such as in-flight refueling, braking on a dry runway, etc.) Radio jamming resulting from these charges takes the form of a general increase in background noise and, in certain cases, may be aggravated by noise resulting from sudden avalanche discharges. Suggested solutions include the development of improved paints with better conductivity properties.
Transl. by Y.J.A.

N76-16265 Technische Hogeschool, Eindhoven (Netherlands).
POLARIZED NOISE IN THE ATMOSPHERE DUE TO RAIN
A. Mawira and J. Dijk *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 23 p refs (For availability see N76-16256 07-32)

Equations describing the propagation of plane waves through a medium containing axisymmetric rain drops are presented. They lead to a general expression for the cross polarization parameter. A transfer equation involving the stokes spectral parameters associated with the electromagnetic field in this medium, is also given. The solution of this equation shows that a polarization of the thermal emission in the atmosphere can be caused by rain. The evaluation of the cross polarization parameter from sky emission measurements is also discussed. Author

N76-16266 Technische Hogeschool, Eindhoven (Netherlands).
DEPOLARIZATION AND NOISE PROPERTIES OF WET ANTENNA RADOMES
J. Dijk and A. C. A. VanDerVorst *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 16 p refs (For availability see N76-16256 07-32)

The influence of artificially wetted radome panels of different materials (Tedlar, Mylar, Teflon) on the performance of antenna systems covered with radomes was measured. Noise, transmission and depolarization measurements have been carried out and when possible compared with the theory. Author

N76-16267 Institut fuer Physikalische Weltraumforshung, Freiburg (West Germany).
ANTENNA RESPONSE TO RANDOM ELECTRIC FIELDS DUE TO THERMODYNAMIC DENSITY FLUCTUATIONS IN PLASMAS
R. Grabowski *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 11 p refs (For availability see N76-16256 07-32)

Thermodynamic density fluctuations of positively and negatively charged components in a plasma are responsible for the occurrence of random electric fields. The antenna response to these fields may be characterized by the quadratic or power spectrum of the voltage fluctuations in a measuring device connected with the antenna. The response is dependent upon the antenna configuration and is described as a filtering effect in wave vector space. Theoretical quadratic spectra are presented for equilibrium plasmas streaming parallel to the antenna axis. The bulk velocity has a strong influence upon the shape of the spectra, especially as it is the cause for a periodic fine structure. Author

N76-16268 Technische Hogeschool, Eindhoven (Netherlands).
THE INFLUENCE OF FREQUENCY AND RECEIVER APERTURE ON THE SCINTILLATION NOISE POWER
M. J. M. VanWeert *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 10 p refs (For availability see N76-16256 07-32)

Some properties of the scintillation noise power are discussed. The used model is essential the same as used by Lee and Harp. Some calculations of different statistical properties of the scintillation noise are shown. Special attention is given to the influence of receiver aperture and frequency on scintillation noise power. It is shown that both parameters have a significant influence on amplitude scintillation, but hardly on phase scintillation. This behavior is explained. To decide whether scintillation does have a significant influence on the performance of a communication link, the total scintillation noise power is compared with thermal noise power on an earth to satellite path. Author

N76-16269 Army Electronics Command, Fort Monmouth, N.J. Communications/ADP Lab.
DOD ELECTROMAGNETIC COMPATIBILITY PROGRAM: AN OVERVIEW
John J. ONeill *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 6 p refs (For availability see N76-16256 07-32)

An overview of the Department of Defense Electromagnetic Compatibility Program is presented. This integrated program intended to ensure the electromagnetic compatibility of all electrical and electronic equipments, subsystems and systems produced and operated by components of the Defense Department in any electromagnetic environment, resulted in the establishment of eight major program areas. The status of each of these areas is examined with particular emphasis on the areas of EMC standards and specifications and measurement techniques and instrumentation. Plans of the Department of Army to solve operational problems are also reviewed. Author

N76-16270 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
GENERAL EMC SPECIFICATION OR SYSTEMS ORIENTED EMC SPECIFICATIONS
D. Jaeger *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 12 p (For availability see N76-16256 07-32)

To ensure electromagnetic compatibility in systems, EMC equipment specifications are required to limit for each unit the interferences emitted and specify a certain degree of unsusceptibility to interference signals. An examination is made as to whether it is more favorable to use a general EMC specification or system oriented specifications for this purpose. The following solution is obtained. The test methods and the test philosophy should be uniform for all systems. MIL-STD 462 (+ 463) could represent a good basis. However, updating and expansion in various respects seem desirable. As far as the limit values are concerned, it becomes evident that the characteristics of the systems themselves, their environment, and the system in conjunction with which they must possibly function differ too greatly. Establishing system related limit values is considered the optimum solution. Author

N76-16271 Societe Nationale Industrielle Aerospatiale, Blagnac (France).
ELECTROMAGNETIC NOISE SPECIFICATIONS [SPECIFICATIONS EMC]
J. C. Delpech *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 21 p In FRENCH (For availability see N76-16256 07-32)

Various EMC standards and specifications now in use were compared, with special emphasis on those applicable to airborne systems. The essential similarities and differences between these specifications were pointed out, in relation to the following: type of tests used, frequency bands applicable, degree of required tolerance demanded, operating regime specified, and recommended hardware. The following points were also emphasized: (1) the lack of adequate tests required by certain specifications (such as those used to evaluate the vulnerability of numerical equipment), (2) the new tests required in the most recent specifications, (3) the lack of precision and unsatisfactory matching between certain limits which have been observed experimentally, and (4) the superiority of certain specifications in relation to the measurement principles and instruments used. Transl. by Y.J.A.

N76-16272 Stanford Research Inst., Arlington, Va.
A STATUS REPORT OF THE IEEE/ECAC ELECTROMAGNETIC COMPATIBILITY FIGURE OF MERIT COMMITTEE
G. H. Hagn and M. N. Lustgarten (IIT Res. Inst., Annapolis, Md.) *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 16 p refs (For availability see N76-16256 07-32)

A practical technical procedure is devised for specifying an electromagnetic compatibility Figure of Merit (FOM) for various electronic devices and systems. An EMC FOM for single channel voice communication systems, based on the channel denial concept, was developed by using a building block approach. The building block approach involves the use of relatively simple scoring formulas for selected EMC parameters, which are then linearly combined, with appropriate weighting factors, to calculate FOMs for transmitters, receivers, and systems. A channel was considered denied if (S + I + N)/(I + N) smaller than or equal to 10 db in a moderately dense co-site environment. The parameter scoring equations were developed to reflect the frequency spectrum denied by each parameter. The weighting factors for the building block approach were determined by running a computer program that kept track of the number of channels denied by each parameter. Example calculations for HF, VHF, and UHF systems are given, and the interpretation of the scores is discussed. Author

N76-16273 Ministry of Defence, London (England).
ELECTROMAGNETIC COMPATIBILITY IN MILITARY AIRCRAFT
D. H. Hight and W. A. Kelly *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 5 p ref (For availability see N76-16256 07-32)

Common sources of electromagnetic compatibility problems are outlined and the difficulties confronting engineers who are responsible for producing successful aircraft weapon systems are discussed. A definition of EMC is given within the context of an aircraft weapon system. EMC problems can be minimized by: defining clearly the requirements of the weapon system; translating this requirement into an overall system specification; defining subsystem and installation specifications; writing an EMC control plan; and producing a detailed test plan. Author

N76-16274 Lucas Aerospace Ltd., Hemel Hempstead (England).
ELECTROMAGNETIC COMPATIBILITY CONTROL PLANS
P. D. Campbell *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 21 p refs (For availability see N76-16256 07-32)

The spectrum and level of radio interference have been measured for years and unwanted emissions reduced retrospectively. This remedial approach is now recognized as inefficient but the concept of electromagnetic compatibility as a design parameter still requires emphasizing. The devices, circuits, components and constructional details which can contribute to the creation, conduction and emission of unwanted signals are indicated and means whereby their effects can be minimized are examined. The problems arising in creating and implementing a control plan for the development of a typical piece of electrical equipment are outlined and the difficulties experienced in balancing operational, theoretical, practical and contractual requirements are highlighted. Author

N76-16275 Signals Research and Development Establishment, Christchurch (England).
A CASE FOR AN EVALUATION AND ADVISORY SERVICE
E. M. Frost *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 5 p (For availability see N76-16256 07-32)

The requirement to exchange, interwork and co-site equipments and systems, coupled with the widening use of semiconductor devices for new as well as traditional applications, has led to the concept of an overall Electromagnetic Compatibility (EMC) activity. However, there is no generally accepted definition for EMC as separate interests are tending to retain their own limited interpretations. It is believed that this is causing interface difficulties that will prevent EMC adapting itself sufficiently rapidly to deal with this changing and expanding electronic situation. After considering EMC as a typical pollution situation a suggestion is made for an evaluation and advisory service that would provide an interface between other EMC and allied activities and also act as a focus and creative development point for new ideas and techniques. Author

N76-16276 Thomson-CSF, Levallois-Perret (France).
INTERFERENCES IN FREQUENCY MODULATION SYSTEMS [INTERFERENCES DANS LES SYSTEMES A MODULATION DE FREQUENCE NO. 21]
G. Crocombette *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 16 p In FRENCH, ENGLISH summary (For availability see N76-16256 07-32)

Interference problems applicable to telephone radio links with multiplexing repeated in frequency (FDM-FM) were discussed. A general treatment applicable to all FM links was first presented, including: (1) typical organization of links and equipments, (2) effects of disturbances on the operation of equipment (capture of AGC and limiters) and on overall performance (noise after demodulation), (4) procedures used to reduce the effects of disturbances, and (5) calculation of the level of disturbances from the radiation diagrams and application to two special cases. The rest of the report was limited to FDM-FM telephone radio links with moderate to large capacities. Measurement results of reciprocal perturbations between different radio links of normal capacity were presented. Finally, radiation pattern diagrams used in the design of a network system were illustrated.
Transl. by Y.J.A.

N76-16277 Army Electronics Command, Fort Monmouth, N.J.
RADAR INTERFERENCE REDUCTION TECHNIQUES
William Fishbein, Reinhard Olesch, and Otto Rittenbach *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 23 p refs (For availability see N76-16256 07-32)

Techniques are described, applicable to radar, which enhance the compatibility of multiple systems in limited frequency space. By appropriate combination of multiple frequencies, the spectral occupancy of a signal can be reduced through pulse shaping, without sacrifice in range resolution. This method is extended to continuous wave radar, resulting in sidelobe reduction without amplitude modulation. A function is defined relating mutual interference of two systems in terms of their waveforms, physical and spectral proximity, and is used as a measure of interference. Ordinary single sideband techniques are modified and applied to radar to reduce spectral width. Considerations for interlacing the discrete line spectra of several radars are given. They include single sideband processing of unidirectional doppler signals and a step scanning scheme which permits increasing the allowable pulse rate. Author

N76-16278 Electromagnetic Compatibility Analysis Center, Annapolis, Md.
APPLICATION OF PROGRAMMABLE CALCULATORS TO EMC ANALYSIS
J. P. Georgi (Dept. of Defense) and Paul D. Newhouse (ITT Research Inst.) *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 14 p refs (For availability see N76-16256 07-32)

The use of programmable calculators is suggested for making electromagnetic compatibility calculations conveniently and economically. Programmable calculators are available at prices ranging from about $800 to $5000. Programs recorded on magnetic cards or tapes for use with the popular U.S. makes of calculators will be available from the Department of Defense, Electromagnetic Compatibility Analysis Center (ECAC) in 1976. Detailed explanations of several of the ECAC programs are given to illustrate the kinds of calculations that can be performed and to indicate the ease with which the programs can be used. Guidelines for the selection of calculators, and the pros and cons of using them are given. Author

N76-16279 Electromagnetic Compatibility Analysis Center, Annapolis, Md

APPLICATION OF MARKOV CHAIN THEORY TO THE MODELLING OF IFF/SSR SYSTEMS

Stephen J. Sutton (IIT Research Inst.) and C. Wayne Ehler (IIT Research Inst.) *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 23 p refs (For availability see N76-16256 07-32)

The automated IFF/SSR prediction model was constructed around the Markov chain models. Inputs to the prediction model include the interrogator environment and an air traffic deployment for a specific geographic area. For each transponder in the deployment the model determines those interrogators whose signals are received, calculate the transition probabilities, selects the proper Markov chain, and calculates transponder performance parameters. These parameters are then used to calculate the performance of a selected interrogator system. To gain confidence in the model predictions, results were compared with predictions from a previously validated simulation and with available measured interrogation and suppression arrival rates. The comparison showed that the IFF/SSR model predictions correlated well with both the other predicted data and the measured data. The results of this paper show that the IFF/SSR prediction model with Markov chain transponder models provides a powerful, flexible, reliable, and accurate analysis capability. Author

N76-16280 British Aircraft Corp., Filton (England). Electronic Systems Group.

COMPUTER GENERATION OF AMBIGUITY SURFACE FOR RADAR WAVEFORM SYNTHESIS

R. J. Morrow and G. Wyman *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 11 p refs (For availability see N76-16256 07-32)

Recent advances in the field of surface acoustic devices are likely to encourage the implementation of complex forms of matched filter radars. As a consequence, the system designer and EMC Analyst will require convenient methods establishing the likely system performance obtained from the various forms of signal processing. One well established technique used to determine the theoretical performance of matched filter or correlation receivers is through the application of the ambiguity function. This function has wide application as it may be employed to evaluate the theoretical received signal response in both the time and Doppler domains. As this function handles both matched and unmatched signals it provides a convenient method of assessing both the design and eventual electromagnetic compatibility of the system. With these considerations in mind a general computer method of solving the ambiguity function has been developed and is described in this paper. Author

N76-16281 Electronic Communications, Inc., St. Petersburg, Fla.

ANTENNA-TO-ANTENNA EMC ANALYSIS OF COMPLEX AIRBORNE COMMUNICATION SYSTEMS

William L. Dillon *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 16 p ref (For availability see N76-16256 07-32)

Methodology and applied techniques for antenna-to-antenna electromagnetic compatibility analysis of complex airborne communication systems are presented. Potential interference modes and system isolation factors are examined in conjunction with a typical equipment complement. A method of analysis is discussed which uses computer calibrated antenna space isolations with conventional analysis techniques. Some typical analysis results are presented in summary form. Antenna isolation is discussed as a limited factor for EMC optimization. The results of past analysis clearly show the need for frequency management to effect interference control as an integral part of the antenna-to-antenna EMC profile of complex airborne systems. Author

N76-16282 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

ANALYSIS OF THE NOISE AND ITS INFLUENCE ON COMMUNICATION SYSTEMS [ANALYSE DU BRUIT ET DE SON INFLUENCE SUR LES SYSTEMES DE COMMUNICATION]

Roger Gouillou *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 7 p refs In FRENCH; ENGLISH summary (For availability see N76-16256 07-32)

The paper aims at providing the communications engineer with guidelines in view to minimize the loss of information through signal reception and processing, by keeping to a minimum the introduction of noise at the different stages of data treatment. It summarizes, from this point of view, the many theoretical works found in the literature, and emphasizes the practical steps leading to the results. Noise and signal are considered through their respective spectral representations. This permits, through well known concepts, a definition of the effect of signal masking by the noise, and the calculation of the noise level as a function of processing means. Formulas established this way are easily applicable to various practical cases. Problems raised by the discovery of the signal within the noise are also mentioned. Author

N76-16283 Rome Air Development Center, Griffiss AFB, N.Y.

COMPUTER MODELING OF COMMUNICATIONS RECEIVERS FOR DISTORTION ANALYSIS

J. F. Spina and D. D. Weiner (Syracuse Univ.) *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 14 p (For availability see N76-16256 07-32)

Details of an analysis technique and companion computer program are presented that have application in the area of design and analysis of electronic circuits. Particular emphasis is placed upon the application of the program to the modeling of nonlinear distortion effects in communication receivers. A discussion of moderately nonlinear systems and the treatment of such systems using the nonlinear transfer function approach is followed by circuit analysis as a potential tool in designing and evaluating circuits from an electromagnetic compatibility point of view. An overview of the computer program in terms of some of its more salient features is provided. Author

N76-16284 Norges Tekniske Hoegskole, Trondheim.

COMPARATIVE ANALYSIS OF MICROWAVE LANDING SYSTEMS WITH REGARD TO THEIR SENSITIVITY TO COHERENT INTERFERENCE

Borje Forssell *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 8 p (For availability see N76-16256 07-32)

Proposed landing systems were computer simulated to examine their behavior in a realistic multipath environment. Models of airfields were elaborated and the reflected and direct signal components were used as inputs to mathematical models of the receiving systems to compute the resulting position errors. This study showed that it would be possible to use groups of synthetic interference components for the same purpose. By carefully choosing the distribution of the coherent interference, the significance of the comparison can be improved and the amount of work reduced. Author

N76-16285 Naval Postgraduate School, Monterey, Calif. Dept. of Electrical Engineering.

THE CROSSED-DIPOLE STRUCTURE OF AIRCRAFT IN AN ELECTROMAGNETIC PULSE ENVIRONMENT

Robert W. Burton *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 15 p refs (For availability see N76-16256 07-32)

The crossed dipole receiving antennas has been used as a representative model to approximate electromagnetic pulse effects on aircraft. Electromagnetic properties of the crossed dipole receiving antenna illuminated by a monochromatic source are considered. Results are presented for electrically moderately thin structures. In practice, when a crossed dipole receiving antenna is excited by a broad spectrum electromagnetic pulse, certain important electrical resonances occur, that is, at specific single frequencies of excitation some portions of the structure can support large amplitude standing waves of current and/or charge. Under such conditions a current maximum/charge minimum, current minimum/charge minimum, or current minimum/charge maximum may occur at the junction region. Examples of resonant and antiresonant situations for the parasitic monopole and the crossed dipole which highlight the possible interactions between the arms of the crossed dipole are presented which give insight into methods of analyzing aircraft in an electromagnetic pulse environment. Author

N76-16286 Telecommunications Radioelectriques et Telephoniques, Le Plesis-Robinson (France).

DESIGN PROBLEMS RELATED TO RADIO COMMUNICATION WITH AN INTEGRATED AIRBORNE SYSTEM [PROBLEMES POSES PAR LA TRANSMISSION DANS UN SYSTEME INTEGRE AEROPORTE]

G. David et Vannetzel *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 10 p refs (For availability see N76-16256 07-32)

An integrated communication system with second order

redundancy (as a back-up against breakdown) was investigated. Reasonable series and parallel circuits, assumed to be controlled by a management unit, and from which exchange principles may be shown, were illustrated. A number of communication problems between the transmission system and hardware components were briefly examined; such communication messages may be transmitted with a NRZ-type code. If distances are taken into account, a biphasic code is preferable since it eliminates any steady component from the main transmission line. Finally, numerical data transmissions facilitate the control of information and thereby decrease the possibility of errors. Transl. by Y.J.A.

N76-16287 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
DIGITAL DATA TRANSMISSION IN AIRCRAFT EMC-PROBLEMS AND POSSIBLE SOLUTIONS
H. Rode *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 10 p (For availability see N76-16256 07-32)

In the use of digital systems in aircraft, where a great deal of interference emission and very sensitive equipment are concentrated in a small space, new problems can arise due to the special type of emission and susceptibility of the digital systems. Great care must therefore be laid on the selection of the cabling (twisting rate, shielding), the line drivers and receivers, the rise and fall time, and the transmission rate. To prove in practice the meaning of theoretical evaluations of a choice of line drivers, line receivers and cables, special tests were performed on EMC test facilities. These tests also covered the different shielding and earthing possibilities. Special EMC tests were established to prove the compatibility of the digital systems with the complete aircraft system. Author

N76-16288 Electronique Marcel Dassault, St. Cloud (France).
GENERATION AND EFFECTS OF CONDUCTION AND RADIATION NOISE VOLTAGES BETWEEN THE COMPONENTS OF A SINGLE SYSTEM [GENERATIONS ET EFFETS DES TENSIONS PARASITES DE CONDUCTION ET DE RAYONNEMENT ENTRE ENSEMBLES D'UN MEME SYSTEME]
A. Quidet *In* AGARD Electromsgnetic Noise Interference and Compatibility Nov. 1975 14 p In FRENCH (For availability see N76-16256 07-32)

The main interference effects between the various components of electronic airborne systems were discussed, with emphasis on protection techniques and policies that should be adopted. In recent years, the introduction of digital numerical techniques, despite their numerous advantages, have complicated the integration of components using these techniques. Protection policies against such interferences rest on the following objectives: (1) limitation, insofar as possible, in the number of static noise generators, (2) reduction of the undesirable coupling effects, (3) avoiding perturbing effects by selecting appropriate techniques for data transmission. In addition, airborne system components are regulated by certain standards and specifications such as AIR 810 C fourth edition of 15 Feb. 1963, Mil Std 461 A of 1 Aug. 1968, Mil Std 462 of 31 July 1967. Transl. by Y.J.A.

N76-16289 Siemens A.G., Munich (West Germany).
THE REDUCTION OF ELECTROMAGNETIC COMPATIBILITY DUE TO NON-LINEAR ELEMENTS AND UNINTENDED RANDOM CONTACTING IN THE PROXIMITY OF THE ANTENNA OF HIGH-POWER RF-TRANSMITTERS
K. Landt *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 10 p refs (For availability see N76-16256 07-32)

With the aid of selective filters it is possible to almost completely eliminate harmonics, spurious emissions and wideband interfering signals on the output of RF transmitters, even those operating at very high output powers. These interfering signals are again generated, if nonlinear junctions or unintended random contacting create secondary radiation sources in the proximity of the transmitting antennas. The problems indicated are discussed with reference to an example for the installation of a UHF-unit and an avionic device in an aircraft, as well as on the example of an installation onboard a ship. Author

N76-16290 Royal Aircraft Establishment, Farnborough (England). Engineering Physics Dept.
IMPROVED DESIGN OF INTERFERENCE SUPPRESSORS AND MEASUREMENT OF ATTENUATION CHARACTERISTICS
M. L. Jarvis and J. D. Hawkett *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 13 p (For availability see N76-16256 07-32)

The mathematic approach and results are reported in the development of a new design of interference suppressor which eliminates the resonances normally occurring between a suppressor and its load. Also described are shortcomings of conventional 50 ohm insertion loss measurements, and a characteristic based on critical load conditions is proposed. Author

N76-16291 Army Missile Command, Redstone Arsenal, Ala.
MISSILE INTERSYSTEM EMC TESTING
Charles D. Ponds *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 10 p refs (For availability see N76-16256 07-32)

The intersystem EMC testing of missiles is described. Systems compatibility to a world wide electromagnetic environment is demonstrated by using mini computer control, broadband emitters, a unique data acquisition system, an infrared data link and a minicomputer data reduction system. Also, redesign information is acquired which will provide EM hardened missiles. The simulation facility used to provide an EM environment from 100 KHz to 15 GHz is described giving the emitter power output, modulations, sweep capabilities, log periodic and horn antenna, transmission line transverse electromagnetic mode test chamber and a minicomputer for close loop control of emitters, power and frequency controller, data acquisition and reduction. Author

N76-16292 Aeritalia, Turin (Italy).
MEASUREMENT OF INTERWIRING COUPLED NOISE
B. Audone and L. Bolla *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 13 p refs (For availability see N76-16256 07-32)

One of the major problems arising in the electromagnetic compatibility analysis of a complex system such as an airplane is the wiring interconnecting the equipments. A large amount of interference is picked-up among cables in the same loom when, due to limited available space, emitting and sensitive wires are not sufficiently separated. A test method to measure the coupling interference and susceptibility in different load configurations (open or short circuit) is proposed with the advantage of having a realistic simulation of the wiring coupling mechanism and valid guidelines for a better cable separation philosophy. Author

N76-16293 Genoa Univ. (Italy).
ON THE EVALUATION OF MAN-MADE ELECTROMAGNETIC NOISE INTERFERING WITH COMMUNICATIONS IN THE E. L. F. RANGE
Giorgio Tacconi *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 18 p refs (For availability see N76-16256 07-32)

The mechanics of some aspects of the man made electromagnetic noise at the E.L.F. are examined that are the most favorable for propagation in dissipative media. In particular, the noise is considered as generated by a moving ship in the vicinity of an electromagnetic sensor immersed in the sea. Mathematical and experimental approaches for an estimation of such noise are proposed. Some experimental results obtained in the Tyrrhenian sea are shown in accordance with theories and experiments. Local natural background noise as well as nearly and far off man made noise are considered in the context of a general transmission channel. Author

N76-16294 Army Electronics Command, Fort Monmouth, N.J. Avionics Lab.
AUTOMATIC TESTING OF AVIONICS SYSTEMS FOR ELECTROMAGNETIC COMPATIBILITY
Edmund T. Tognola *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 10 p refs (For availability see N76-16256 07-32)

A technique of semi-automatic electromagnetic compatibility testing is described that involves the use of a data acquisition unit integrated into the aircraft avionics and electrical subsystems. This enables the test engineer to gather EMC performance data on the system in its natural environment. The onboard recorded data is subsequently reduced by computer using specially developed programs to determine areas of non-compatibility. The results of the investigation indicate that the technique of using a data acquisition system for EMC testing is feasible and requires

less test effort and provides more complete and accurate results than conventional EMC testing. Author

N76-16295 American Electronic Labs., Inc., Lansdale, Pa. Communications Lab.
DESIGN OF A COMMUNICATIONS TEST (TEMPEST) RECEIVER FOR MAXIMUM BROADBAND DYNAMIC RANGE
J. B. Hager, J. C. Jones, and J. R. VanCleave. *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 6 p (For availability see N76-16256 07-32)

In any receiving system, but especially in communications test receiving systems, dynamic range is a key parameter. A particularly difficult receiving frequency range is 1 kHz to 1 MHz, where unshielded ambient noise intensity is very high, and adequate shielding is impractical. In a high noise ambient, the receiving system sensitivity becomes equal to the ambient level minus the receiving system dynamic range, which is invariably higher than KTB (thermal) noise. The design of a receiver for maximum performance in detection of broadband signals is significantly more stringent than that of narrow band signals, and requires the techniques described in this paper. Importance is placed on successive filtering of the receiver channel and maximizing signal handling capability. The related considerations concerning local oscillator rejection for maximization of tuning range and equipment shielding are also presented. Author

N76-16296 Ministry of Defence, Tel-Aviv (Israel). Armament Development Authority.
A STRAIGHT FORWARD COMPUTER ROUTINE FOR SYSTEM CABLE EMI ANALYSIS
M. Russo and O. Hartal. *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 11 p refs (For availability see N76-16256 07-32)

A method is reported that provides harness compatibility in a complex system, the design of which is limited. The method outlined provides a way whereby engineering effort and a computational backup check are combined to generate the EMC requirements in as short a time as possible. The data reduction phase is simple, time and effort saving and may be performed, after the primary effort phase, by non-EMC-skilled workers. The method as such is system oriented and meets the requirements of a specific design problem. Author

N76-16297 American Electronic Labs., Inc., Lansdale, Pa.
A UNIVERSAL ELECTROMAGNETIC COMPATIBILITY (EMC) ANALYZER UTILIZING BASIC CIRCUIT MODULES
Karl E. Wieler and Warren A. Kesselman (Army Electron. Command, Fort Monmouth, N. J.) *In* AGARD Electromagnetic Noise Interference and Compatibility Nov. 1975 16 p (For availability see N76-16256 07-32)
(Contract DAABO7-71-C-0339)

A measurement instrument was developed to give EMI-RFI testers more reliable information on received signals of an unknown nature. The amplitude distribution measurement can be applied to any situation where the distribution of a signal is desired. An evaluation of various detector modules defined usable measurement techniques for various signal types. New measurement concepts are introduced to the EMI/RFI field to give increased data on a detected unknown signal and certainly more reliable data than that taken with present measurement techniques and systems. Author

N76-20302# Advisory Group for Aerospace Research and Development, Paris (France).
RADIO SYSTEMS AND THE IONOSPHERE
1976 424 p refs In ENGLISH; partly in FRENCH Conf. held at Athens, Greece, 26-30 May 1975
(AGARD-CP-173) Avail: NTIS HC $11.00

The effects of the ionosphere on high frequency communication system are considered. For individual titles, see N76-20303 through N76-20332.

N76-20303 Lincoln Lab., Mass. Inst. of Tech., Lexington.
IONOSPHERIC LIMITATIONS ON THE ANGULAR ACCURACY OF SATELLITE TRACKING AT VHF OR UHF
J. V. Evans and R. H. Wand. *In* AGARD Radio Systems and the Ionosphere 1976 11 p refs Sponsored in part by US Army (For availability see N76-20302 11-32)

The maximum values of the radar metric errors are summarized that are liable to be encountered at 400 MHz at low elevations (2 deg) in the northern United States. The errors will generally be less than the values given here, and all tend to decrease with elevation E although for some (e.g., TIDs) the dependence is weak, and, in the case of scintillation, is controlled principally by the level of magnetic activity. Author

N76-20304 Air Force Cambridge Research Labs., L. G. Hanscom Field, Mass.
AMPLITUDE SCINTILLATION OBSERVATIONS AND SYSTEMS APPLICATION
Herbert E. Whitney and Jules Aarons. *In* AGARD Radio Systems and the Ionosphere 1976 16 p refs (For availability see N76-20302 11-32)

For the design of a transionospheric communications link, scintillation data are to be reduced to statistical descriptions during those intervals for which there is stationariness of the rms fluctuations of the signal. The fade statistics are useful in choosing coding and/or time diversity techniques to overcome this fading. Signal statistics of this type are illustrated using data recorded at equatorial, sub-auroral, and auroral latitudes. These signal statistics are folded into a morphological pattern which contains statistics of scintillation fading as a function of geomagnetic latitude, instantaneous magnetic excursion, and local time. Recent data taken at auroral and sub-auroral latitudes have shown the effects on F layer irregularities of magnetic storms. In particular, the magnetic storms of August 1972 illustrate worst case scintillation levels. Data during the storm of Oct. 31 - Nov. 1, 1973 are used to show the correlation of scintillation with local magnetic variations. Author

N76-20305 Air Force Avionics Lab., Wright-Patterson AFB, Ohio.
SIMULATION AND IMPLEMENTATION OF A MODULATION SYSTEM FOR OVERCOMING IONOSPHERIC SCINTILLATION FADING
Allen L. Johnson. *In* AGARD Radio Systems and the Ionosphere 1976 5 p refs (For availability see N76-20302 11-32)

Ionospheric scintillation has been recognized as a major problem in VHF/UHF satellite communication systems. An extensive computer simulation was done in an attempt to find an economical coding-interleaving combination which could be implemented for an airborne VHF/SHF SATCOM system. A variety of coding techniques were investigated. An actual ionospheric scintillation signal was recorded and digitized for the use in the simulation. The various coding interleaving techniques were played through this simulated channel; the results of each combination were tabulated. It was decided to implement a complete 75 bit-per-second teletype modem utilizing the results of the simulation. The modem being built utilizes frequency shift keyed modulation. In order to operate the encoder and interleaver, a received data clock is needed. It is derived by sampling the input data and incrementally shifting a reference clock until the best fit is achieved between the reference clock and a number of bits of the incoming data. This data clock is then used for timing the interleaver and encoder. Author

N76-20306 Communications Research Centre, Ottawa (Ontario). Dept. of Communications.
CHANNEL FADING ON AIR MOBILE SATELLITE COMMUNICATIONS LINKS
L. A. Maynard. *In* AGARD Radio Systems and the Ionosphere 1976 9 p (For availability see N76-20302 11-32)

Statistical measurements of the fading and time dispersion of the earth-space path have been made at locations varying in geomagnetic latitude. These measurements have demonstrated that the required system margins for a given grade of service vary strongly with frequency, geomagnetic latitude, and the way in which system reliability is specified. Preliminary measurements of the multipath characteristics of the North Atlantic show that the reflection process is diffuse. Author

N76-20307 General Electric Co., Schenectady, N.Y. Corporate Research and Development.
TRANSIONOSPHERIC EFFECTS ON RANGE MEASUREMENTS AT VHF
Roy E. Anderson. *In* AGARD Radio Systems and the Ionosphere 1976 14 p refs (For availability see N76-20302 11-32)

A fully integrated satellite ranging system for locating ships was implemented at VHF. Performance of the system was examined to determine the effects of ionospheric group delay

on the accuracy of the position fixes. Several 24-hour periods of ranging from a geostationary satellite to a widespread network of transponders yielded data on diurnal variations in delay and estimates on residual errors when ionospheric models are applied to the measurements. Some data on correlation distances in the ionosphere were obtained. The results suggest that a VHF position fixing system using two geostationary satellites could be operated with an accuracy better than 1 nautical mile when the ionosphere is not disturbed. Author

N76-20308 Army Electronics Command, Fort Monmouth, N.J. Communications/Automatic Data Processing Lab.
PLASMASPHERIC CONTRIBUTION TO GROUP-PATH-DELAY OF TRANSIONOSPHERIC SATELLITE NAVIGATION SIGNALS
H. Soicher *In* AGARD Radio Systems and the Ionosphere 1976 15 p refs (For availability see N76-20302 11-32)

A satellite navigation concept requires measurement of the time delay that satellite-emitted signals experience when traversing the distance between satellite and user. A pulse propagating this distance is slowed somewhat by an amount which is directly proportional to the total number of free electrons (TEC) along its path. For high orbit satellites, TEC includes the ionospheric as well as the plasmaspheric electron contents. The Radio Beacon Experiment (RBE) aboard the ATS-6 satellite examined the ionospheric content, N sub I (by the Faraday technique), the total ionospheric and plasmaspheric contents, N sub T (by the group delay technique), and the plasmaspheric content (N sub T - N sub I) = N sub p. Although diurnal, day-to-day, and seasonal variations of N sub p were observed, they were much smaller than corresponding variations of N sub I and N sub T. The ratio of plasmaspheric to ionospheric contents varied diurnally, seasonally, and from day-to-day. The diurnal variation exhibits basically a nearly constant night behavior and a much lower day behavior with rapid changes just after local sunrise and just after local sunset. Author

N76-20309 General Electric Co., Syracuse, N.Y.
IONOSPHERIC RADAR RANGE ERROR CORRECTION BY THE INCOHERENT SCATTER-FARADY ROTATION TECHNIQUE
George H. Millman and Glenn M. Reinsmith *In* AGARD Radio Systems and the Ionosphere 1976 13 p refs Sponsored by RADC (For availability see N76-20302 11-32)

The incoherent scatter phenomenon in conjunction with the Faraday effect is evaluated as a technique for near real time correction of ionospheric radar range error. The study was performed utilizing a simulator computer program, the major components of which consisted of a time variant three dimensional electron density model and an earth magnetic field model expressed in terms of a series of spherical harmonics. Theoretical estimates of the Faraday polarization angle and the incoherent backscatter power are made for an assumed high powered radar located in the mid-latitudes with the antenna beam oriented in various azimuth elevation angle configurations. Radar range bias errors derived from the incoherent scatter and Faraday rotation simulated data are compared with the true reference errors. An evaluation is given of the residual range errors, i.e., difference between the predicted and true errors, computed for the months of June and December and sunspot numbers of 10 and 60. Author

N76-20310 National Observatory of Athens (Greece). Ionospheric Inst.
LONG RANGE VHF TRANSEQUATORIAL FOR THE EUROPEAN-AFRICAN PATH, A REVIEW OF TIME DELAY MEASUREMENTS
Michael Anastassiadis and George Stefanou *In* AGARD Radio Systems and the Ionosphere 1976 22 p (For availability see N76-20302 11-32)

Five years of measurements of time delay of VHF signals transmitted from Athens and received at Roma (Lesotho) and later at Salisbury and retransmitted by a triggered device back at Athens, support the mechanism of a supermode propagation. The shape of time delay curves during presunset and aftersunset hours are explained on the basis of a simple geometrical model taking into consideration the height of reflecting layers in both hemispheres, the elevation angles, and the central angles between the points of emission and the points of reflections all of which affect the time of propagation of the emitted wave. The influence of thermospheric winds is also considered particularly for the explanation of lengthening during early evening hours. From all above experiments, the exact magnetic conjugacy seems to be of minor importance, and rather large areas surrounding the conjugate point, are regions of high interest, permitting the realization of good communication systems on 30-90 MHz band with a very low peak radiated power. Author

N76-20311 Appleton Lab., Slough (England).
A NEW COMPUTER-BASED METHOD OF HF SKY-WAVE SIGNAL PREDICTION USING VERTICAL-INCIDENCE IONOSONDE MEASUREMENTS
P. A. Bradley *In* AGARD Radio Systems and the Ionosphere 1976 16 p refs (For availability see N76-20302 11-32)

A knowledge of ionospheric propagation modes and signal strengths is important for the successful operation of HF point-to-point communication circuits and over-the-horizon radars. Predictions use representations of the state of the ionosphere based either on long term trends in past ionospheric data, or on near real time ionospheric soundings at vertical incidence or over oblique paths. A new prediction scheme is described which can be used with either forecast values or direct measurements of the standard ionospheric characteristics derived from vertical incidence soundings. Its important features include an improved model of the vertical distribution of electron concentration, a homing procedure to determine the rays which travel between specified terminals, an allowance for the focusing of rays with low elevation angles, an expression for ionospheric absorption based on the ionospheric characteristic foE and the inclusion of the effects of polarization coupling loss determined in terms of ray path and magnetic field geometry. Author

N76-20312 Forschungsinstitut der Deutschen Bundespost, Darmstadt (West Germany).
A COMPARISON BETWEEN THE DEUTSCHE BUNDESPOST IONOSPHERIC HF RADIO PROPAGATION PREDICTIONS AND MEASURED FIELD-STRENGTHS
Th. Damboldt *In* AGARD Radio Systems and the Ionosphere 1976 18 p refs (For availability see N76-20302 11-32)

The Deutsche Bundespost makes long term propagation predictions for use by its own frequency planning department and for various other users. The forecast computer program is reported, followed by an outline of field strength measurements. Afterwards the measurements are compared with the forecasts. Some of the deviations between forecasts and measurements are analyzed. Author

N76-20313 Max-Planck-Institut fuer Aeronomie, Lindau Uber Northeim (West Germany).
SWEEP FREQUENCY PROPAGATION ON AN 8,000 km TRANSEQUATORIAL NORTH SOUTH PATH
H. G. Moeller *In* AGARD Radio Systems and the Ionosphere 1976 7 p refs (For availability see N76-20302 11-32)

Two prediction improvements are suggested according to sweep frequency observations between Tsumeb, South West Africa and West Germany. In summer daytime the observed MOF is up to a factor of two higher than the predicted MUF. This error can be reduced to a factor of 1.2 if an Es-transmission factor of 7 is applied instead of a factor of 5 which had been used hitherto. In the existing predictions for long distance medium wave propagation only E-layer reflections are taken into account. In contrast to this assumption strong F-layer reflections have been observed. The median F-layer LOF was 1.3 MHz after midnight. At these low frequencies, signals reflected at the E-layer were quite often weaker than the signals reflected at the F-layer. Author

N76-20314 GEC-Marconi Electronics Ltd., Chelmsford (England). Research Lab.
AN IONOSPHERIC STORM MODEL USED FOR FORECASTING
L. W. Barclay *In* AGARD Radio Systems and the Ionosphere 1976 5 p refs (For availability see N76-20302 11-32)

Long term, monthly or seasonal, predictions are prepared in advance for both point to point and mobile communications requirements. Such predictions are intended to be used for planning and for contingencies and are not intended as an accurate guide for day to day operation. Forecasts prepared a few hours in advance and distributed rapidly can be used to inform the operators how the operational frequency band on a particular day differs from that shown in the long term predictions. The relationship between solar events and radio communication frequencies is incorporated in an ionospheric storm model in order to produce an acceptable forecast from the data received. Author

N76-20315 Barry Research Corp., Sunnyvale, Calif.
TECHNIQUES FOR REAL-TIME HF CHANNEL MEASUREMENT AND OPTIMUM DATA TRANSMISSION
George Barry and Robert B Fenwick *In* AGARD Radio Systems and the Ionosphere 1976 10 p (For availability see N76-20302 11-32)

The time variability of path loss, noise, interference, and dispersion which characterize an HF channel can be overcome by adding three elements to the conventional communication system (1) a transmission test set; (2) an interference monitor; and (3) high order time diversity The transmission test set continuously monitors the circuit loss and multipath, 3-30 MHz The optimum operating frequency is obvious from the test set display, but the specific frequency must be selected from among the allocated choices on the basis of interference. The interference monitor measures and stores the percentage occupancy of all HF channels and the operating frequency is chosen from the monitor display. Although a clear, propagating frequency is selected, noise and fading cause data transmission errors; the most effective solution is high order time diversity. Author

N76-20316 Admiralty Surface Weapons Establishment, Portsmouth (England).
CHANNEL ESTIMATION TECHNIQUES FOR HF COMMUNICATIONS
M. Darnell *In* AGARD Radio Systems and the Ionosphere 1976 11 p refs (For availability see N76-20302 11-32)

Channel estimation is a term used to describe the process of monitoring and measuring selected parameters of a communications channel with the aim of describing quantitatively the absolute or relative states of a given set of communications channels. This information can then be employed to optimize use of the dispersive, time variable HF propagation medium. The paper discusses the philosophy and applications of estimation techniques. Three basic classes of channel estimation systems are defined and the most important practical implementations of these basic classes are described. Author

N76-20317 Societe Telecommunications Radioelectriques et Telephoniques (France).
SELECTION TECHNIQUE OF THE OPTIMAL FREQUENCY FOR DATA TRANSMISSION THROUGH THE IONOSPHERE [PROCEDE DE SELECTION DE LA FREQUENCE OPTIMALE POUR UNE TRANSMISSION DE DONNEES SUR CANAL IONOSPHERIQUE]
G. David, C. Goutelard (Laboratoire d'Etude des Transmissions Ionospheriques), and J. P. VanUffelen *In* AGARD Radio Systems and the Ionosphere 1976 16 p refs In FRENCH (For availability see N76-20302 11-32)

A technique was described by which the reception conditions for a radio-electric channel, preselected according to an operational sequence, may be assured to be satisfactory. Criteria are given by which a test sequence may be transmitted and analyzed following its reception. The relationship of the stations and their operating mode in centralized networks was then given, based on information received from an ionosonde; a discussion of decentralized networks with a reduced number of stations was also given. Transl. by Y.J.A.

N76-20318 Southampton Univ. (England).
REAL-TIME HF CHANNEL ESTIMATION BY PHASE MEASUREMENTS ON LOW-LEVEL PILOT TONES
J. A. Betts and M. Darnell (ASWE, Portsdown, Engl.) *In* AGARD Radio Systems and the Ionosphere 1976 12 p refs (For availability see N76-20302 11-32)

The principles of a method of real time channel estimation based upon measurements of the phase perturbations imposed on a low level pilot tone by the HF propagation path are described. Results of three sets of trials carried out over short, medium and long range HF paths in order to verify the theoretical basis of the technique are then presented. Consideration is also given to possible future development of the technique and three operational scenarios in which this type of channel estimation might be applied are discussed. Author

N76-20319 GEC-Marconi Electronics Ltd., Chelmsford (England). Research Labs.
SHIP-SHORE COMMUNICATION AT SHORT RANGES
L. W. Barclay *In* AGARD Radio Systems and the Ionosphere 1976 15 p refs (For availability see N76-20302 11-32)

Communication between ship and shore, when the ships are sailing in coastal waters, is usually conducted in the VHF band for very short ranges and at MF and low HF frequencies, up to say 4 MHz, for ranges up to several hundred miles. MF propagation is essentially by the ground wave mode but the addition of sky wave modes at night increases the potential coverage area, increases the interference levels in the MF band and creates an interference zone where the ground and sky waves are of comparable amplitudes. The ground wave propagation mode is assessed by taking account of system parameters, of propagation and noise characteristics and of the distance of the shore station from the coast. The optimum frequency for ground wave communication, for a particular system is indicated. The effect of sky wave propagation on the conclusions reached is also discussed. The results of some experimental work are presented which show that, for communication quality SSB telephony, operation may be extended through the fading zone. Author

N76-20320 Naval Research Lab., Washington, D.C.
NARROWBAND HF COMMUNICATION SYSTEMS FOR DIGITAL VOICE
W. Jewett and R. Cole *In* AGARD Radio Systems and the Ionosphere 1976 13 p refs (For availability see N76-20302 11-32)

Source encoding techniques for narrowband digital voice generate a number of PCM symbols that represent different weight functions. The relative weights of the bits/symbols are considered in the optimization of the communication circuit. This minimizes the effect of transmission errors on the synthesized speech. Thus, the channel encoding selectively adds redundancy to the signal to maximize protection to portions of the digital source signal. This is the approach that is being followed to determine the optimum characteristics for a voice processor/HF modem. Author

N76-20321 Thomson-CSF, Gennevilliers (France).
HF TRANSMISSION OF NUMERICAL DATA [TRANSMISSIONS NUMERIQUES SUR VOIES HF]
C. Dechaux and J. M. Lebidois *In* AGARD Radio Systems and the Ionosphere 1976 16 p In FRENCH; ENGLISH summary (For availability see N76-20302 11-32)

In the field of digital transmissions, the major characteristic of the ionosphere is that it behaves as a multipath propagation medium. This paper describes a type of 1,200 bits/s - MODEM fitted to that kind of transmission medium and which is to be used for SSB radio transmission. After a short introduction about data transmission on HF channels, the MODEM operation mode and its implementation are reviewed; to conclude, the MODEM real life experiment results are discussed. Author

N76-20322 Manchester Coll. of Science and Technology (England). Dept. of Electrical Engineering and Electronics.
IMPROVEMENTS TO HF FSK DATA TRANSMISSION
Geoffrey F. Gott and Brian Hillam *In* AGARD Radio Systems and the Ionosphere 1976 7 p refs (For availability see N76-20302 11-32)

An FSK signal keyed at 75 bauds, with 850 Hz frequency shift, can have one of several frequency allocations within any given 2.4 KHz voice channel. In the presence of interference from other users, or slow selective fading, the FSK system performance may be significantly improved by using a frequency allocation appropriate to the prevailing channel conditions. This paper reports on an 800 km HF link experiment which investigated this principle, with a view to improving air/ground data transmission. Author

N76-20323 Admiralty Surface Weapons Establishment, Portsdown (England).
ADAPTIVE SIGNAL SELECTION FOR DISPERSIVE CHANNELS AND ITS PRACTICAL IMPLICATIONS IN COMMUNICATIONS SYSTEM DESIGN
M. Darnell *In* AGARD Radio Systems and the Ionosphere 1976 14 p refs (For availability see N76-20302 11-32)

Possible techniques are considered whereby the operation of an HF communications system could be made adaptive in response to the state of the channel Adaptive RF equipment, source encoding/decoding and channel encoding/decoding procedures are described and their interactions discussed. Adaptive signal selection implies adaptive signal generation and processing equipment Possible formats for such units are outlined, together with the inputs required for their operation and the advantages accruing from their use. Author

N76-20324 Societe Telecommunications Radioelectriques et Telephoniques (France).
DESCRIPTION OF A SELF-ADAPTIVE SYSTEM FOR DATA TRANSMISSION THROUGH THE IONOSPHERE [DESCRIPTION D'UN DISPOSITIF AUTOADAPTIVE POUR TRANSMISSION DE DONNEES SUR LIAISONS IONOSPHERIQUES]
J P VanUffelen *In* AGARD Radio Systems and the Ionosphere 1976 13 p refs In FRENCH (For availability see N76-20302 11-32)

A data transmission system in which distortions due to ionospheric propagation are corrected by a self-adaptive equalizer was described. More specifically, a description of the equalizer is given, whose adjustment is performed continuously from the received signals. A data transmission system with a capacity of 1,200 bauds and conceived with the self-adaptive filter was tested over a distance of 2,800 km. Measurement results obtained in the laboratory and in the field are given. Transl. by Y.J.A.

N76-20325 Centre National d'Etudes des Telecommunications, Lannion (France).
FEASIBILITY STUDY OF A HF ANTENNA WITH ELLIPTICAL POLARIZATION USED FOR TELEGRAPHIC TRANSMISSION WITH VERY HIGH SPEED [POSSIBILITES DE REALISATION ET D'EMPLOI D'UNE ANTENNE A POLARISATION ELLIPTIQUE DANS LA BANDE H. F. POUR UNE LIAISON A GRANDE VITESSE TELEGRAPHIQUE]
R. Hanbaba and J. C. Zehren *In* AGARD Radio Systems and the Ionosphere 1976 18 p refs In FRENCH (For availability see N76-20302 11-32)

The design of an HF antenna radiating, in a given direction, a wave with elliptical or circular polarization was considered. The radiating system consists of two intersecting half-wave dipoles with an angle 2 beta between them, and located in a plane inclined at an angle alpha to the vertical. The effect of the finite permittivity of the ground on the directivity diagram was analyzed, and the gain was computed with the type of polarization considered. The feasibility of obtaining an elliptical polarization with a fixed vector orientation was then studied as a function of the current fed to each dipole. Finally, a numerical application was presented for a frequency of 10 MHz, including the computation of the soil coupling impedances. Transl. by Y.J.A.

N76-20326 Max-Planck-Institut fuer Aeronomie, Lindau Uber Northeim (West Germany).
INFLUENCE OF SPREAD-F ON HF RADIO SYSTEMS
J. Roettger *In* AGARD Radio Systems and the Ionosphere 1976 19 p refs (For availability see N76-20302 11-32)

Fading power spectra and amplitude distributions of trans-equatorial HF signals are evaluated. The special type of ionospheric transhorizon radar which is applied for these investigations locates side reflecting spread-F irregularities in the equatorial ionosphere. By means of the digitized data, the characteristics of TEP signals, which are strongly influenced by the side reflecting equatorial spread-F irregularities, are determined. Considerable pulse dispersion is observed. Strong flutter fading is evident during spread-F conditions. The fading power spectrum and the amplitude distribution of the TEP signals is calculated from the observational data and matched to a Nakagami-Rice distribution. The parameters obtained from this data reduction state that strong electron density gradients in the irregularities give rise to side reflection of HF signals. Effective radar cross sections and the mean conservation time of irregularity structures are calculated from the amplitude evaluation. Author

N76-20327 Laboratoire d'Etude des Transmissions Ionospheriques, Cachan (France).
APPLICATION OF PSEUDO-ORTHOGONAL CODES TO TRANSMISSION THROUGH THE IONOSPHERE [UTILISATION DE CODES PSEUDO-ORTHOGONAUX ADAPTES AUX TRANSMISSIONS IONOSPHERIQUES]
F Chavand, M Gindre, and C Goutelard *In* AGARD Radio Systems and the Ionospure 1976 24 p refs (For availability see N76-20302 11-32)

The application of pseudo-orthogonal codes to signal transmission through the ionosphere was considered so that the receiver characteristics need not be modified permanently as a function of the transmission parameters. The pseudo-orthogonality of these codes was defined and discussed. The code parameters were determined from the propagation characteristics and their random variations. An optimization technique was used in this regard, taking into account the propagation and receiving conditions. Families of codes were obtained and their validity confirmed by experimental results. The data rate that may be reached corresponds, in some cases, to a gain of 25, with a better protection against disturbances and allowance for error corrections. Transl. by Y.J.A.

N76-20328 Lincoln Lab., Mass. Inst of Tech., Lexington
POLAR IONOSPHERE MODELING BASED ON HF BACKSCATTER, BEACON, AND AIRBORNE IONOSONDE MEASUREMENTS
B J. Burdick, J H Chisholm, and B E Nichols *In* AGARD Radio Systems and the Ionosphere 1976 18 p refs Sponsored by ARPA (For availability see N76-20302 11-32)

An experiment to investigate the polar ionosphere was undertaken during the period November 1971 through November 1972 with an HF radar stationed in Northern Maine, U.S.A. operating on a regular schedule collecting backscatter data over a 90 deg azimuthal sector of the polar ionosphere and monitoring beacons located at Keflavic, Iceland and at Thule and Narsarssuaq, Greenland. From this data base, a daytime and a nighttime period were selected for ionospheric modeling and raytracing analysis. The structure of the nighttime ionosphere was determined from simultaneous radar, beacon and airborne ionosonde measurements and was found to include the F-layer trough, plasma ring and auroral E-layer. On the basis of the radar backscatter and beacon data alone, the structure of the daytime ionosphere was found to be consistent with a one dimensional model. Author

N76-20329 Paris Univ. (France).
OBSERVATION OF IRREGULARITIES IN THE SUB-AURORAL F REGION OF THE IONOSPHERE THROUGH A BACKSCATTER TECHNIQUE AND A MID-LATITUDE STATION [OBSERVATION AU MOYEN DE LA TECHNIQUE DE RETRODIFFUSION ET A PARTIR D'UNE STATION DE MOYENNE LATITUDE DES IRREGULARITES DE LA REGION F SUB AURORALE]
A. Bourdillon *In* AGARD Radio Systems and the Ionosphere 1976 14 p refs In FRENCH (For availability see N76-20302 11-32)

A.H.F. backscatter sounder located at Valensole (44 d.g N; 6 deg E), coupled to a wide band highly directive antenna with a capacity of six discrete radiating directions on each side of the geographic north, recorded in 1972 and 1973 frequent occurrence at night of irregularities located in the high latitude ionosphere (latitude 56-66 degrees). Interpretation of the data using ray tracing techniques showed that field aligned irregularities often occurred simultaneously at low altitudes (240-280 km) and above the F region maximum (340-400 km). A swept azimuth recording is produced showing at a given time a wide extension in range of the irregularities. A series of recordings was made under conditions of high magnetic activity, showing a displacement towards the equator of the zones of occurrence of irregularities. The displacement is about 2.1 degrees in latitude per unit Kp. Author

N76-20330 Oslo Univ. (Norway)
FORMATION AND MOVEMENTS OF IONOSPHERIC IRREGULARITIES IN THE AURORAL E-REGION
Alv Egeland *In* AGARD Radio Systems and the Ionosphere 1976 15 p refs (For availability see N76-20302 11-32)

The auroral E-region undergoes more or less continuous, unpredictable, structural ionization changes of almost all scales of size and time. These ionospheric irregularities, with rapid motions and oscillations, are superimposed on the large scale, long term variations in the medium. The irregularities will change the propagation conditions and degrade radio communication and radar performance. The ionization structures also upset the delicate energy balance in the upper atmosphere by changing almost every parameter which specifies normal conditions. Formation and movements of small scale irregularities in the auroral E-region are reviewed. A variety of instability concepts, which may explain the production of ionization irregularities, have been postulated. Some of these will be mentioned and compared with recent ground and in-situ measurements. In addition, macroscopic drift motions in the E-region of ionization irregularities will be summarized. Author

N76-20331 Communications Research Centre, Ottawa (Ontario)
HIGH RESOLUTION MEASUREMENTS OF TIME DELAY AND ANGLE OF ARRIVAL OVER A 911 km HF PATH
D. W. Rice *In* AGARD Radio Systems and the Ionosphere 1976 15 p refs (For availability see N76-20302 11-32)

The results of some 40 hours of afternoon and evening measurements of HF propagation over a 911 km path are presented. An FMCW sounding technique was employed with a linear receiving array of 1.2 km aperture. These arrangments made it possible to resolve modes differing in time of arrival by as little as 20 microseconds, and to determine the angle of arrival of each mode. The results show that markedly nonlinear phase fronts can occur even for apparently single modes of propagation, as a result of the irregular structure of the ionosphere which splits the signal into a number of sub-modes. This finding presents a possible limitation to the accuracy of HF direction-finding, which applies even to systems capable of resolving the modes. Author

N76-20332 Leicester Univ. (England). Physics Dept.
THE CORRECTION OF ERRORS IN HF DIRECTION FINDERS BY TRAVELLING IONOSPHERIC DISTURBANCES
T. B. Jones and C. T. Spracklen *In* AGARD Radio Systems and the Ionosphere 1976 9 p refs (For availability see N76-20302 11-32)

Traveling ionospheric disturbances (TIDs) produce changes in the bearing of the signals received from a distant transmitter via the ionosphere. By monitoring the Doppler frequency shifts in the reflected signal at three or more receiving sites the speed, direction and magnitude of the TID can be determined. If the Doppler frequency shift at the direction finder is also measured, the displacement of the reflection point and hence the bearing deviation produced by the TID can be calculated. A very considerable improvement in accuracy is obtained when such corrections are applied to signals propagated over an 850 km path. Author

33 ELECTRONICS AND ELECTRICAL ENGINEERING

Includes test equipment and maintainability; components, e.g., tunnel diodes and transistors; microminiaturization; and integrated circuitry. For related information see also *60 Computer Operations and Hardware* and *76 Solid-State Physics*.

N74-31667# Advisory Group for Aerospace Research and Development, Paris (France).
ANTENNAS FOR AVIONICS
Jun. 1974 526 p refs In ENGLISH and partly in French Presented at the 26th meeting of the Avionics Panel Symp., Munich, 26-30 Nov. 1973
(AGARD-CP-139) Avail: NTIS HC $29.50

The application of avionics antennas in Aerosat systems is considered by analyzing the feasibility of realizing required radiation patterns either on the aircraft, on the satellite, or on the ground. For individual titles, see N74-31668 through N74-31708.

N74-31668 Naval Electronics Lab. Center, San Diego, Calif.
CONFORMAL ARRAYS FOR AIRCRAFT
J. Provencher, J. Boyns, and A. Hessel (Polytechnic Inst. of New York) *In* AGARD Antennas for Avionics Jun. 1974 15 p refs (For availability see N74-31667 21-09)

Design consideration involved with the multifrequency conformal array are: (1) element pattern effects in non-planar arrays, (2) multifrequency array techniques; and (3) MIC components and cost considerations. The element patterns of conical arrays are examined to determine if behavior is similar to known element patterns for the cylindrical or planar arrays, and a conical sector experimental array is used to simulate selected scanned beam positions to determine array behavior, i.e., beamwidth, scan limits, polarization and side lobe level. The concept of the multifrequency array has been shown to be feasible, and the use of the interlacing technique with the conformal array allows more flexibility due to the larger element spacing possible. These features, combined with MIC hybrid matrix techniques for multiple beams, diode phasors and hybrid drivers for beam steering, and flush mounted radiating elements provide the system designer with a versatile antenna system. Prototype arrays designed at wavelengths of 30cm, 10cm, 7cm and 3cm are described. Author

N74-31669 Naval Research Lab., Washington, D.C. Radar Div.
PATTERNS AND POLARIZATIONS OF SIMULTANEOUSLY EXCITED PLANAR ARRAYS ON A CONFORMAL SURFACE
J. K. Hsiao and A. G. Cha *In* AGARD Antennas for Avionics Jun. 1974 16 p refs (For availability see N74-31667 21-09)

A conformal array on a surface of small curvature can be approximated by a number of planar arrays, several of which may be excited simultaneously so as to achieve a performance similar to that of a conformal array. Since the main beam of a planar array can be steered to any direction in visible space, several arrays, each oriented in a different direction, can be steered cooperatively to form a single beam in a desired direction. A general formulation of the radiated field of such an array of arrays is developed with the aid of formulas which relate the components into which a vector is resolved in one orthogonal coordinate system with those into which the same vector is resolved in a second orthogonal coordinate system. Using this formulation, it can be shown that within each array, the conventional row and column phase setting can be used. As examples, the radiation patterns and polarizations of multiple arrays of short dipoles are studied using the present formulation. A comparison of the multiple planar array with the conventional conformal array is also presented. Author

N74-31670 Terma Elektronisk Industri A/S, Aarhus (Denmark).
DESIGN OF PERIODICALLY MODULATED TRI-PLATE ANTENNAS
Finn Laursen *In* AGARD Antennas for Avionics Jun. 1974 6 p refs (For availability see N74-31667 21-09)

A new configuration of periodically modulated traveling wave tri-plate antennas has been developed. The physical complexity of this new configuration implies that sufficiently accurate design data are extremely difficult to predict by any known analytical methods. Three different measuring methods to achieve experimental design data are discussed. The far field method, which has been further developed during this investigation, the near field method, and the insertion loss method. The most appropriate combination of the three methods is used to find the design data. An X-band antenna array is designed and discussed. The new structure is mechanically simple, it has good impedance characteristics, allows good control of the aperture illumination, and radiates a linear polarized field with a very low cross polarized component. Author

N74-31671 Ferranti, Ltd., Edinburgh (Scotland)
HIGH EFFICIENCY ANTENNAS FOR AIRBORNE RADAR
R. W. Forrester and A. J. Lait *In* AGARD Antennas for Avionics Jun. 1974 9 p refs (For availability see N74-31667 21-09)

Consideration is given to antenna types which are suitable for use in airborne radars, and their advantages and disadvantages discussed. Several important antenna properties are efficiency, sidelobe level, scanning rate, weight, cost, etc. Emphasis is concentrated on methods which give a high antenna efficiency, whilst trying to maintain as many of the other properties as possible. An experimental Cassegrain antenna has been designed and built. It employs energy redistribution techniques to give a high efficiency, whilst retaining a reasonable sidelobe level. A measured efficiency of 70% was obtained at the design frequency, which only dropped to 65% at 500 MHz above design frequency. The antennas gave good sum and difference patterns over a 2 GHz band in X-band. Author

N74-31672 Radio Corp. of America, Moorestown, N.J. Missile and Surface Radar Div.
SHF HIGH POWER AIRBORNE COMMUNICATIONS ANTENNA
J. P. Grabowski and F. L. Lanphear *In* AGARD Antennas for Avionics Jun. 1974 12 p refs (For availability see N74-31667 21-09)

The high power SHF antenna, which is mounted atop the fuselage of a KC-135 aircraft, is part of a link which permits communication between tactical terminals by means of a synchronous altitude satellite. The antenna can acquire and track a satellite beacon signal, hold a stable line of sight for a short period of time, and is capable of being computer pointed. The antenna configuration was specifically designed for handling high CW power levels at X-band frequencies without the use of forced air or liquid cooling. A 32-inch Cassegrain antenna system was selected to provide a minimum antenna gain of 32.5 db over a 5% transmit frequency band and a separate 5% receive frequency band. The antenna radiates a right hand circularly polarized signal at a CW power level of 12.5 kW and simultaneously receives left hand circularly polarized signals. Computations utilizing measured antenna patterns indicate the antenna noise temperature to be 84 K. The feedhorn is a simple conical horn aperture operating in the dominant mode. A 2-mil H-film aperture window serves as the feed radome and pressure barrier. Compactness is achieved in the feed design by incorporating a circularly polarized dual mode transducer which generates the required senses of circular polarization and at the same time provides the duplexing between the transmit and receive signals. Author

N74-31673 Electra, Suresnes (France).
PROBLEMS OF ANTENNAS OPERATING IN THE TELEMETRIC S BAND REGION [PROBLEMES D'ANTENNES POSES PAR LE PASSAGE EN BANDE S DES TELEMESURES]
M. Nicolas and C. Mast *In* AGARD Antennas for Avionics Jun. 1974 13 p In FRENCH (For availability see N74-31667 21-09)

Principles of ground antennas, noting S band and automatic tracking are given along with design examples. The antennas are of the parabolic reflector type with a monopulse source. The separate signals are treated as a function of composite analog signals generated and delivered by a conical sweeping arrangement. An example was also given of a ground antenna simultaneously receiving in two bands, S and VHF.
Transl. by E.H.W

N74-31674 Royal Aircraft Establishment, Farnborough (England).
RADIATION CHARACTERISTICS OF HF NOTCH AERIALS INSTALLED IN SMALL AIRCRAFT
N. A. D. Pavey *In* AGARD Antennas for Avionics Jun. 1974 15 p refs (For availability see N74-31667 21-09)

The radiation characteristics of HF notch aerials in small aircraft are analyzed for the band 2 to 10 MHz. Radiation occurs in two main modes: a magnetic dipole mode resulting from the high local RF currents flowing around the notch, and an electric dipole mode resulting from longitudinal RF currents in the fuselage. A procedure is given for the estimation of the radiation

efficiency of an aircraft notch aerial. It is shown that high radiation efficiencies may be realized at frequencies near the aircraft electrical resonance, typically 10 MHz, but that a rapid reduction of radiation efficiency occurs at lower frequencies. A radiation efficiency of less than 0.1% at 2 MHz is to be expected for many aircraft notch aerials. Author

N74-31673 Collins Radio Co., Cedar Rapids, Iowa. Telecommunications Equipment Div.
HF ANTENNA SYSTEMS FOR SMALL AIRPLANES AND HELICOPTERS
R. E. Deasy. *In* AGARD Antennas for Avionics Jun. 1974 18 p. (For availability see N74-31667 21-09)

Basic information is presented to help antenna designers and installers provide optimum HF antenna systems on small airplanes and helicopters. Discussion involves practical antenna installation considerations rather than detailed antenna theory. Wire, shunt/notch, and tuned monopole types of antennas and associated antenna couplers are discussed. Important details related to the selection, installation, and successful operation of these antenna systems are given. Typical antenna location, size, and configuration are related to aircraft characteristics. Three common forms of wire antennas (long wire, inverted V, and short grounded wire) are illustrated. Techniques such as RF grounding, bonding, and shielding to eliminate RFI are discussed in detail. Shielded antenna feedline techniques (including efficiency considerations) are shown. Voltage-altitude design considerations are given. Shunt and notch type antennas are illustrated and general details of location, size, and construction are discussed. A typical installation is detailed showing RFI considerations. A tuned monopole (with load wire) antenna is discussed for applications on small airplanes and helicopters. Typical installation guidelines are given along with details showing RFI considerations. Author

N74-31676 MEL Equipment Co., Ltd., Crawley (England)
VERY SLIM, HIGH GAIN PRINTED CIRCUIT MICROWAVE ANTENNA FOR AIRBORNE BLIND LANDING AID
W. Hersch. *In* AGARD Antennas for Avionics Jun. 1974 2 p (For availability see N74-31667 21-09)

A very slim stripline microwave antenna designed for C-Band consists basically of two selectively etched POLYGUIDE boards. The integral radiating elements are 2 stacked dipoles, backed by a reflector, yielding a cardioid shaped beam approximately 40 degrees wide. An aerodynamically shaped radome and the use of high temperature materials makes this antenna suitable for all supersonic aircraft. Author

N74-31677 Marconi-Elliott Avionic Systems Ltd., Borehamwood (England).
POLYROD AERIALS FOR AVIONIC APPLICATIONS
M. Scorer and A. M. Smith. *In* AGARD Antennas for Avionics Jun. 1974 13 p refs (For availability see N74-31667 21-09)

The effect of adding rectangular dielectric slabs, having cross sections of the order of tens of square wavelengths, to the aperture of an aerial is studied with a view to increasing its gain. A theory has been developed to describe the performance of such an aerial and has been verified experimentally. Theoretical and experimental curves of gain enhancement versus slab length for slabs having various dielectric constants are presented. Hybrid slabs, comprising sections of different dielectric constants, have been designed according to the theory and show improved performance over slabs of constant dielectric constant. Slabs excited by feeds whose apertures have cross sections smaller than the slab cross section have also been examined. Author

N74-31678 Royal Radar Establishment, Malvern (England).
LINEAR PHASED ARRAY FOR YAW STABILISATION
D. S. Hicks. *In* AGARD Antennas for Avionics Jun. 1974 14 p refs (For availability see N74-31667 21-09)

The theoretical performance of a linear digital phased array with both equal and unequal interelement spacing has been investigated with the aid of a computer program written in ALGOL 68R. Three aerials have been studied. The first is a conventional linear phased array in which each element consists of a waveguide horn. The elements are placed side by side to form a fully filled aperture. The other two arrays consist of identical waveguide horn elements but the spacing is not equal. Two arbitrarily chosen spacing laws were studied each of which had an exponential form. The loss in gain due to phase quantization has been calculated and the effects of the unequal inter-element spacing law on gain and beamwidth is estimated. The beam pointing error, the beam granularity and the magnitude of the peak sidelobes are presented here for the three arrays. It is shown that some reduction in the number of elements required to fabricate an array may be achieved if the inter-element spacing is not made equal, the magnitude of the grating lobes may be significantly reduced if the spacing law is chosen correctly. Lastly a simple means by which a static split system may be achieved is discussed and some simulation program results presented. Author

N74-31679 Naval Research Lab., Washington, D.C.
AEW RADAR ANTENNAS
Tomos Llewelyn ap Rhys and Grealie Anderson Andrews, Jr. *In* AGARD Antennas for Avionics Jun. 1974 17 p refs (For availability see N74-31667 21-09)

It is shown that the single most important factor influencing the ability of the AEW radar system to operate is the antenna's sidelobe performance. In general, this sidelobe performance is dominated by the airframe on which it is mounted. Careful design is needed, considering both aerodynamic as well as electrical aspects, before an overall optimal system configuration can be determined. Once this antenna sidelobe performance has reached an acceptable level, it is then found that the next limitation is that due to errors in the compensation of platform motion. Recent advances in digital processing technique offer many advantages in connection with moving-target indication (MTI) but these can only be realized when the platform-motion compensation is sufficiently accurate. The various system considerations governing this performance are discussed and the requirements reflecting on the antenna performance described in detail. Author

N74-31680 Chelton (Electrostatics) Ltd., Marlow (England)
AIRBORNE LOW-VHF ANTENNAS
Charles E. Cooper. *In* AGARD Antennas for Avionics Jun. 1974 8 p (For availability see N74-31667 21-09)

A blade type antenna design is considered for airborne transmission and reception, with variants covering major sections of the overall frequency band from 26 to 100 MHz. It uses miniature high vacuum relays to tune via pre-selection of up to six binary related inductors, providing up to sixty four tuning combinations, with individual band widths varying from about + or - 0.5 to 5.0 MHz. The relays are remotely controlled either manually or automatically, and the retune process can be virtually instantaneous upon both receive and ready to transmit modes, without having to be incepted by any period of transmission. Incorporation of a variable tuning system was compelled by the specified combination of total frequency coverage and maximum allowable dimensions for the antenna. However, experimental investigations into the practical limits of broadbanding produced an antenna design fixed tuned to cover 38 to 46 MHz, which is briefly described. A brief outline of a wideband VHF homing antenna which uses elements formed out of transparent metallic-film depositions upon the acrylic canopy of the Gazelle helicopter is included. Author

N74-31681 Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Lab. du DERMO.
TE SUB 11 CIRCULAR WAVEGUIDE FERRITE PHASERS OPTIMIZATION
A. M. Dupuy and A. C. Priou. *In* AGARD Antennas for Avionics Jun. 1974 16 p refs (For availability see N74-31667 21-09)

An exact analytical and numerical method has been elaborated for the complete determination of the propagating modes in a reduced size circular TE 1 waveguide partially or fully filled with a lossy axially partially magnetized ferrite rod. Computed results at 17 GHz and 9.5 GHz are presented which allow for optimization of circulary polarised phasers such as Dual Diode Phasers (D.M.P.) or Polarization Insensitive Phasers (P.I.P.). Author

N74-31682 Communications Research Centre, Ottawa (Ontario). Dept. of Communications.
A CROSSED-SLOT BELT ARRAY ANTENNA FOR SATELLITE APPLICATION
R. Breithaupt, B. Clarke, and D. Waung. *In* AGARD Antennas for Avionics Jun. 1974 14 p refs (For availability see N74-31667 21-09)

A partially complete feasibility study of the design and fabrication of a fixed beam, circular-polarized belt array for possible use as a telemetry/command antenna on a geostationary communications satellite, is described. This application requires a toroid

shaped coverage pattern for use when the satellite is not oriented on station. The belt array of circular-polarized elements used is fed using travelling wave excitation by a thin plated dielectric waveguide of .060 in. x 2.350 in. cross section. After some measurements on round hole radiating elements, crossed slots with external dielectric loading were finally chosen. These elements were matched and characterized in terms of scattering parameters in an active array environment. Measured performance of this array was less than expected due to significant effects of tolerance and placement of the external dielectric loading on individual elements. Author

N74-31683 Birmingham Univ. (England). Dept. of Electronic and Electrical Engineering.
CROSS-POLARISED RADIATION FROM SATELLITE REFLECTOR ANTENNAS
A. W. Rudge, T. Pratt, and A. Fer. *In* AGARD Antennas for Avionics Jun. 1974 9 p refs (For availability see N74-31667 21-09)

The limited RF spectrum which is available for satellite communication systems has led to increased interest in the use of dual polarized and orthogonally polarized multiple beam antennas. Since an accurate knowledge of the antenna side-lobes and cross polarized radiation is necessary to ensure adequate isolation between RF channels, this paper examines some available techniques which can be employed to predict the vector fields of reflector antennas. The problem of providing an adequate description of the antenna primary feed radiation is found to be a critical factor. Results for predicted and measured cross polarized radiation fields are presented. Author

N74-31684 Royal Radar Establishment, Malvern (England).
PROBLEMS OF LONG LINEAR ARRAYS IN HELICOPTER BLADES
R. H. J. Cory. *In* AGARD Antennas for Avionics Jun. 1974 18 p refs (For availability see N74-31667 21-09)

Helicopter blades offer sites for the inclusion of long microwave antennas to give narrow azimuthal beams scanned by the rotation of the blades. The variation of blade attitude as it rotates is such that it may lag, lead, bend in vertical and horizontal planes and twist, and in consequence places limits on the practical length of a linear array. The choice of location for antennas, either in the front or trailing edge, or out or inboard is discussed. Certain advantages accrue from a design where the antenna is located near the center of gravity of the blade section, and radiating rearwards through the trailing edge, which requires to be of dielectric material. The length of the section of the trailing edge can be employed as a dielectric tapered slab antenna to shape the beam in the vertical plane and give more gain and direct the beam in a given direction. Theoretical discussion of the mechanism of this antenna and the choice of permittivity for the dielectric slab is discussed. Author

N74-31685 Societe Technique d'Application et de Recherche Electronique, Massy (France)
A COMMUTATION ON ANTENNA SYSTEMS COVERING STANDARD AIRCRAFT AND BALLOONS [SYSTEME D'ANTENNES A COMMUTATION REALISANT UNE COUVERTURE AVION AUX NORMES AEROSAT]
C. Ancona and P. Froidure. *In* AGARD Antennas for Avionics Jun. 1974 8 p refs In FRENCH (For availability see N74-31667 21-09)

Aeronautical satellite design, utilizing aircraft antenna systems, to assure hemispheric coverage with a minimum of gain was discussed. Three types of systems were considered: the electric scanner network, mechanical orientation solutions, and commutable antenna systems. Several theoretical aspects of the problem including angular relations, gain of antenna axis assuring such coverage, and the minimum gain in the angular zone considered, were examined. Transl. by E.H.W.

N74-31686 National Aerospace Lab., Amsterdam (Netherlands).
A LINEAR ARRAY OF BLADE ANTENNAS AS AN AIRCRAFT ANTENNA FOR SATELLITE COMMUNICATION
O. B. M. Pietersen, J. P. B. Vreeburg, and F. Klinker. *In* AGARD Antennas for Avionics Jun. 1974 13 p refs (For availability see N74-31667 21-09)

In a ground-satellite-aircraft communication system the aircraft antenna is a critical part since it has to meet the typical environmental requirements and possess a rather high gain. This paper describes a suitable antenna system, installed on a Fokker Friendship aircraft. It consists of a linear array of blade antennas, a power division and phase shifting network in coax technique and a manual controlled beam selector/indicator. The design of the array is based on a mathematical model that has been constructed from theoretical considerations and experimental results. Mutual coupling effects are accounted for by using scattering coefficients. With the aid of a computer the spacings between the antennas were determined in such a way that a nearly constant directivity in the yaw plane of the aircraft could be expected. The performance of the array was evaluated in several flights in which radiation patterns were measured in the receive and the transmit mode. From these measurements it is concluded that with the linear phased array of eight blade antennas a gain of 10 db can be achieved. Author

N74-31687 Communications Research Centre, Ottawa (Ontario). Dept. of Communications.
UHF LINEAR PHASED ARRAYS FOR AERONAUTICAL SATELLITE COMMUNICATIONS
H. L. Weratiuk, J. D. Lambert, L. A. Maynard, and J. H. Chinnick. *In* AGARD Antennas for Avionics Jun. 1974 14 p refs (For availability see N74-31667 21-09)

An ultrahigh frequency phased array antenna has been developed and test flown on a Canadian Forces C-47 Dakota and a C-130 Hercules. Successful voice communications were achieved with the aircraft terminals via the Lincoln Experimental Satellite LES-6 at 300 MHz. The prototype antenna system consists of nine blade antenna elements mounted along the top of the aircraft fuselage. The antenna is electronically scanned and generates a series of symmetrical conical fan beams. The electronics necessary to control the array scan are relatively simple because of the single dimension of the array and the insensitivity of the patterns to large phase errors at each element. This paper describes the techniques used to construct the phased array, and some of the test results obtained. Two methods developed to provide automatic tracking for the array are also described. Author

N74-31688 Transportation Systems Center, Cambridge, Mass.
A COMPARISON OF TWO L-BAND AIRCRAFT ANTENNAS FOR AERONAUTICAL SATELLITE APPLICATIONS
Robert G. Bland and John M. Clarke. *In* AGARD Antennas for Avionics Jun. 1974 24 p refs (For availability see N74-31667 21-09)

A comparison is made of the measured performance characteristics of two circularly polarized flush mounted L-band aircraft antennas for aeronautical satellite applications. In order to facilitate radiation pattern measurements, the previously validated technique of using a scale model aircraft antenna was employed. One of the candidate antennas under comparison is a cavity backed dipole fed slot configuration. Measurements were conducted on a 1/10th scale model of a Convair 880 aircraft. The other antenna is an orthogonal mode crossed-slot configuration. In this case measurements were conducted on a 1/20th scale model of a Boeing 707 aircraft which is almost identical in size to the Convair 880. The basic requirements of this class of antenna are to provide moderate gain of +4 above istropic at L-band over the upper hemispheric region of the aircraft. A diversity combination technique study for the two antennas under comparison considers a switched multiple element system in which various fuselage placement and combination arrangements of elements are evaluated. Author

N74-31689 Selenia S.p.A., Rome (Italy). Antenna Section.
CIRCULARLY POLARIZED L-BAND PLANAR ARRAY FOR AERONAUTICAL SATELLITE USE
Benito Palumbo and Salvatore Cosentino. *In* AGARD Antennas for Avionics Jun. 1974 15 p refs (For availability see N74-31667 21-09)

A circularly polarized L-band planar array for aeronautical satellite use is presented. A simple trade-off is outlined among the several earth coverage antenna types mainly for what concerns the constraints on weight and size. From this trade-off a planar array, consisting of two interlaced arrays of transverse and longitudinal slots, appears the most attractive solution, mainly if wide operating bandwidths are not required. The design criteria for such an antenna are presented and the principal electrical critical areas together with the main technological and mechanical characteristics are discussed. The main results on an experimental work on transverse slots are reported with their implications on the antenna design criteria. Experimental results (radiation patterns, VSWR) on a breadboard and on the L-band model are presented. Author

N74-31690 EMI Electronics Ltd., Feltham (England).
UPPER L-BAND TELEMETRY AERIALS FOR ROCKETS AND MISSILES
J Mahoney *In* AGARD Antennas for Avionics Jun 1974 17 p refs (For availability see N74-31667 21-09)

Future telemetry systems on missiles and rockets are likely to operate at upper L-band frequencies. The advantages to be gained and the problems likely to be encountered at these higher frequencies and the effects of change in the radiation pattern due to increased electrical spacing between individual aerials is given for a wide range of missile diameters. Methods of improving the radiation pattern coverage by altering the phase distribution to individual aerials and/or increasing the number of aerials are described. Effects caused by missile projections, i.e. wings and tailfins and surrounding structures such as launcher tubes and aircraft fuselage upon the radiation pattern are discussed. A comparison between the performance of existing telemetry aerials operating at 450 MHz and various prototype upper L-band aerials is given. Problems relating to the working environmental conditions for a wide range of missile applications are described. Author

N74-31691 Rome Air Development Center, Griffiss AFB, N.Y.
ELECTRONICALLY SCANNED TACAN ANTENNA AS AN ENROUTE AND TERMINAL NAVIGATIONAL AID
Edward J. Christopher *In* AGARD Antennas for Avionics Jun. 1974 11 p refs (For availability see N74-31667 21-09)

The principles of operation of present mechanically rotated Tacan antenna systems and their performance characteristics are considered. A Tacan capable of providing full band operation and electronic scanning in a single radiating structure is demonstrated. The array approach permits elevation pattern shaping. Through a combination of steep pattern slope at the horizon and low side lobes below the horizon, siting is less sensitive, i.e. bearing errors over the required spacial coverage of the Tacan system, which are introduced by the antenna environment, are minimized. There are no moving parts that require preventive maintenance and modular design allow most repairs to be made in the field, reducing both mean time and mean cost to repair when compared with existing mechanical systems. Author

N74-31692 AEG-Telefunken, Ulm (West Germany).
ANALYSIS OF FINITE ARRAYS OF RECTANGULAR APERTURES ON CONDUCTING ELECTRIC COATED CYLINDERS
J. Vogt *In* AGARD Antennas for Avionics Jun. 1974 7 p refs (For availability see N74-31667 21-09)

The aim of the presented theory is to investigate the influence of mutal coupling and creeping waves on the performance of a phased array antenna, consisting of a finite number of apertures flush-mounted on the surface of an infinite conducting cylinder with a concentric dielectric covering. The numerical results show that mutual effects are reduced due to the cylindericul structure of the surface, but are increased due to the dielectric covering. Author

N74-31693 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
MICROWAVE ANTENNAS FOR HYPERSONIC MISSILES
Christian Poulit *In* AGARD Antennas for Avionics Jun. 1974 4 p refs In FRENCH, ENGLISH summary (For availability see N74-31667 21-09)

Within a flight program aimed at analyzing physical phenomena during reentry of an hypersonic missile into the atmosphere, three types of antennas were used, radiating in the S, C and X frequency bands. The type of antenna chosen (rectangular iris embedded in alumina) allowed a design satisfying particularly severe environment conditions while retaining a widely open radiation pattern, which permitted an omnidirectional pattern set, to be obtained, by a combination of sets. Author

N74-31694 Royal Aircraft Establishment, Farnborough (England)
THE DESIGN OF WIDE BAND NOTCH AERIALS AND SOME APPLICATIONS TO AVIONICS
George Bagley *In* AGARD Antennas for Avionics Jun 1974 9 p refs (For availability see N74-31667 21-09)

Experimental results obtained from notches of a variety of rectangular shapes cut in semi-infinite metal sections are reported, and the various conbinations of center frequency and impedance bandwidth which can be obtained from a notch of fixed physical length are illustrated. The results relate to notch used in the self resonant mode, without any additional lumped reactan-

The variables investigated (for a fixed length notch) are notch width, thickness of the section, and feed point position. It is possible to drive the notch either as a narrow band quarter wave radiator, or as a half wave radiator with a frequency bandwidth of 2.0:1. Several possible applications are discussed, including an omni-azimuthal horizontally polarized radiator with a band width of 3.0:1. Author

N74-31695* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena
DUAL FREQUENCY DICHROIC FEED PERFORMANCE
D. A. Bathker *In* AGARD Antennas for Avionics Jun. 1974 10 p refs (For availability see N74-31667 21-09)
(Contract NAS7-100)
CSCL 17B

The NASA Deep Space Net (DSN) in support of the Viking Mars Project in 1976, and for science and technology demonstrations during the Mariner-Venus-Mercury mission in 1974, has developed and implemented a dual (S- and X-band) feed for large ground microwave antennas. This feed provides for a multiplicity of functions; very low listening capability at each downlink (spacecraft-to-earth) band as well as simultaneous diplexed very high cw power uplink (earth-to-spacecraft) at the S-band frequency. Total 64-m antenna system performance, is considered in terms of gain, operating noise temperature and dual beam pointing or boresight coincidence. Because of the unique ability to fold or stow the dual band feed elements for single band operations, the performance definition between single and dual band operations will be reliable and accurate. Author

N74-31696 Siemens A.G., Munich (West Germany). Zentrallab. fuer Nachrichtentechnik.
EMPLOYMENT OF NEARFIELD CASSEGRAIN ANTENNAS WITH HIGH EFFICIENCY AND LOW SIDELOBES, TAKING THE INTELSAT-GROUND STATIONS AND THE GERMAN HELIOS-TELECOMMAND STATION AS EXAMPLES
Uwe Leupelt and Wolfgang Rebhan *In* AGARD Antennas for Avionics Jun. 1974 10 p refs (For availability see N74-31667 21-09)

A number of the large reflector antennas now employed by ground stations for satellite communication are constructed according to the nearfield Cassegrain technique. After a short description of the basic electrical principles involved as well as of the method of obtaining constant aperture illumination with the nearfield antenna also and thus optimizing efficiency by suitable shaping of the reflectors, a novel design for antennas of this type discussed. It allows the sidelobes of the radiation pattern to be reduced without excessively reducing gain. A special toroidal aperture illumination and a favorable arrangement of the subreflector supports are used for this purpose. The dimensions and design of the 28.5-m antennas already mentioned in connection with the Intelsat system are discussed and the 30-m antenna now under construction for the German Helios telecommand satation described as an example for the realization of an antenna with low sidelobes. The radiation characteristics at higher frequencies and the cross-polarization properties with the aid of measured radiation patterns are illustrated. Author

N74-31697 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Dynamics Div.
DEVELOPMENT OF AN S-BAND DUAL MODE HORN FOR TELEMETRY RECEPTION BY THE 100 M EFFELSBERG RADIO TELESCOPE
W. Hess and B. Liesenkoetter *In* AGARD Antennas for Avionics Jun. 1974 8 p refs (For availability see N74-31667 21-09)

A Gregorian antenna system with 100 m paraboloid is being equipped with a dual mode horn feed in the secondary focus to provide favorable gain and noise temperature characteristics. The limited size of the apex cabins demanded length reduction by optimizing the horn feed zone. In addition a directional coupler, integrated in the horn feed zone, is developed for special test purposes. All measurements during the development period as well as the qualification tests are been carried out on a X-band scaled model. The design of the original horn feed aimed in particular at cheapness, a short manufacturing period and a low weight. Thus a frame construction with non supporting inner horn structure is applied. Author

N74-31698 Air Force Cambridge Research Labs., L. G. Hanscom Field, Mass. Microwave Physics Lab.
ARRAY AND REFLECTOR TECHNIQUES FOR AIRPORT PRECISION APPROACH RADARS

Robert J. Mailloux and Philipp Blacksmith *In* AGARD Antennas for Avionics Jun. 1974 14 p refs (For availability see N74-31667 21-09)

The current state-of-the-art among array and array/reflector antennas for limited scan coverage, is surveyed and some new array techniques for this application are introduced. Other system parameters, such as frequency selection, are discussed in light of their influence on antenna design requirements but the principle task addressed by the paper is to use the parameters of present PAR antenna systems to estimate the potential advantages of new technology. Examples cited as new technology include the use of arrays to feed dual reflectors or lenses for improved aperture efficiency and reduced array size, and the AFCRL array techniques using large multimode apertures for grating lobe suppression and pattern control. Comparisons of these types of technology are given for selected applications. Author

N74-31699 Royal Aircraft Establishment, Farnborough (England).
NOTES ON THE RADIATION PATTERNS OF HF AERIALS INSTALLED ON HELICOPTERS
W. T. Blackband *In* AGARD Antennas for Avionics Jun. 1974 6 p (For availability see N74-31667 21-09)

The fundamental modes of electrical oscillation of a helicopter are considered and their radiation patterns predicted. Scale model experiments have confirmed these predictions. Two modes of rotor modulation are possible. These have different characteristics, the first affecting signals at all azimuths while the effects of the other are most apparent near to minima in the radiation pattern. Author

N74-31700 Forschungsinstitut fuer Hochfrequenzphysik, Werthhoven (West Germany).
RADIATION CHARACTERISTICS OF THINNED ARRAY ANTENNAS
W. Soentgerath *In* AGARD Antennas for Avionics Jun. 1974 10 p refs (For availability see N74-31667 21-09)

The well known statistical relations between element distribution and radiation pattern of density tapered arrays are surveyed. Following a discussion of the statistical distribution of the signal energy in sidelobe directions, the effects on the radiation pattern of a special element distribution, i.e. the minimum distance of half a wavelength between adjacent elements is increased to one wavelength, are also treated. A brief study concerning the problems which are caused by the digitally controlled phase shifters commonly used in phased array technique is included. Author

N74-31701 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugfuehrung.
IN-FLIGHT MEASUREMENT OF AIRCRAFT ANTENNAS RADIATION PATTERNS
Helmut Bothe *In* AGARD Antennas for Avionics Jun. 1974 9 p refs (For availability see N74-31667 21-09)

An in-flight measuring system which is completely independent from groundbased position finding equipment like radar and kinetheodolites. The measuring method is based on VOR (Very High Frequency Omnidirectional Range System) and DME (Distance Measuring Equipment) information obtained onboard the aircraft. This information is telemetered together with the other necessary parameters like heading, altitude, pitch and roll angles. These parameters are used to calculate the aspect angle and the distance of the aircraft from the ground based field intensity measuring device. Real time calculation is done on a digital computer. The computer output supplies aspect angle and distance corrected field intensity as well as flight-path parameters in analog voltages for graphic presentation. After a detailed description of the measuring method and system some examples of measured patterns are shown. In addition the magnitude of possible errors in the plotted radiation patterns are discussed. Author

N74-31702 Naval Research Lab., Washington, D.C.
DYNAMIC MEASUREMENT OF AVIONIC ANTENNAS
I. D. Olin and E. E. Maine, Jr. *In* AGARD Antennas for Avionics Jun. 1971 14 p refs (For availability see N74-31667 21-09)

The equipment, data handling, flight control and some of the results obtained with a system specifically designed for dynamic measurements is described. The determination of aircraft aspect angle uses an approach based on measurements made at the ground radar site with the aircraft flying straight line courses. Then making certain assumptions regarding flight attitude, a proper coordinate transformation can be effected and principal plane measurements plotted. The antenna signal source is provided by a delayed beacon triggered by an illuminating radar and driving the antenna under tests. To illustrate the results patterns for a X-band installation are shown. Coverage can be provided for an azimuth profile from nose-on (0 deg) to tail-on (180 deg) and for an elevation profile beam 0 deg to 30 deg below the aircraft for fixed azimuth aspects of nose-on and tail-on. Angle accuracy is + or - 2 degrees and the accuracy of antenna gain measurements is estimated to be + or - db. Author

N74-31703 Technische Hochschule, Aachen (West Germany).
AN IMPROVED MEASURING TECHNIQUE FOR INVESTIGATIONS OF THE NEAR FIELD REGION OF ANTENNAS
Ruediger Anders *In* AGARD Antennas for Avionics Jun. 1974 8 p refs (For availability see N74-31667 21-09)

A new scattering technique for low reaction measurements of electromagnetic fields is presented using a small diode probe without any conductive feeder. The basic principle of this technique makes use of the frequency mixing property of a microwave diode as scatterer to convert the probe signal to the X-band microwave range where it easily can be transmitted and picked up by a remote auxiliary antenna. The theoretical background is given and several measurement set-ups for different operation conditions are discussed. Author

N74-31704 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. fuer Flugfunk und Mikrowellen.
DETERMINATION OF THE MOVEMENT OF THE APPARENT PHASE CENTERS OF AIRCRAFT ANTENNAS FOR CALIBRATING THE ZDBS INTERFEROMETER
A. Ischrott and S. Modabber *In* AGARD Antennas for Avionics Jun. 1974 26 p refs (For availability see N74-31667 21-09)

A new method for the determination of the curve on which the apparent phase centers for an aircraft antenna moving with respect to aspect angles is presented. The definition of the apparent phase center is discussed. The test equipment is explained by means of a schematic diagram. Sources of error and the accuracy of the approximation method for analytical determination of the phase function are also discussed. An ALGOL computer program is developed for the calculation of apparent phase centers from measured data. Finally, the development and the optimization of the radiators meeting the requirements are described. Author

N74-31705 Forschungsinstitut fuer Funk und Mathematik, Werthoven (West Germany).
OFF-BORESIGHT ANGLE ESTIMATION WITH A PHASE COMPARISON MONOPULSE SYSTEM
W. Sander *In* AGARD Antennas for Avionics Jun. 1974 13 p refs (For availability see N74-31667 21-09)

The problem of estimating the angle of arrival is considered for phase comparison monopulse (PCM) system in the presence of internally generated thermal noise. A maximum likelihood analysis produces the form of the estimate which does not differ essentially from that found earlier for an amplitude comparison monopulse (ACM) system. In deriving the probability density function of the estimate, no approximations of the nonlinear monopulse error curve are made. Therefore mean and variance of the estimate computed by numerical integration are valid at any signal noise-ratio and at any angle. The bias of the estimate at low and moderate SNR is higher than known by other theories. A computer simulation proves the correctness of the results. A comparison between radar and passive beacon tracking mode is made, and the problem of bidimensional angle measurement is mentioned. Author

N74-31706* Ohio State Univ., Columbus. ElectroScience Lab.
ROLL PLANE ANALYSIS OF ON-AIRCRAFT ANTENNAS
W. D. Burnside, R. J. Marhefka, and C. L. Yu *In* AGARD Antennas for Avionics Jun. 1974 23 p refs (For availability see N74-31667 21-09)
(Grant NGR-36-008-144)
CSCL 17B

The roll plane radiation patterns of on-aircraft antennas are analyzed using high frequency solutions. This is a basic study of aircraft-antenna pattern performance in which the aircraft is modelled in its most basic form. The fuselage is assumed to be a perfectly conducting elliptic cylinder with the antennas mounted

near the top or bottom. The wings are simulated by arbitrarily many sided flat plates and the engines by circular cylinders. The patterns in each case verified by measured results taken on simple models as well as scale models of actual aircraft. Author

N74-31707 Hughes Aircraft Co., Fullerton, Calif. Ground Systems Group.
INVESTIGATION OF CHARACTERISTICS AND PRACTICAL IMPLEMENTATION OF ARBITRARILY POLARIZED RADIATORS IN SLOT ARRAYS
J. S. Ajioka, D. M. Joe, R. Tang, and N. S. Wong. *In* AGARD Antennas for Avionics Jun. 1974 15 p refs (For availability see N74-31667 21-09)
(Contract F19628-70-C-0142)

The feasibility of obtaining arbitrary polarization in both one and two dimensional arrays of slots in dual mode bifurcated waveguides has been demonstrated. The radiating element consists of a pair of crossed slots in the sidewall of a bifurcated rectangular waveguide that couple to even and odd waveguide modes. One linear polarization is excited by the even or sum mode and the orthogonal linear polarization is excited by the odd or difference mode. By superposing the sum and difference modes in the proper amplitude and phase, any arbitrary polarization can be synthesized. A two-dimensional array consisting of eight waveguide linear arrays, ferrite phase shifters for scanning in the plane normal to the linear arrays and a feed network for power distribution and polarization control was constructed. Good radiation performance for various polarizations was obtained. In the case of linear polarization, the cross polarization component was down on the order of minus 25 db and in the case of circular polarization, the axial ratio was on the order of 1 db. The polarization was controlled with a phase shifter. Close in sidelobes of better than 20 db were obtained for all polarizations. Author

N74-31708 Fernmeldetechnisches Zentralamt, Darmstadt (West Germany).
STEPPED REFLECTOR ANTENNA WITH A SECTOR SHAPED MAIN BEAM
H. Thielen. *In* AGARD Antennas for Avionics Jun. 1974 15 p refs (For availability see N74-31667 21-09)

The optimum pattern of an antenna of telecommunication or television broadcasting satellites consists in a sector shaped main beam without any side lobes. In this case the edge gain is 4.1 db higher than that of a conventional antenna. Theory indicates that such a pattern is produced by a circular aperture illuminated by the oscillating function. Measurements were made with a paraboloid reflector antenna containing a dielectric dish in its central zone. This dish effects a phase reversal of 180 deg between the central zone and the remaining ring zone of the reflector. the edge gain of this antenna is 1 db higher than that of a conventional antenna. An increase of 1.4 db obtained by a better feed system. It is also possible to achieve the phase reversal by an arrangement of metallic stems with a height of about one quarter wavelength. If an antenna with two or more ring zones is used, a further increase of the edge gain can be obtained. Author

N75-25047# Advisory Group for Aerospace Research and Development, Paris (France).
CUSTOM DESIGN FOR LARGE SCALE INTEGRATION (LSI)
Apr. 1975 150 p refs Conf. held at Paris 21-22 Apr. 1975, at London 24-25 Apr. 1975, at Rome 28-29 Apr. 1975
(AGARD-LS-75) Avail: NTIS HC $5.75

The techniques and methods of designing custom circuits for large scale integration are outlined. Circuit design lectures are presented which cover metal oxide semiconductor, bipolar, and standard cell monolithic technology in addition to film hybrid techniques for multi-chip modules. The preparation of master artwork by computer graphics and the establishment of satisfactory quality assurance interfaces are also discussed. For individual titles, see N75-25048 through N75-25053.

N75-25048 Plessey Co. Ltd., Towcester (England).
HIGH PERFORMANCE BIPOLAR TECHNOLOGY FOR LSI
P. C. Newman. *In* AGARD Custom Design for Large Scale Integration (LSI) Apr. 1975 22 p refs (For availability see N75-25047 16-33)

The Plessey bipolar process 3 and the Fairchild isoplanar process are described in detail. Performance characteristics of the basic npn transistors in process 3 are briefly discussed. Some circuit designs conducted on the two processes include a programmable logic array, an error detector for digital transmissions, and random access 256- and 1024-bit memories. Injection logic is described and its impact on large scale integration and processing technology is discussed. L.B.

N75-25049 Associated Semiconductor Manufacturers, Ltd., Southampton (England).
THE DESIGN OF MOS INTEGRATED CIRCUITS
R. A. Hilbourne. *In* AGARD Custom Design for Large Scale Integration (LSI) Apr. 1975 20 p refs (For availability see N75-25047 16-33)

The principles, constraints, and techniques which determine the methods used for the design of metal oxide semiconductor integrated circuits are described. The two basic approaches are unichannel circuits, using either p or n channel transistors, and complementary circuits, using a combination of both types of transistors. The technologies and circuit implications of these two approaches are discussed and related to the large scale integration requirements of high packing density and low power dissipation per gate. The concepts of dynamic and static logic and the advantages of combining enhancement and depletion devices in a circuit are included. The design procedure is described and circuit subsystems and the complete circuit are simulated on a computer to ensure proper operation. The mask circuit layout is also simulated the check for correspondence with logic simulation. Author

N75-25050 Mullard, Ltd., Mitcham (England).
FILM HYBRID CIRCUITS FOR LSI
Mervyn G. Harwood. *In* AGARD Custom Design for Large Scale Integration (LSI) Apr. 1975 16 p refs (For availability see N75-25047 16-33)

Thick and thin film hybrid technologies are discussed for use with large scale integrated devices. Materials used for the passive portion of the circuit and their properties are outlined, with particular attention to interaction with bonding materials. Types of integrated and attached components are included (i.e. resistors, capacitors, and semiconductors) and materials and techniques most suitable for attaching components to the film circuit are indicated. The effects of environmental treatment and of various packaging methods are considered, and damage prevention measures are established. Basic design guidelines are given. Author

N75-25051 Calma Co., Wiltshire (England).
INTERACTIVE GRAPHICS AND ARTWORK PREPARATION
Michael A. Northwood. *In* AGARD Custom Design for Large Scale Integration (LSI) Apr. 1975 8 p (For availability see N75-25047 16-33)

The techniques available to produce final production artwork from an engineering layout sketch are described. Various computer aids capable of assisting in the design and production of the large scale integration layout are examined, with emphasis on the use of interactive graphics systems. The hardware components and software facilities of the graphics systems are described in detail. Machines for transferring circuit layout from a computer data base to final production artwork are examined. The merits and disadvantages of the techniques of cutting, scribing, photoplotting, and pattern generation are weighed. Author

N75-25052 Motorola, Inc., Phoenix, Ariz. Semiconductor Products Div.
QUALITY ASSURANCE ASPECTS OF CUSTOM LSI
J. L. Flood. *In* AGARD Custom Design for Large Scale Integration (LSI) Apr. 1975 26 p refs (For availability see N75-25047 16-33)

The importance of standardizing the design, manufacturing, and testing of custom large scale integrated circuits is emphasized to assure high quality and reliability. The complexities of manufacturing and electrical testing standardization are outlined and the need for inspector/vendor/customer interaction is suggested. L.B.

N75-25053* Radio Corp. of America, Camden, N.J.
DESIGN AUTOMATION TECHNIQUES FOR CUSTOM LSI ARRAYS
Albert Feller. *In* AGARD Custom Design for Large Scale

Integration (LSI) Apr. 1975 15 p (For availability see N75-25047 16-33)
(Contracts NAS12-2233; NAS8-29072; DAAB07-0176)
CSCL 09C

The standard cell design automation technique is described as an approach for generating random logic PMOS, CMOS or CMOS/SOS custom large scale integration arrays with low initial nonrecurring costs and quick turnaround time or design cycle. The system is composed of predesigned circuit functions or cells and computer programs capable of automatic placement and interconnection of the cells in accordance with an input data net list. The program generates a set of instructions to drive an automatic precision artwork generator. A series of support design automation and simulation programs are described, including programs for verifying correctness of the logic on the arrays, performing dc and dynamic analysis of MOS devices, and generating test sequences. Author

34 FLUID MECHANICS AND HEAT TRANSFER

Includes boundary layers, hydrodynamics, fluidics, mass transfer, and ablation cooling For related information see also *02 Aerodynamics* and *77 Thermodynamics and Statistical Physics*

N74-18928# Advisory Group for Aerospace Research and Development, Paris (France)
AN INVESTIGATION OF DIFFERENT TECHNIQUES FOR UNSTEADY PRESSURE MEASUREMENTS IN COMPRESSIBLE FLOW AND COMPARISON WITH LIFTING SURFACE THEORY
R. Destuynder (ONERA) and H. Tijdeman (NLR, Amsterdam, Netherlands) Jan 1974 35 p Presented at the 37th AGARD Struct. and Mat Panel Meeting, The Hague, 7-12 Oct. 1973 (AGARD-R-617) Avail NTIS HC $4.75

Wind tunnel measurements of unsteady aerodynamic pressures at high subsonic speeds were conducted. The results obtained by two different procedures are presented. Flutter tests were also conducted on the same model as that used for unsteady pressure measurements. Natural frequencies and damping values were determined at constant Mach number and varying free-stream dynamic pressure. Tables of data and graphs are included to compare the results obtained by the two methods Author

N74-26822# Advisory Group for Aerospace Research and Development, Paris (France).
THEORY OF FLOWS IN COMPRESSIBLE MEDIA WITH HEAT ADDITION
Juergen Zierep (Karlsruhe Univ.) May 1974 65 p refs
(AGARDograph-191; AGARD-AG-191) Avail: NTIS HC $6.25

A systematic survey is undertaken, of the theory of the effect of a given heat addition on the flow of a compressible medium. Here steady flows, both one-dimensional and multi-dimensional, linear and nonlinear, are treated. Consideration is given to addition of mass and momentum to a streamtube as well as of energy, interesting equivalences arise here. The heat can be distributed continuously in the flow field or added at fronts. For practical applications, the reduction of the drag of a body in flight by heat addition in the flow field is important. At extremely high velocities the problem arises of propulsion by external combustion. Here, the energy is to be transferred directly to the flowing medium, at the high velocity. For the evaluation of such an energy addition, reference is made to the propulsive efficiency, as well as the lift and drag of the body Author

N74-28766# Advisory Group for Aerospace Research and Development, Paris (France).
NUMERICAL METHODS FOR PREDICTING SUBSONIC, TRANSONIC AND SUPERSONIC FLOW
T. D. Taylor (Aerospace Corp., El Segundo, Calif.) and P. F. Yaggy, ed (Army Air Mobility Res. and Develop. Lab., Moffett Field, Calif.) Jan 1974 52 p refs
(AGARDograph-187, AGARD-AG-187) Avail: NTIS HC $5.75

The methods available for numerical computation of subsonic, transonic and supersonic flows are discussed and comments are included on the characteristics of the popular methods. Both inviscid and viscous computation methods are addressed. A brief account of the basic approaches for developing methods initiates the discussion. Also included is a general summary of the state of the art of computational methods along with suggested approaches for solving problems in each area. The report is concluded with recommendations for future study and development. Author

N74-30827# Advisory Group for Aerospace Research and Development, Paris (France)
ANNULUS WALL BOUNDARY LAYERS IN TURBOMACHINES
J. H. Horlock (Cambridge Univ.) and H. J. Perkins (GE, Whetstone, Engl.) May 1974 69 p refs
(AGARD-AG-185, AGARDograph-185) Avail NTIS HC $6.50

A study was conducted to determine the characteristics of annulus wall boundary layers in turbomachines. The subjects covered include the following (1) simple two-dimensional boundary layer calculation methods for analyzing flow characteristics, (2) the nature of cascade secondary flows, and (3) information on cascades, annular cascades, and compressors which provide the experimental input essential to the development of calculation methods. The study produced a method for predicting the full three-dimensional boundary layer that develops through a single blade row of a turbomachine. A computer program for the estimation of annulus blockage is listed Author

N74-32215# Advisory Group for Aerospace Research and Development, Paris (France).
RADIATION COOLING OF PROPULSIVE NOZZLES [LE REFROIDISSEMENT PAR RAYONNEMENT DES TUYERES PROPULSIVES]
J. J. Bernard (Paris Univ.) and J. Genot (ONERA, Paris) May 1974 51 p refs In FRENCH
(AGARD-AG-184(fr), AGARDograph-184) Avail: NTIS HC $5.75

In the study of the revolution of propulsive nozzles, calculations were made of heat conduction as a function of exchange between isothermal lines when any line is parallel to the revolving surface or slightly parallel to the inclined sections of the plane. Numerical results are presented in the form of universal functions of geometric parameters of the meridian. For the schematic configuration of the more usual nozzle the direct values of transfer functions are given. Transl. by E.H.W.

N75-19585# Advisory Group for Aerospace Research and Development, Paris (France).
TECHNICAL EVALUATION REPORT ON FLUID DYNAMICS PANEL SYMPOSIUM ON V/STOL AERODYNAMICS
B. M. Spee (Natl. Aerospace Lab.) Feb. 1975 13 p refs Symp. held at Delft, Netherlands, 24-26 Apr. 1974
(AGARD-AR-78) Avail: NTIS HC $3.25

Papers presented at the Fluid Dynamics Panel Symposium are reviewed along with the current situation in V/STOL aerodynamics research. The following areas were discussed; powered high-lift systems; mechanical high-lift systems and jet lift. It is concluded that the direct operating cost of V/STOL must be decreased through optimization of aerodynamic characteristics in order to compete with conventional aircraft. Author

N75-30471# Advisory Group for Aerospace Research and Development, Paris (France).
MODERN METHODS OF TESTING ROTATING COMPONENTS OF TURBOMACHINES (INSTRUMENTATION)
M. Pianko, ed. (ONERA) Apr. 1975 186 p refs
(AGARD-AG-207; AGARDograph-207) Avail: NTIS HC $7.00

Various flow measuring techniques used in turbomachinery and cascade wind tunnels are reviewed. Flow visualization, laser anemometry, and pressure sensors are among the methods discussed For individual titles, see N75-30472 through N75-30475

N75-30472 Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium)
AERODYNAMIC MEASUREMENTS IN CASCADES
M. C. Sieverding, H. Starken (DFVLR), H. J. Lichtfuss, and P. Schimming *In* AGARD Modern Methods of Testing Rotating Components of Turbomachines (Instrumentation) Apr 1975 p 1-76 refs (For availability see N75-30471 21-34)

The usefulness of cascade flow measurements used to acquire detailed blade performance data is discussed. The design of a cascade wind tunnel is described. Factors considered include: two dimensional and periodic flow, variations of inlet and outlet conditions, and three dimensional effects. Data reduction methods are presented along with factors which influence the choice of appropriate pressure probes. J.M.S.

N75-30473 Air Force Aero Propulsion Lab., Wright-Patterson AFB, Ohio
AERODYNAMIC MEASUREMENTS IN TURBOMACHINES
David W. Fleeger and Noel J. Seyb (Rolls-Royce, Ltd., Bristol, Engl.) *In* AGARD Modern Methods of Testing Rotating Components of Turbomachines (Instrumentation) Apr 1975 p 79-121 refs (For availability see N75-30471 21-34)

The problems encountered in designing instrumentation for component and engine testing are discussed. Trade-offs must be made between probe strength, blockage, accuracy, cost, and installation problems. Many of the basic parameters often measured are summarized in tabular form listing typical methods and citing references. Conventional techniques concerning pressure (steady state and high response) and gas temperature measurement are discussed in detail. Methods to couple the use of

both steady state and high pressure transducers involve the flush mounted diaphram, resonant tube, resonant damped and non-resonant tube methods. Special considerations are required to measure the time weighted value of a high frequency pressure signal. For thermocouple design many factors including wire type, recovery, convection, conduction, radiation, chemical reactions, and time response are considered. Calibration techniques are discussed for both pressure probes and thermocouples. Typical probe designs with calibration data which were provided by engine manufacturers are compared. Author

N75-30474 Office National d'Etudes et de Recherches Aerospatiales, Paris (France)
OPTICAL MEASUREMENTS IN TURBOMACHINERY
Jacques Paulon *In* AGARD Modern Methods of Testing Rotating Components of Turbomachines (Instrumentation) Apr. 1975 p 123-139 refs (For availability see N75-30471 21-34)

Flow visualization and optical measurement techniques used to determine the structure of the flow and measure local values of velocity, pressure, or temperature in turbomachinery without introducing any material probe are reviewed. Methods discussed include: visualization by means of smoke filaments, hydraulic models, shadow and schlieren techniques, holography techniques, laser anemometry, laser dual beam method, and Raman scattering. The optical measurement techniques allow, in the rotor as well as the stator, the determination of the mean and time-dependent characteristics of the flow field without any disturbance. J.M.S.

N75-30475 Advisory Group for Aerospace Research and Development, Paris (France).
UNSTEADY FLOW MEASUREMENTS IN TURBOMACHINERY
H. Weyer and R. Schodl *In its* Modern Methods of Testing Rotating Components of Turbomachines (Instrumentation) Apr. 1975 p 141-182 refs (For availability see N75-30471 21-34)

Determination of strong pressure oscillations of high frequency and high amplitudes which occur in the region of turbomachine rotors is considered in terms of immediate measuring of the fluctuating pressures at the casing in the rotor zone, as well as behind the rotor exit plane, and determination of the average pressures resulting from these oscillating pressures. The application of the modern high response pressure transducers and of new techniques, which enable the measurement of well defined average values of the oscillating pressures in turbomachines are described along with a method for instantaneous flow angle measurement in centrifugal compressors. Emphasis is placed on the development of a laser dual beam technique for flow velocity measurements in turbomachines. Author

N75-31385# Advisory Group for Aerospace Research and Development, Paris (France).
COMPUTATIONAL METHODS FOR INVISCID AND VISCOUS TWO-AND-THREE-DIMENSIONAL FLOW FIELDS
Feb. 1975 200 p refs
(AGARD-LS-73) Avail: NTIS HC $7.00

Developments in the numerical approach of fluid flow problems are presented. Particular emphasis is placed on numerical techniques for the solution of the compressible Navier-Stokes equations and the implementation of turbulence models, the computational techniques for boundary layers, hyperbolic partial differential equations, numerical stability of finite difference methods, numerical solutions of the Navier-Stokes equations for compressible fluids, and finite elements. For individual titles, see N75-31386 through N75-31392.

N75-31386 Technische Hochschule, Aachen (West Germany). Aerodynamisches Inst.
FLOW ANALYSIS THROUGH NUMERICAL TECHNIQUES
Egon Krause *In* AGARD Computational Methods for Inviscid and Viscous Two-and-Three-Dimensional Flow Fields Feb. 1975 11 p refs (For availability see N75-31385 22-34)

Flow analysis by using numerical techniques is demonstrated. Results obtained from integrations of the governing equations are compared with experimental data. The following problems are discussed: the inviscid flow about a sphere at supersonic Mach-numbers, calculated with Rusanov's algorithm; incompressible and compressible laminar turbulent boundary layers on infinite swept wings, calculated with second- and fourth-order accuracy for three different scalar closure assumptions; and hypersonic laminar and turbulent slot injection of frozen flow (He and H2) and flow in approximated chemical equilibrium (H2). Finally applications of finite-difference solutions are to be discussed for fully viscous flows in biofluidmechanical problems. Author

N75-31387* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
NUMERICAL TECHNIQUES FOR THE SOLUTION OF THE COMPRESSIBLE NAVIER-STOKES EQUATIONS AND IMPLEMENTATION OF TURBULENCE MODELS
Barrett S. Baldwin, Robert W. MacCormack, and George S. Deiwert *In* AGARD Computational Methods for Inviscid and Viscous Two-and-Three-Dimensional Flow Fields Feb. 1975 24 p refs (For availability see N75-31385 22-34)

The time-splitting explicit numerical method of MacCormack is applied to separated turbulent boundary layer flow problems. Modifications of this basic method are developed to counter difficulties associated with complicated geometry and severe numerical resolution requirements of turbulence model equations. The accuracy of solutions is investigated by comparison with exact solutions for several simple cases. Procedures are developed for modifying the basic method to improve the accuracy. Numerical solutions of high-Reynolds-number separated flows over an airfoil and shock-separated flows over a flat plate are obtained. A simple mixing length model of turbulence is used for the transonic flow past an airfoil. A nonorthogonal mesh of arbitrary configuration facilitates the description of the flow field. For the simpler geometry associated with the flat plate, a rectangular mesh is used, and solutions are obtained based on a two-equation differential model of turbulence. Author

N75-31388 Sandia Labs., Albuquerque, N.Mex.
COMPUTATIONAL TECHNIQUES FOR BOUNDARY LAYERS
F. G. Blottner *In* AGARD Computational Methods for Inviscid and Viscous Two-and-Three-Dimensional Flow Fields Feb. 1975 51 p refs Sponsored by ERDA (For availability see N75-31385 22-34)

The status of the numerical computation of boundary layers is given for two- and three-dimensional flows. The appropriate transformations to apply to the governing equations are considered, and the possible solution procedures are dismissed. Emphasis is on the finite-difference procedures which are illustrated for two-dimensional, incompressible flows. For compressible flows the Crank-Nicolson technique is given. The changes which are needed to this approach when the flow is turbulent, are presented. The finite-difference procedures utilized for unsteady flows are given. Solution techniques for three-dimensional flows are described and the features which are different from two-dimensional flows are emphasized. Author

N75-31389 Uppsala Univ. (Sweden). Dept. of Computer Sciences.
DIFFERENCE APPROXIMATIONS FOR TIME DEPENDENT PROBLEMS
Heinz-Otto Kreiss *In* AGARD Computational Methods for Inviscid and Viscous Two-and-Three-Dimensional Flow Fields Feb. 1975 33 p refs (For availability see N75-31385 22-34)

The Cauchy problem for partial differential equations is considered. Examples and notations are given which include initial value problems, wave equations, heat equations, and linearized shallow water equations. Other topics discussed include: difference approximation for the Cauchy problem, initial boundary value problems for hyperbolic partial differential equations, the energy method, and the Laplace transform. J.M.S.

N75-31390 Reading Univ. (England). Dept. of Mathematics.
STABILITY AND ACCURACY OF NUMERICAL APPROXIMATIONS TO TIME DEPENDENT FLOWS
K. W. Morton *In* AGARD Computational Methods for Inviscid and Viscous Two-and-Three-Dimensional Flow Fields Feb. 1975 12 p refs (For availability see N75-31385 22-34)

The basic Lax-Richtmyer theory of the stability and convergence of linear difference schemes is considered. Some of the more demanding requirements met in practical fluid flow calculations, including the control of nonlinear instabilities, dissipation, and dispersion are discussed along with the modeling of conservation properties and the implementation of boundary conditions. The use of the modified equation approach is studied as an alternative to the Lax-Richtmyer theory. An error analysis for finite element methods is given showing the high accuracy that may sometimes be achieved with the correct treatment of nonlinear terms. Author

N75-31391 Paris Univ. (France).
NUMERICAL SOLUTION OF THE NAVIER-STOKES EQUATIONS FOR COMPRESSIBLE FLUIDS

Roger Peyret and Henri Viviand (ONERA) *In* AGARD Computational Methods for Inviscid and Viscous Two-and-Three Dimensional Flow Fields Feb. 1975 14 p refs (For availability see N76-31385 22-34)

Numerical methods for the solution of the Navier-Stokes equations for compressible fluids are discussed. A short review of the Navier-Stokes equations and of their qualitative mathematical properties, and a discussion of their interest in aerodynamics problems are presented. The following aspects of numerical methods are considered: limitation of the domain of calculation and boundary conditions on the outer boundary; various approaches in finite difference methods and properties of some representative schemes; treatment of the boundary condition at a solid wall; treatment of shock waves and general considerations on accuracy and computation times. Author

N76-31382 Laboratoire d'Informatique pour la Mecanique et les Sciences de l'Ingenieur, Paris (France).
APPLICATIONS OF FINITE ELEMENT METHODS IN FLUID DYNAMICS
C. Bellevaux and M. Maille (Pierre et Marie Curie Univ.) *In* AGARD Computational Methods for Inviscid and Viscous Two-and-Three-Dimensional Flow Fields Feb. 1975 28 p refs (For availability see N76-31385 22-34)

An example of the finite element method is considered which demonstrates the problems of functional analysis and the numerical techniques used. Elements of functional analysis necessary for a rigorous formulation are used to generalize the example. Other topics discussed include: the method of singularities and the linear and nonlinear case of Navier-Stokes equations for viscous flows. Author

N76-11380# Advisory Group for Aerospace Research and Development, Paris (France).
COMPUTATION OF VISCOUS COMPRESSIBLE FLOWS BASED ON THE NAVIER-STOKES EQUATIONS
Roger Peyret, Henri Viviand, and J. J. Smolderen, ed. Sep. 1975 50 p refs
(AGARD-AG-212; AGARDograph-212) Avail: NTIS HC $4.00

Problems relating to the computation of viscous compressible flows based on numerical solutions of the Navier-Stokes equations are reviewed. A general introduction to the Navier-Stokes equations and a discussion of their interest in aerodynamic problems are presented. The following aspects of numerical methods are considered: limitation of the computational domain and boundary conditions on the outer boundary; various approaches in finite difference methods and description of some representative schemes; treatment of boundary conditions at a solid wall; treatment of shock waves; and general considerations on accuracy and computing times. Reported computations of two-dimensional or three-dimensional flows are presented in table form with summary indications on the problems treated and the methods used. Author

N76-16357# Advisory Group for Aerospace Research and Development, Paris (France).
IMPROVED NOZZLE TESTING TECHNIQUES IN TRANSONIC FLOW
A. Ferri, ed. Oct. 1975 384 p refs In ENGLISH and FRENCH Conf. held at Rome, 4-10 Sep. 1974
(AGARD-AG-208; AGARDograph-208) Avail: NTIS HC $10.75

Conference papers on international testing of nozzle designs and performance at transonic flow are summarized. Data cover the effects of experimental techniques used, influence of various jet parameters-static pressure distribution, temperature, pressure drag, boattail drag, and jet exhaustion nozzle performance. For individual titles, see N76-16358 through N76-16371.

N76-16358 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
ONERA: EXPERIMENTAL STUDY OF 15 DEG. STANDARD AGARD NOZZLE IN SUBSONIC AND TRANSONIC FLOW [ETUDE EXPERIMENTALE DE LA TUYERE ETALON AGARD 15 DEG. EN ECOULEMENTS SUBSONIQUE ET TRANSSONIQUE]
B. Mechin *In* AGARD Improved Nozzle Testing Tech. In Transonic Flow Oct. 1975 52 p refs In FRENCH (For availability see N76-16357 07-34)

A test facility designed to study the performance of a standard 15 deg AGARD nozzle at subsonic and transonic flow is described. Data studied include the effects of sound, pressure, and temperature on internal flow, nature of the boundary layer, performance of the nozzle at a fixed point and with external flow, and static pressure distribution on the exterior surface of the nozzle. Transl. by E.H.W.

N76-16359 Rolls-Royce, Ltd., Bristol (England).
DESCRIPTION OF TESTS CARRIED OUT AT ROLLS ROYCE (1971) LTD BRISTOL ENGINE DIVISION
L. R. Harper *In* AGARD Improved Nozzle Testing Tech. in Transonic Flow Oct. 1975 22 p refs (For availability see N76-16357 07-34)

Three nozzle afterbody models were tested in the Rolls-Royce (1971) Ltd. transonic wind tunnel at Bristol using a model support sting which provided means for boundary layer thickness variation by blowing. The tests covered the Mach number range 0.75 to 0.95 and nozzle pressure ratios were in the range 1.7 to 4.7:1. The model surface static pressure distributions were measured and integrated to obtain pressure drag coefficients. Measurements are also presented of model internal pressures, boundary layer profiles and tunnel wall static pressure distributions. Author

N76-16360 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
AN EXPERIMENTAL STUDY OF THE INFLUENCE OF THE JET PARAMETERS ON THE AFTERBODY DRAG OF A JET ENGINE NACELLE SCALE MODEL
H. Dissen and A. Zacharias *In* AGARD Improved Nozzle Testing Tech. In Transonic Flow Oct. 1975 14 p ref (For availability see N76-16357 07-34)

Numerous experimental tests with an engine nacelle scale model were made to investigate the influence of engine jet parameters on the pressure distribution of the engine nacelle and therefore on the boattail pressure drag. Regarding the planned flight tests on the HFB 320 Hansa Jet at the end of 1975, the experimental work was done with a model of the GE CJ 610 engine nozzle, including its nacelle. The influence of jet pressure ratio and jet temperature on the boattail pressure distribution at different flight Mach numbers are shown. The effect of boundary layer control and the influence of changing the internal nozzle geometry on the pressure drag is also investigated. Author

N76-16361 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (West Germany).
CONTRIBUTION OF THE INSTITUT FUER ANGEWANDTE GASDYNAMIK OF THE DFVLR, PORZ-WAHN
H. Emunds and H. Riedel *In* AGARD Improved Nozzle Testing Tech. In Transonic Flow Oct. 1975 42 p (For availability see N76-16357 07-34)

The results presented relate to the AGARD models with 10 deg and 15 deg boattail chord angle. They cover the static pressure distributions on the afterbody and wall of the propulsive nozzle as well as the total pressure distributions in the nozzle flow and in the external flow field. The latter was only investigated for the model with 10 deg boattail. From the surface static pressure distributions on the afterbody of the models the boattail pressure drag coefficient was deduced. A cold propulsive jet of air was used, the nozzle total pressure ratio ranging from 1.0 to 6.83. The free stream Mach numbers covered the regime 0.5 < free stream Mach number < 0.96. Author

N76-16362 National Aerospace Lab., Amsterdam (Netherlands).
RESULTS OF NLR CONTRIBUTION TO AGARD AD HOC STUDY
D. Rozendal, C. C. Groothoff, and W. B. G. Derksen *In* AGARD Improved Nozzle Testing Tech. In Transonic Flow Oct. 1975 41 p refs (For availability see N76-16357 07-34)

A description is given of a series of experiments in order to assess the influence of jet exhaust parameters - total pressure distortion, nozzle pressure ratio, jet temperature (ratio of specific heats) - at transonic Mach numbers in the range of .8 to .96 on the nozzle thrust and discharge coefficients, on afterbody pressure distribution, and on the afterbody pressure drag. A model of .08 m diameter was tested in the .27 x .27 sq m transonic test section of a continuous blow-down wind tunnel. The 15 deg boattailed afterbody configuration as proposed by AGARD was supplemented by an afterbody with a twice as large nozzle area. The fuselage boundary layer thickness was varied by increasing the forebody length. A method was developed to define a valid total pressure, based on a mass flow averaging procedure, for a distorted jet pipe flow. The results for the AGARD nozzle, contraction ratio 3.24, show that in the investigated range of NPR's there is only a small effect due to the jet pipe total pressure distortion, while for the larger nozzle with a contraction ratio of 1.62 the hollow velocity profile, compared to a flat profile, significantly lowered the nozzle discharge coefficient (3.2%), raised the specific thrust + 2.1% and changed the afterbody

pressure distribution at free stream Mach number = .8. Effects on afterbody pressure distribution and pressure drag due to different NPR and free stream Mach number were evident, while an influence due to fuselage boundary layer thickness is indicated. Author

N76-16363 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
EFFECTS OF VARYING REYNOLDS NUMBER AND BOUNDARY LAYER DISPLACEMENT THICKNESS ON THE EXTERNAL FLOW OVER NOZZLE BOATTAILS
D Zonars, James A. Laughrey, and Douglas L. Bowers *In* AGARD Improved Nozzle Testing Tech. in Transonic Flow Oct. 1975 28 p refs (For availability see N76-16357 07-34)

Data for the 10 deg, 15 deg, and 25 deg AGARD nozzle boattails presented are from those test facilities in which the Reynolds number was varied at constant Mach number or where the boundary layer was varied by blowing or changing the length of the model. Evaluation and discussion of the data concentrates on the trends in pressure drag and static pressure distributions when the external flow conditions (specifically Reynolds number and/or boundary layer displacement thickness) are altered over the Mach number range of 0.8 through 0.95. In general when the Reynolds number was increased or the boundary layer displacement thickness was decreased, the static pressures decreased at the beginning of the boattail (flow expansion region) and increased near the nozzle exit (flow recompression region). The pressure drags associated with these changes in the pressure distributions varied only slightly at 0.8 Mach number, but increased measurably at 0.9 Mach number. Increasing the Reynolds number or decreasing the displacement thickness at a Mach number of 0.95 changed the flow such that the expansion was greater and the recompression was less resulting in a significant increase in pressure drag. The flow separated just downstream of the shoulder on the 25 deg boattail for all Mach numbers investigated and a change in Reynolds number or displacement thickness did not noticeably influence the point at which the flow separated although there was some variation on the level of pressure in the separated zone. Author

N76-16364 Arnold Engineering Development Center, Arnold Air Force Station, Tenn.
DESCRIPTION OF THE AGARD NOZZLE AFTERBODY EXPERIMENTS CONDUCTED BY THE ARNOLD ENGINEERING DEVELOPMENT CENTER
L. L. Gulligher, F. M. Jackson, and C. E. Robinson *In* AGARD Improved Nozzle Testing Tech. in Transonic Flow Oct. 1975 6 p refs (For availability see N76-16357 07-34)

A comprehensive test program, directed toward evaluation of Reynolds number and exhaust plume temperature effects on nozzle afterbody pressure drag, was conducted. Reynolds number effects were obtained by varying both model scale and wind tunnel pressure level. At AEDC, Ethylene(R)/air combustor, installed in the nozzle flow tube, was used to provide hot exhaust products which very closely duplicate the exhaust products of JP-4 burned in air. Ignition was accomplished by injecting a small quantity of tri-ethyl borane (a pyrophoric fuel) into the combustor flameholder. Nozzle afterbody pressure drag, determined from pressure integration, was obtained at freestream Mach numbers of 0.6, 0.8, 0.9, 0.95, 1.1, and 1.6. Reynolds number (based on model length) and nozzle total pressure-to-free-stream static pressure ratio was varied from 2 million to 62 million and from jet-off to a maximum of 22, respectively, depending upon the free-stream Mach number. Fuel/air ratio was varied from 0 to 0.05, which corresponds to an exhaust plume total temperature range from 306 K to approximately 1889 K. Model angle of attack was zero degrees at all test conditions. To evaluate the effect of test section wall porosity on the performance of transonic wind tunnels the walls were modified for wall porosities of 2 and 4 percent in addition to the normal 6 percent, through the Mach number range from 0.6 to 0.95. Author

N76-16365* National Aeronautics and Space Administration, Langley Research Center, Langley Station, Va.
CONTRIBUTION OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION LANGLEY RESEARCH CENTER
William B. Compton, III and Jack F. Runckel *In* AGARD Improved Nozzle Testing Tech. In Transonic Flow Oct. 1975 9 p refs (For availability see N76-16357 07-34)
CSCL 20D

As part of a special international effort, three nozzles were designed and tested on single nacelle models in wind tunnels of several nations belonging to the North Atlantic Treaty Organization. All three of these nozzles were investigated in the Langley 16-foot transonic wind tunnel at the National Aeronautics and Space Administration's Langley Research Center. Langley Research Center also contributed theoretical calculations of the jet plume boundary and afterbody pressures. The calculations were obtained using an iterative solution which combined the inviscid Douglas Neumann method for the external flow with the method of characteristics for the flow in the jet plume. For the investigation, the nozzles were mounted on a single nacelle model 15.24 centimeters in diameter and 162.56 centimeters long. Tests were made at free stream Mach number from 0.4 to 1.2, and at Reynolds numbers per meter from 7.38 million to 13.78 million depending on the Mach number. Four types of data were recorded: afterbody pressure data, afterbody force data, model boundary layer data, and tunnel wall pressure data. The ratio of jet total pressure to free stream static pressure ranged up to 8.6. A description of the wind tunnel, model, and test procedure is included. Author

N76-16366 Rolls-Royce, Ltd., Bristol (England).
THE INFLUENCE OF MODEL EXTERNAL GEOMETRY
L. R. Harper and W. J. Lewis *In* AGARD Improved Nozzle Testing Tech. in Transonic Flow Oct. 1975 11 p refs (For availability see N76-16357 07-34)

The results of model tests of three axisymmetric afterbodies in a number of different wind tunnels were examined in terms of the influence of model external geometry. The variation of drag with afterbody geometry was shown to be in accord with the trend for drag to increase and drag rise Mach number to decrease as the body is made less slender. It is found that drag and drag rise Mach number can be correlated quite well with boattail chord angle for a wide range of afterbody geometries in addition to those tested in this exercise. Increase of boundary layer thickness was shown to decrease the effective curvature of the afterbody. At speeds below the drag rise Mach number for any particular geometry this modifies the afterbody pressure distribution but has little effect on the pressure drag. Above the drag rise Mach number drag coefficients measured with a boundary layer thickness typical of model test conditions were about 0.01 lower than when the boundary layer thickness was reduced to a value typical of flight conditions. Comparison of results obtained in various wind tunnels covering blockage ratios from 0.2% to 7% failed to show any discernable effect of tunnel interference at least for Mach numbers up to about 0.9 to 0.95. At high blockages static pressure varies considerably along the tunnel wall and it becomes crucial to select a reference static pressure which is substantially free from the influence of the afterbody pressure field. The overall conclusion is that results obtained in the various facilities are in good agreement and the techniques of afterbody drag measurement in current use are generally satisfactory although correct simulation of boundary layer thickness is sometimes necessary. Author

N76-16367 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
INFLUENCE OF THE JET PRESSURE RATIO ON THE PERFORMANCE OF AN AGARD SINGLE FLOW AFTERBODY IN THE 0.60-0.95 MACH RANGE
Bernard Mechin and Jean-Marie Hardy *In* AGARD Improved Nozzle Testing Tech. in Transonic Flow Oct. 1975 8 p refs In FRENCH; ENGLISH summary (For availability see N76-16357 07-34)

The synthesis of experimental data concerning the effect of jet stagnation conditions on the drag of various afterbodies is presented. Jet pressure ratio effect on boattail pressure and on boundary layer separation is analyzed. This study is made for several values of the boundary layer thickness, taking into account the fact that some test rigs make its control possible by means of tangential blowing. Author

N76-16368 National Aerospace Lab., Amsterdam (Netherlands).
INFLUENCE OF JET PARAMETERS: NOZZLE THRUST AND DISCHARGE COEFFICIENTS
C. C. Groothoff *In* AGARD Improved Nozzle Testing Tech. In Transonic Flow Oct. 1975 22 p refs (For availability see N76-16357 07-34)

Internal flow and nozzle characteristics were analyzed. All available data were used in a comparison of the nozzle discharge and thrust coefficients and jet pipe wall static pressures of similar model configurations. It was found necessary to take into account the distortion of the total pressure profiles in the jet pipe. The mass flow averaged total pressure was used in the calculations. The distortion coefficient DCM proved to be a useful tool in the comparison of the mass flow averaged total pressure with the 1-D isentropical total pressure, derived from mass flow,

temperature and static pressure. The discharge coefficients that were found in the range of nozzle pressure ratios of about 1.3 to 12 were in good agreement. For the specified nozzle A the discharge coefficient Cd = .986. For this nozzle configuration with a contraction ratio of 3.24 hardly any influence on Cd of jet medium or distortion was found. External air flow did influence Cd, mainly through the boattail overpressure near the nozzle lip. The thrust coefficients were found to be difficult to compare, one set of data however shows an unexplained higher level (about 1 - 2%). Nozzle B (contraction ratio 1.62) showed more influence of distortion in the jet flow. The values for the choked nozzle discharge coefficients were Cd = .978 (no dist.) and Cd = .946 (dist.). Distortion was also found to influence the wall static pressures in the jet pipe. Author

N76-16369 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
INFLUENCE OF JET PARAMETERS: BOATTAIL PRESSURE DISTRIBUTION AND PRESSURE DRAG
H. Diesen, H. Emunds, H. Riedel, and A. Zacharias *In* AGARD Improved Nozzle Testing Tech. in Transonic Flow Oct. 1975 17 p refs (For availability see N76-16357 07-34)

Preliminary results are presented of the influence of the jet parameters on the boattail pressure distribution and on the boattail pressure drag with reference to the AGARD models and a model of the HFB 320 engine nacelle. The jet parameters investigated were the jet temperature, the wake and jet mixing, the internal nozzle configuration, and the jet distortion. Concerning the influence of jet temperature two contrasting effects were observed. These differences may be due to different surface temperatures and base areas of the models tested. Further investigations as regards these temperature effects seem to be necessary. Very little information has become available on wake and jet mixing, so that in this area further research is also needed. No effect was observed for changes of the internal nozzle geometry and of the jet distortion. Author

N76-16370 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
DATA VARIANCE DUE TO DIFFERENT TESTING TECHNIQUES
J. A. Laughrey, G. K. Richey, and Antonio Ferri, (N. Y. Univ., N. Y.) *In* AGARD Improved Nozzle Testing Tech. in Transonic Flow Oct. 1975 21 p refs (For availability see N76-16357 07-34)

A comparison of the boattail pressure distributions from data presented earlier shows that there is a significant variance in the data obtained in the various facilities, particularly at 0.9 and 0.95 Mach numbers. The analysis is concentrated on the 15 deg AGARD boattail tested in the 0.8 to 0.95 Mach number range. Differences in model support, model scale, tunnel blockage, tunnel buoyancy, wall type and porosity, and determination of tunnel reference flow conditions are examined in an attempt to understand the disagreement in the data. Model and wall static pressure distributions from various facilities are analyzed to try to isolate the reasons for these differences and to determine if there is a significant effect on the flow over the nozzle boattail. An indication of possible wall interference is obtained by comparing the measured wall static pressure distributions to those determined analytically with a far field boundary condition corresponding to free flight conditions. Author

N76-16371 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
FORE- AND AFTBODY FLOW FIELD INTERACTION WITH CONSIDERATION OF REYNOLDS NUMBER EFFECTS
Felix Aulehla and Geert Besigk *In* AGARD Improved Nozzle Testing Tech. in Transonic Flow Oct. 1975 22 p refs (For availability see N76-16357 07-34)

Recent aftbody drag results obtained from different transonic wind tunnel measurements showed such large increases in aftbody pressure drag with increasing Reynolds number that extrapolation to full scale became questionable. Attempts made to clarify this unexpected Reynolds number effect with the aim of contributing to improved testing techniques are outlined. An analysis of a wind tunnel investigation at Mach number 0.8 on a series of axisymmetric bodies showed as main result that varying Reynolds number produced in the wind tunnel opposite changes in pressure drag on fore- and aftbody, respectively. It is explained that this result probably was caused by small deviations in free stream static pressure to which part-models are by an order of magnitude more sensitive than complete models. Therefore, unless a wind tunnel is calibrated to considerably better standards than usual it is recommended to take into account the compensating effects on the forebody; the buoyancy corrections due to pressure gradients, however, have to be considered in addition. In the present measurements the changes of the mean wall pressures seemed to correlate with the corresponding changes on the model and were used as a correction term. Finally it is pointed out that modifications in aftbody geometry affect forebody drag. Results from the commonly used aftbody test rigs with forebodies fixed to the ground therefore need appropriate corrections. Author

N76-21430# Advisory Group for Aerospace Research and Development, Paris (France).
FLUIDICS TECHNOLOGY
J. M. Kirshner, ed. (Harry Diamond Labs., Adelphi, Md.) Jan. 1976 592 p refs
(AGARD-AG-215; AGARDograph-215) Avail: NTIS HC $13.75

This AGARDograph is based on material presented at a symposium on fluidics held by the Harry Diamond Laboratories of the United States Army. It largely represents a selection of material from the proceedings of this symposium, edited in the interests of a wider audience. The compilation is an overview in concise form of the present state of research, technology and applications of fluidics. An opening section on sensors is followed by sections on circuit components, systems and signal aspects, and design and application. A final section is concerned with research and fabrication needs in the future. The table of contents of the original HDL Symposium is appended. For individual titles, see N76-21431 through N76-21448.

N76-21431 Picatinny Arsenal, Dover, N.J.
FLUIDIC SENSORS: A SURVEY
Albertus E. Sukhaldin and Joseph M. Kirshner (Harry Diamond Labs.) *In* AGARD Fluidics Technol. Jan. 1976 p 3-62 refs (For availability see N76-21430 12-34)

Types of fluidic sensors and the phenomena that make them possible are discussed. Various kinds of proximity sensors, force sensors, velocity sensors, position sensors, angular rate sensors, accelerometers, level sensors, temperature sensors, and concentration sensors are included. Author

N76-21432 Massachusetts Inst. of Tech., Cambridge.
A REVIEW OF VORTEX DIODE AND TRIODE STATIC AND DYNAMIC DESIGN TECHNIQUES
D. N. Wormley *In* AGARD Fluidics Technol. Jan. 1976 p 83-112 refs (For availability see N76-21430 12-34)

Vortex diode and triode amplifiers and their operating characteristics are described. Experimental and analytical studies of the essential characteristics of vortex chamber flow fields are briefly reviewed. Data and design techniques developed for the static design of diodes and triodes are summarized, and methods to estimate the small signal and global dynamic response of diodes and triodes are reviewed. Studies describing the application of vortex diodes and triode amplifiers in engineering systems are cited. Author

N76-21433 State Univ. of New York, Buffalo. Dept. of Mechanical Engineering.
THE TURBULENCE AMPLIFIER: STATIC AND DYNAMIC CHARACTERISTICS
Adam C. Bell *In* AGARD Fluidics Technol. Jan. 1976 p 113-156 refs (For availability see N76-21430 12-34)

The transition from laminar to turbulent flow in jets is discussed along with the advantages and disadvantages of the turbulence amplifiers (TA). The static performance, design parameters, analysis for jet and tube flow are also discussed for TA. F.O.S.

N76-21434 Harry Diamond Labs., Adelphi, Md.
ANALYTIC DESIGN OF LAMINAR PROPORTIONAL AMPLIFIERS
Francis M. Manion and Tadeusz M. Drzewiecki *In* AGARD Fluidics Technol. Jan. 1976 p 157-207 refs (For availability see N76-21430 12-34)

The analytic design of laminar proportional amplifiers is discussed. After a historical review of analog fluidic devices, the advantages of and rationale for using laminar devices are shown. Among some of the more desirable features of laminar devices are the improvements obtained in gain, dynamic range and signal-to-noise ratio, not to mention the ease of scaling. A general geometric configuration for laminar proportional (analog) amplifiers is presented that considers control and output-port width, splitter-to-nozzle distance, splitter thickness, aspect ratio, and spacing between downstream edges of the control ports normalized to the supply nozzle width as the parameters of

concern in design. The approach geometry, such as the supply, control, output and vent lines, is treated in terms of known viscous impedance variables. Staging techniques are presented also. Author

N76-21435* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
EXPERIMENTAL DESIGN OF LAMINAR PROPORTIONAL AMPLIFIERS
R. F. Hellbaum *In* AGARD Fluidics Technol. Jan. 1976 p 209-227 refs (For availability see N76-21430 12-34)

An experimental program was initiated at Langley Research Center to study the effects of various parameters on the design of laminar proportional beam deflection amplifiers. Matching and staging of amplifiers to obtain high-pressure gain was also studied. Variable parameters were aspect ratio, setback, control length, receiver distance, receiver width, width of center vent, and bias pressure levels. Usable pressure gains from 4 to 19 per stage can now be achieved, and five amplifiers were staged together to yield pressure gains up to 2,000,000. Author

N76-21436 Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mechanical Engineering.
THE EFFECT OF GEOMETRIC AND FLUID PARAMETERS ON STATIC PERFORMANCE OF WALL-ATTACHMENT-TYPE FLUID AMPLIFIERS
H. L. Moses and R. A. Comparin (Newark Coll. of Eng.) *In* AGARD Fluidics Technol. Jan. 1976 p 229-248 refs (For availability see N76-21430 12-34)

The current state-of-the-art in relating the geometry and fluid parameters to the static performance characteristics of wall-attachment-type fluid amplifiers is reviewed. The basic concepts involved in available analytical approaches are outlined with some experimental results. The effect of these parameters on amplifier performance is summarized, with reference to the analyses and experiments. Author

N76-21437 Harry Diamond Labs., Adelphi, Md.
THE DESIGN OF FLUERIC, TURBULENT, WALL ATTACHMENT FLIP-FLOPS
Tadeusz M. Drzewiecki *In* AGARD Fluidics Technol. Jan. 1976 p 249-290 refs (For availability see N76-21430 12-34)

A guide is presented for the design of turbulent, wall attachment flip-flops with straight walls and sharp splitters. The analysis provides the steady state and transient characteristics, and the results are presented graphically to facilitate design. Fabrication techniques are discussed where they may compromise design criteria. A specific design for minimum response time is followed from conception to final component status. In addition a typical design problem is considered and solved. Author

N76-21438 Surrey Univ., Guildford (England). Dept. of Mechanical Engineering.
DIGITAL FLUIDIC COMPONENT AND SYSTEM DESIGN
G. A. Parker *In* AGARD Fluidics Technol. Jan. 1976 p 293-316 refs (For availability see N76-21430 12-34)

Moving part and nonmoving part digital fluid devices are discussed. Digital component characteristics, digital modules, sensors, combinational, and sequential circuit design are described. F.O.S.

N76-21439 Fachhochschule, Cologne (West Germany).
SIGNAL ANALYSIS OF FLUIDIC NETWORKS
H. M. Schaedel *In* AGARD Fluidics Technol. Jan. 1976 p 317-388 refs (For availability see N76-21430 12-34)

The problems of signal processing in fluidic networks are compared to those in electrical communication. Topics discussed include: the electric-fluidic analogy, turbulent resistance, transmission lines, ac-circuits, and pulses in fluidic networks. F.O.S.

N76-21440 Lehigh Univ., Bethlehem, Pa.
ANALOG FLUIDIC CIRCUITRY: REVIEW, CRITIQUE AND A NEW OPERATIONAL AMPLIFIER
Forbes T. Brown *In* AGARD Fluidics Technol. Jan. 1976 p 389-407 refs (For availability see N76-21430 12-34)

Two different approaches to analog fluidic circuitry are found in the literature. The first utilizes high gain amplifiers with feedback (operational amplifiers) to achieve easy design, excellent linearity, low noise and low sensitivity to disturbances at a cost of limited bandwidth, high power consumption and high expense. The second utilizes fewer amplifiers with feed-forward and a minimum of feedback to achieve the opposite consequences. An operational amplifier is proposed which, through resonance tubes placed in the forward loop upstream of the gain block, has a greatly extended bandwidth at a cost of increased sensitivity to load changes at high frequencies. Author

N76-21441 Harry Diamond Labs., Adelphi, Md.
FLUIDIC NOTCH FILTERS
Gary L. Roffman *In* AGARD Fluid Technol. Jan. 1976 p 409-443 refs (For availability see N76-21430 12-34)

Ten notch-filter circuits with biquadratic transfer functions are described. Notch filters are used in control systems to prevent instabilities due to mechanical resonances. The electronic circuit literature was searched to find circuits with biquadratic transfer functions that could be implemented with fluidic amplifiers. The amplifiers are assumed to have equal input and output impedances, and all high-gain amplifiers used are assumed to have a pressure gain of 2,000. Using these characteristics, the frequency response of the circuits is calculated using a digital, circuit-analysis program. The best circuit, based on accuracy in producing a required transfer function for the M60A1 tank control system, gain insensitivity, and least number of compliances (bellows) requires three high-gain amplifiers. Advantages and disadvantages of all the circuits are discussed. Author

N76-21442 Harry Diamond Labs., Adelphi, Md.
CIRCUIT MODELS OF PASSIVE PNEUMATIC FLUIDIC COMPENSATION NETWORKS
Joseph M. Iseman *In* AGARD Fluidic Technol. Jan. 1976 p 445-484 refs (For availability see N76-21430 12-34)

Circuit models of passive pneumatic fluidic components are summarized, and the feasibility of a circuit approach for designing passive fluidic control system circuits is described. Starting with a set of fluidic components: capillaries, enclosed volumes, bellows modules, and diaphragm modules. Circuit models were synthesized from an analytical-experimental-computational approach. Simple, ideal electronic circuit models that are linear and frequency independent were extended to models that are nonlinear and frequency dependent. These circuit models are described by analytic expressions. A few test configurations were built and their responses were measured. Simulation for these configurations was performed with digital computer programs. Comparisons between the test data and simulated models were made and qualitatively evaluated; these data are generally in agreement over the ranges tested. Author

N76-21443 Harry Diamond Labs., Adelphi, Md.
FLUIDIC STANDARDIZATION EFFORTS
R. Pierce Trask, II *In* AGARD Fluidics Technol. Jan. 1976 p 487-496 (For availability see N76-21430 12-34)

Fluidic standards are discussed with respect to their development, subject material, use within the fluidic technology, and to some extent their relationship to other technologies. The many groups that are active in developing standards and the standard documents they issue are described. Among the most active groups are the Government Fluidics Coordination Group (GFCG) and the National Fluid Power Association (NFPA). Two military standards on fluidic terminology, symbology, and test methods, were developed and recently revised by the GFCG. Two additional standards on moving-part fluid-logic symbols and data presentation were developed by the NFPA. These four documents form the framework of the current fluidic standards used in the United States. Author

N76-21444 Harry Diamond Labs., Washington, D.C.
MILITARY APPLICATIONS IN FLUIDICS
R. N. Gottron and L. S. Cox *In* AGARD Fluidics Technol. Jan. 1976 p 497-510 refs (For availability see N76-21430 12-34)

U.S. Government programs in fluidics are discussed with brief descriptions of current system applications along with present government efforts in fabrication and reliability. Author

N76-21445 AiResearch Mfg. Co., Phoenix, Ariz.
AEROSPACE FLUIDICS APPLICATIONS AND CIRCUIT MANUFACTURE
T. G. Sutton, Sr. and W. J. Anderson *In* AGARD Fluidics Technol. Jan. 1976 p 511-536 (For availability see N76-21430 12-34)

The application of fluidics to the solution of aerospace control problems began at AiResearch in 1964. Several development programs have resulted in production applications related to the major AiResearch product lines which include gas turbines, propulsion engines, air motors, and environmental control systems. Early in these development programs, it was realized that the

manufacture of monolithic fluerlc circuits would be necessary for aerospace use of this new technology. Research and investigation of production processes resulted in the use of photo-chemical machining and assisted diffusion bonding for manufacture of production and development fluidic circuitry. The use of these processes has led to the successful application of fluidics to aerospace products. Author

N76-21446 Sheffield Univ. (England). Dept of Chemical Engineering
FLOW CONTROL CIRCUITS FOR TOXIC FLUIDS
J. R. Tippetts, N. Syred, J. Grant (United Kingdom Atomic Energy Authority, Risley), and R. E. Strong (Brit. Nucl. Fuels) *In* AGARD Fluidics Technol. Jan. 1976 p 537-566 refs (For availability see N76-21430 12-34)

Classical and newly-developed fluidic devices which are being used to handle active fluids in a nuclear fuel processing plant are described. Author

N76-21447 Sheffield Univ. (England). Dept. of Chemical Engineering and Fuel Technology.
DEVELOPMENT NEEDS
J. R. Tippetts *In* AGARD Fluidics Technol. Jan. 1976 p 567-582 refs (For availability see N76-21430 12-34)

The importance of development as a rational process is emphasized. Scope for future development with a reasonable prospect of pay-off is discussed. It is shown that the general field of flow control is worthy of intensive development. Numerous useful applications for fluidic techniques exist in chemical and nuclear plans. Some useful circuits are suggested; the development needs are self-evident. The many diverse flow control elements are interrelated by the indefinite circle diagram. This results in the identification of certain desirable properties which may guide the future development of devices and circuits. Author

N76-21448 Harry Diamond Labs., Adelphi, Md.
FABRICATION REQUIREMENTS IN FLUIDICS TECHNOLOGY
Lyndon S. Cox *In* AGARD Fluidics Technol. Jan 1976 p 583-593 refs (For availability see N76-21430 12-34)

The relationship between the manufacturing processes and the successful fabrication of a fluidic item for a specific use is discussed. The fabrication process including cutting, etching, casting, electroforming, and forming are reviewed along with the problem areas. Types of applications such as switching and logic circuits, and analog circuits are presented. F.O.S.

N76-23535# Advisory Group for Aerospace Research and Development, Paris (France).
IMPROVED NOZZLE TESTING TECHNIQUES IN TRANSONIC FLOW
F. Jaarsma (Natl. Aerospace Lab., Amsterdam) Feb. 1976 16 p refs
(AGARD-AR-94) Avail: NTIS HC $3.50

Summary and conclusions are presented on the tests and joint analyses performed on nozzle testing techniques. Effects of wind tunnel static pressure, Reynolds Number, boundary layer, model support, wall interference, buoyancy, afterbody geometry, nozzle pressure ratio, and jet temperature are reported. Author

N76-23536# Advisory Group for Aerospace Research and Development, Paris (France).
FLOW SEPARATION
Feb. 1976 40 p refs Presented at the AGARD Fluid Dyn Panel Symp., Goettingen, Germany, 27-30 May 1975
(AGARD-CP-168-Suppl) Avail: NTIS HC $4.00

The calculation is discussed of laminar separation which has always represented one of the most relevant problems of boundary layer theory, even within the classical Prandtl's assumption of vanishing transverse pressure gradients. Recent theories attempting to calculate separation after relaxing Prandtl's assumption are reviewed. Purely numerical results based on the finite difference solution of the complete Navier-Stokes equations are briefly mentioned. The analytical procedure based on a multiple layer treatment developed independently by Neiland and by Stewartson and Williams is discussed in detail both in the foundations and in the developments. Some as yet unmentioned results are also given. A critical discussion follows, showing the insufficiency of the present asymptotic treatment of the return flow. A third procedure is thought to present a certain interest, that is the generalization of von Karman momentum integral procedure taking into account the existence of transverse pressure gradients. The attempt by Holden and Moselle, containing some arbitrariness, is mentioned. It is shown how the arbitrary elements can be removed and a perfectly coherent set of equations in integral form obtained. The possibility is shown of a fundamental improvement in the calculation of the distributions through the use of a three or four-parameter family of generalized similar solutions taking into account the transverse variability of the pressure. Author

N77-11357# Advisory Group for Aerospace Research and Development, Paris (France).
FLUID DYNAMICS PANEL SYMPOSIUM ON FLOW SEPARATION
D. J. Peake (NAE, Ottawa) and W. J. Rainbird (Carleton Univ.) Oct. 1976 18 p refs
(AGARD-AR-88) Avail: NTIS HC A02/MF A01

This report contains an evaluation and appraisal of the subject with recommendations for future research. Current knowledge and understanding of the fluid physics of 2D and 3D flow separation and reattachment, particularly for turbulent flows, is limited. It is necessary that high quality, carefully planned 2D and 3D boundary layer experiments be conducted to obtain dependable experimental data to enhance our basic knowledge, and for use in verification, validation and development of theoretical prediction methods. These complete, unambiguous data sets should include detailed documentation of all measurable quantities, both mean and fluctuating at the wall, in the viscous boundary layer and in the external flowfield. Emphasis should be placed on redundant measurement techniques to ensure high data reliability. Author

N77-12352# Advisory Group for Aerospace Research and Development, Paris (France).
FLOW OF SOLID PARTICLES IN GASES
George Rudinger (State Univ. of New York, Buffalo) and A. Auriol, ed. (l'Inst. Franco-Allemand de Recherches de Saint-Louis, France) Oct. 1976 94 p refs
(AGARD-AG-222; ISBN-92-835-1228-6) Avail: NTIS HC A05/MF A01

Research on gas-particle flow in Germany, Great Britain, France, and the United States is presented. Fluidized beds and laser-Doppler anemometers were used to measure solid particles and gas flow. For individual titles, see N77-12353 through N77-12357.

N77-12353# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
FRENCH CONTRIBUTION TO AERODYNAMICS OF GAS-PARTICLE MIXTURES
Paul Kuentzman *In* AGARD Flow of Solid Particles in Gases Oct. 1976 p 1-18 refs (For primary document see N77-12352 03-34)
Avail: NTIS HC A05/MF A01

Three examples, concerning the aerospace field, are presented; they concern rocket propulsion, laser anemometry and capture of droplets. A precise knowledge of the particle size distribution is essential in most cases, and improvements in optical techniques are desirable. Velocity measurements, satisfactory for small concentrations, should be extended to larger ones. Temperature measurement methods for both phases exist. Interactions between particles should be better known. Author

N77-12354# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
GAS FLOWS WITH SOLID PARTICLES: RESEARCH AND DEVELOPMENT IN GERMANY
W. Wuest *In* AGARD Flow of Solid Particles in Gases Oct. 1976 p 19-32 refs (For primary document see N77-12352 03-34)
Avail: NTIS HC A05/MF A01

Fundamental research on force and heat-transfer laws and propagation of sound and shock waves is discussed as well as more applied work on generation, conveying, separation and measurement of particles. Author

N77-12355# City Univ., London (England). Dept. of Mechanical Engineering.
A REVIEW OF RESEARCH IN THE UNITED KINGDOM IN THE FIELD OF MULTIPLE FLOWS OF SOLIDS AND GASES
R. A. Duckworth *In* AGARD Flow of Solid Particles in Gases Oct. 1976 p 33-46 refs (For primary document see N77-12352 03-34)
Avail: NTIS HC A05/MF A01

Understanding of solid-gaseous flows is much less complete than in the case of fluid flows partly because of the limitations imposed by the available measuring techniques. Several such techniques are discussed. The complex nature of gas-particle flows has led to an attempt to obtain a generalized empirical solution which is briefly described. Particle deposition, entrainment, and erosion caused by the impact of airborne particles are also discussed. Author

N77-12356# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium)

FLOW OF SOLID PARTICLES IN GASES: ACTIVITIES AT THE VON KARMAN INSTITUTE FOR FLUID DYNAMICS

Jean J. Ginoux and Michel Riethmuller *In* AGARD Flow of Solid Particles in Gases Oct. 1976 p 47-54 refs (For primary document see N77-12352 03-34)

Avail: NTIS HC A05/MF A01

Low speed and high speed gas-particle flow are discussed. Theoretical and experimental aspects are also discussed, as well as some work on instrumentation. In addition, observations in a fluidized bed are briefly described, and development of a laser Doppler velocimeter is outlined. Author

N77-12357# Textron Bell Aerospace Co., Buffalo, N.Y.

FUNDAMENTALS AND APPLICATIONS OF GAS-PARTICLE FLOW

George Rudinger *In* AGARD Flow of Solid Particles in Gases Oct. 1976 p 55-86 refs (For primary document see N77-12352 03-34)

(Contracts F44620-70-C-0116; N00014-67-A-0226, Proj. SQUID)

Avail: NTIS HC A05/MF A01

This survey deals with flows of a gas in which small, rigid, and permanent particles are suspended. Particle concentrations range from so low that the particles do not affect the gas flow and can be treated as single particles to so high that the particles occupy an appreciable volume fraction of the mixture. The dynamics of single particles in continuum and low-density flow, the thermodynamics of gas-particle mixtures, and the basic flow equations for one-dimensional flow are discussed. Wave propagation, nozzle flow and gas-particle jets are also discussed. Additional examples of analytical and experimental results are given to illustrate important situations. Emphasis is placed on work performed in the United States. Author

35 INSTRUMENTATION AND PHOTOGRAPHY

Includes remote sensors, measuring instruments and gages, detectors, cameras and photographic supplies, and holography. For aerial photography see *43 Earth Resources*. For related information see also *06 Aircraft Instrumentation* and *19 Spacecraft Instrumentation*.

N74-35095# Advisory Group for Aerospace Research and Development, Paris (France)

TESTING OF PRECISION INERTIAL GYROSCOPES

Dino A. Lorenzini (Air Force Acad.) Jun. 1974 73 p refs (AGARD-AG-192; AGARDograph-192) Avail: NTIS HC $6.75

The basic phases of environment, excitation, monitor, and evaluation involved in inertial sensor tests are reviewed. Techniques considered for application to known gyro testing problems are described, and base motion environment, computer-controlled test operation, data acquisition, and data handling problems are identified. The studies suggest that the development of a more comprehensive gyro error model is needed to uncover some of the coefficient disagreements and instabilities which occur between different tests, and different test equipment. Mini-computers are discussed in terms of their advanced capabilities in data acquisition and processing methods for improved test accuracy, speed, and versatility. Author

N75-26835# Advisory Group for Aerospace Research and Development, Paris (France).

A REVIEW OF ANTHROPOMETRIC DATA OF GERMAN AIR FORCE AND UNITED STATES AIR FORCE FLYING PERSONNEL, 1967 - 1968

H. J. Grunhofer, ed. (German Air Force) and G. Kroh, ed. (German Air Force Inst. of Aviation Med.) Apr. 1975 180 p refs (AGARD-AG-205; AGARDograph-205) Avail: NTIS HC $7.00

Standardized equipment, definitions and procedures were used according to Hertzberg for each program. Both data collections were obtained from preselected personnel and are not representative of the whole male population of the respective country; however, the results are representative of the reference collectives. For each body dimension the following detailed information is given: the definition, written and illustrated, of body dimension to be measured; the frequency of certain ranges; a breakdown of GAF and USAF data in percentile; essentials on the statistics of data distribution. The correlation matrix of GAF data is also included. Author

N75-21492# Royal Aircraft Establishment, Farnborough (England).

THE POSSIBILITIES OF USING A SCANNING ELECTRON MICROSCOPE FOR THE STUDY OF COMPOSITE MATERIALS HAVING AN ORGANIC MATRIX

J. Auvinet and J. Rouchon Dec. 1975 12 p refs Transl. into ENGLISH from the French Report AGARD CP 163 (RAE-Lib-Trans-1874, BR50919, AGARD-CP 163) Avail: NTIS HC $3.50

The scanning electron microscope, with its large depth of field and high resolution makes possible the direct examination of fine and deeply contoured surfaces and is thus particularly suitable for the study of composite materials. The use is described of a scanning electron microscope for product quality control and the study of failure surfaces and corrosion in glass and high modulus fibre/epoxy matrix composites. Each of these facets is illustrated photographically. Author

36 LASERS AND MASERS

Includes parametric amplifiers

N74-23082# Advisory Group for Aerospace Research and Development, Paris (France).
LASER INSTRUMENTATION FOR FLOW FIELD DIAGNOSTICS
J. D. Trolinger (ARO, Inc.), S. M. Bogdonoff, ed. (Princeton, Univ.), and J. A. Smith, ed. Mar. 1974 128 p refs (AGARDograph-186; AGARD-AG-186) Avail: NTIS HC $9.50 CSCL 20E

An introduction to coherent optics and holography is presented. A discussion of the application of lasers in aerodynamics is presented and examples taken from many different laboratories are included. The use of lasers to complement conventional optical methods is reviewed while more advanced techniques are presented in greater detail. These include new methods in interferometry, holography, and laser Doppler techniques. Author

N75-16828# Advisory Group for Aerospace Research and Development, Paris (France).
EVALUATION OF THE POTENTIAL BENEFIT TO THE AERONAUTICAL FIELD FROM LASER TECHNOLOGY
Dec. 1974 251 p refs Partly in ENGLISH; partly in FRENCH (AGARD-AG-195; AGARDograph-195) Avail: NTIS HC $8.50

The characteristic properties of lasers are reported and their applications to aeronautical engineering are discussed. For individual titles, see N75-16829 through N75-16843.

N75-16829 Royal Radar Establishment, Malvern (England).
REVIEW OF CHARACTERISTIC LASER PROPERTIES
M. J. Taylor *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 24 p refs (For availability see N75-16828 08-36)

Lasers can be made from solid, gaseous or liquid materials, and the emission may be either continuous wave (CW) or pulsed, depending on the system. The range of CW power in laser beams varies from milliwatts to kilowatts and pulsed systems give peak powers of up to terrawatts with pulse widths in the picosecond range. The energy in such short, intense pulses may not, however, be very high. The principles and properties of lasers are summarized, emphasizing aspects which are particularly relevant to avionic systems design. Author

N75-16830 Service Technique des Telecommunications de l'Air, Paris (France).
POSSIBLE APPLICATION OF LASERS IN AERONAUTICS [DOMAINES POSSIBLES D'APPLICATION DES LASERS EN AERONAUTIQUE]
Jean Bertrais *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 5 p In FRENCH (For availability see N75-16828 08-36)

Laser use in aeronautics covering data transmission support, analysis of structures, tests of aircraft equipment, and as a source of light in holographic procedures is reported. Image storage trajectory determinations, and reconnaissance missions are also discussed. Transl. by E.H.W.

N75-16831* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
OPTICAL COMMUNICATION IN FREE SPACE
Henry H. Plotkin, Nelson McAvoy, and Michael W. Fitzmaurice *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 24 p refs (For availability see N75-16828 08-36)

Two classes of laser communication systems for handling very high data rates across inter-satellite distances are considered that provide for high antenna gains, wide modulation bandwidths, and optical receiver sensitivities. System design considerations are based upon the carbon dioxide laser modulation to accommodate digital or analog information, and the neodymium doped YAG laser pulse for digital modulation. G.G.

N75-16832 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. fuer Flugfunk und Mikrowellen.
AIRBORNE INSTRUMENTATION ALTIMETERS, DOPPLER-NAVIGATORS, VELOCIMETER, CAT-DETECTION
F. Maiota *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 12 p refs (For availability see N75-16828 08-36)

The possible uses of lasers in airplanes as altimeters, velocimeters, for Doppler navigation and for clear air turbulence detection are discussed. It is shown that the shorter wavelengths of lasers have some advantages over microwaves and radiowaves in avionics applications G.G.

N75-16833 Army Electronics Command, Fort Monmouth, N.J.
THE APPLICATION OF LASERS TO THE PROBLEMS OF VERY LOW LEVEL FLIGHT OBSTACLE AVOIDANCE AND TERRAIN FOLLOWING
C. M. Kellington *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 9 p refs (For availability see N75-16828 08-36)

Lasers have found application in helping to solve the problems of very low level flight by U.S. Army aircraft. In the following is discussed: the reasons why Army aircraft fly low, the nature of the operational problems encountered at low altitudes, the technical problems associated with the design of systems to enhance low level flight capability, research efforts to date directed toward solution of the problem of low level flight and finally a comparison of the capabilities of microwave and laser systems in this area. The limitations of laser systems and research areas still requiring investigation are also discussed. Author

N75-16834 Lincoln Lab., Mass. Inst. of Tech., Lexington.
AIRBORNE SURVEILLANCE AND RECONNAISSANCE
R. H. Kingston *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 3 p Sponsored by Dept. of the Air Force (For availability see N75-16828 08-36)

The use of a laser for illumination offers many advantages over reconnaissance and surveillance using either standard photography or microwave radar. Foremost among these advantages are high resolution images not dependent upon daylight, much higher resolution than that obtainable with radar, and the possibility of range-gating for suppression of foreground backscatter as well as range determination. In this review of the use of lasers in airborne surveillance and reconnaissance, the detailed advantages of such systems, the types of systems and possible applications, and the problem areas requiring further research and development are discussed. Author

N75-16835 Royal Aircraft Establishment, Farnborough (England).
RANGING GUIDANCE AND DESIGNATION
A. R. Newbery and J. C. Mabberley *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 10 p refs (For availability see N75-16828 08-36)

The use of lasers for ranging, guidance and designation is reviewed and advantages and disadvantages over more conventional techniques are indicated. The discussion is mainly limited to systems employing basic components which are currently available. Possible future systems are mentioned, with some emphasis on the development trends expected. Author

N75-16836 Thomson-CSF, Issy les Moulineaux (France).
TRAJECTOGRAPHY: TRACKING [TRAJECTOGRAPHIE: POURSUITE]
H. Maillet (Labs. de Marcoussis), G. Coudero, P. Sergent, M. deNoray (Engins MATRA), and R. Moreau (ONERA) *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 38 p refs In FRENCH; ENGLISH summary (For availability see N75-16828 08-36)

Problems relating to the optical tracking of a target, either friend or foe are discussed. Generalities are given on methods used to solve these problems and the main types of lasers that were used. A survey was also made of the methods applicable to air target trajectography, including those parts of the trajectory that are in contact with the ground. Satellite trajectography from ground based stations and optical tracking in the instance of antiaircraft defense operations are included. Author

N75-16837 Compagnie Generale d'Electricite, Marcoussis (France). Div. des Applications Optiques.
HOLOGRAPHIC STORAGE OF OPTICAL IMAGES AND VISUALIZATION OF LASER SYSTEMS [STOCKAGE HOLOGRAPHIQUE DES IMAGES OPTIQUES ET SYSTEMES VISUALISATION A LASER]

G. Courrier *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol Dec. 1974 26 p refs In FRENCH, ENGLISH summary (For availability see N75-16828 08-36)

The state of the art in the fields of holographic storage and retrieval and large screen displays was examined. Particular attention was given to methods, as the Fourier transform holography and frequency carrier photography. Advantages of the methods using laser sources were reviewed along with main parameters influencing design concepts Author

N75-16838 Physics Lab RVO-TNO, The Hague (Netherlands).
OPTICAL CORRELATION
J. A. Boden *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 20 p refs (For availability see N75-16828 08-36)

A survey is given of the most common types of coherent optical correlators, which are classified as spatial plane correlators, frequency plane correlators and special reference correlators. Only the spatial plane correlators are dealt with rather thoroughly. Basic principles, some special features, advantages and disadvantages mostly are given with references to relevant literature. Optical processing of sideways looking synthetic aperture radar data and the acousto-optical processing of linear FM radar signals are described as special reference correlators, of which the first has become the most important application of optical data processing to date. Some advantages and disadvantages of incoherent correlators are given for comparison along with some examples of the most common types. A detailed description of a simple coherent spatial plane correlator is given. Some experimental results are mentioned. The reference function in this correlator is realized as a hard clipped phase plate, which results in a large detection region and a high signal output. Author

N75-16839 Army Electronics Command, Fort Monmouth, N.J.
THE LASER GYRO
Vernon Dickey *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 10 p refs (For availability see N75-16828 08-36)

A general discussion of laser gyro technology is presented which includes basic principles of operation and various effects which introduce errors. This is followed by a review of the engineering aspects of design and contruction. Finally, the potential capabilities and limitations as related to system applications are considered. Author

N75-16840 Office of Naval Research, Arlington, Va.
APPLICATIONS OF LASER OPTICS TO AERONAUTICAL ENGINEERING
Robert D. Matulka *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 23 p refs (For availability see N75-16828 08-36)

The use of lasers and laser optics is discussed for several fields of aeronautical engineering which include experimental fluid and structural mechanics and testing. The advantages of laser optics and the application to laser scattering, holography, and photography are outlined. The application of holography to wind tunnel diagnostics is detailed as a tutorial example of applied laser optics. State of the art description is also attempted for the fields of non-destructive testing, vibration analysis, laser Raman spectroscopy, velocimetry, and photo-elasticity Suggestions for potential applications are made when appropriate, throughout the paper. Author

N75-16841 Compagnie Generale d'Electricite, Marcoussis (France). Section Electronique et Photonique
OPTICAL FIBER COMMUNICATION ONBOARD AIRCRAFT [COMMUNICATIONS PAR FIBRES OPTIQUES A BORD D'AVIONS]
J Ernest *In* AGARD Evaluation of the Potential Benefit to the Aeron Field from Laser Technol Dec 1974 11 p refs In FRENCH, ENGLISH summary (For availability see N75-16828 08-36)

Recent advances in optical fiber transmission and their potential use in some specific areas are reported. These advances include: different types of low pass optical fibers, single mode cladded glass fibers, multimode cladded glass fibers, multimode cladded liquid core cladded fibers and SELFOC glass fibers. Important components of an optical fiber link, mostly light emitters, are examined along with tradeoffs and possible combinations of components for specific system applications. Advantages of optical fiber transmission are discussed with emphasis on features related specifically to communication link problems with an aircraft. Author

N75-16842 Service Technique des Telecommunications de l'Air, Paris (France).
CONCLUSIONS AND RECOMMENDATIONS [CONCLUSIONS ET RECOMMANDATIONS]
J Bertrais *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec 1974 7 p In FRENCH (For availability see N75-16828 08-36)

Recommendations regarding the feasibility, use, and applications of various laser types and laser systems in aerospace are given. Special attention was given to tracking studies, communication, surveillance and reconnaissance onboard aircraft, and image storage techniques Transl by E.H.W.

N75-16843 Direction des Recherches et Moyens d'Essais, Paris (France).
ATMOSPHERIC LASER BEAM PROPAGATION
A. Laurent *In* AGARD Evaluation of the Potential Benefit to the Aeron. Field from Laser Technol. Dec. 1974 21 p refs In FRENCH; ENGLISH summary (For availability see N75-16828 08-36)

Laser beam propagation is modified by absorption, by scattering and by turbulence. Absorption in the atmosphere is brought about by molecular constituants. The absorption by scattering depends on Rayleigh scattering and Mie scattering; Rayleigh scattering can be neglected for wavelengths longer than 0.5 microns. Mie scattering is related to the dimensions of the particles; the attenuation of hazes and selective fogs decreases when the wavelength increases. The effects of turbulence on laser beam propagation are beam spreading, beam deviation, amplitude and phase variations whose consequences are scintillation and coherence losses; those effects are more important for short wavelengths than for long wavelengths. Author

N75-16844# Advisory Group for Aerospace Research and Development, Paris (France).
EVALUATION OF THE POTENTIAL BENEFIT TO THE AERONAUTICAL FIELD FROM LASER TECHNOLOGY [EVALUATION DES APPLICATIONS POTENTIELLES DU LASER DANS LE DOMAINE AEROSPATIAL]
J. Bertrais (STTA, Paris) Dec. 1974 8 p In FRENCH
(AGARD-AR-65) Avail: NTIS HC $3.25

A resume on lasers and their application to aerospace are presented. Data cover: trajectography - tracking, characteristic properties of lasers, laser telemetry, holographic storage of optical images, and optical fiber communication. Transl. by E.H.W.

37 MECHANICAL ENGINEERING

Includes auxiliary systems (non-power); machine elements and processes; and mechanical equipment

N75-22749# Advisory Group for Aerospace Research and Development, Paris (France)
ADVANCED MANUFACTURING METHODS AND THEIR ECONOMIC IMPLICATIONS: SOME PILOT PAPERS ON POWDER METALLURGY AND JOINING
Mar 1975 112 p refs In ENGLISH, partly in FRENCH (AGARD-R-627) Avail. NTIS HC $5.25

A systematic examination of the field of advanced fabrication techniques is reported, together with an analysis of the impact of these new procedures on costs. Six papers, given before the AGARD Structures and Materials Panel in the spring and fall of 1974, are contained in this document. These six papers explore the latest state-of-the-art and the potentials for future development of various methods of fabrication of aerospace hardware. Analyzed in these papers are such areas as metal joining methods, production techniques for dispersion-strengthened materials and various aspects of powder metallurgy. The six papers contained in this report constitute a pilot effort by the Structures and Materials Panel to determine the direction of future work of the panel in this important field. For individual titles, see N75-22750 through N75-22755.

N75-22750 Air Force Materials Lab., Wright-Patterson AFB, Ohio. Metals Branch.
POWDER METALLURGY PRODUCTION PROCESSES
Larry P. Clark *In* AGARD Advan. Manuf. Methods and their Econ. Implications Mar. 1975 18 p (For availability see N75-22749 14-37)

A review of the current status of powder metallurgy (P/M) technology and its application to aircraft engines and recommendations of the Powder Metallurgy Seminar are discussed. The state-of-the-art in powder production, consolidation methods, secondary operations and NDE is discussed for titanium, aluminum and superalloy P/M products. Also, a summary of pertinent United States Air Force manufacturing technology programs in P/M is presented. Author

N75-22751 Air Force Materials Lab., Wright-Patterson AFB, Ohio. Metals Branch.
A REVIEW OF SELECTED MANUFACTURING TECHNOLOGY PROGRAMS FOR METALS JOINING
Fred R. Miller *In* AGARD Advan. Manuf. Methods and their Econ. Implications Mar. 1975 33 p refs (For availability see N75-22749 14-37)

An overview is presented of the United States Air Force Materials Laboratory, Manufacturing Technology Division's involvement in the development of a variety of advanced metals joining processes. Processes discussed in this paper include electron beam welding, plasma arc welding, inertia welding, weldbonding and diffusion bonding. Author

N75-22752 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (West Germany). Inst. fuer Werkstoff-Forschung.
PROCESSING OF DISPERSION HARDENED MATERIALS
G. Wirth *In* AGARD Advan. Manuf. Methods and their Econ. Implications Mar. 1975 16 p refs (For availability see N75-22749 14-37)

Production methods for dispersion-strengthened metals and alloys, especially materials for high-temperature applications, are reviewed including commercial as well as advanced experimental techniques. Their effect on mechanical properties and economic aspects are discussed. Because of the nearly exclusive application of powder-metallurgical techniques to the production of dispersion-strengthened materials, this production method preferably is discussed. Also, special strengthening mechanisms are pointed out. Comparisons are made to other high-temperature strengthening approaches as directional solidification of eutectic alloys. Advanced processes like ZAP, applied to mechanically alloyed dispersion-strengthened age-hardenable superalloys, cancel the complicated and expensive thermomechanical treatments and seem to shift the dispersion strengthening up to a level of strength and economy comparable to the directional solidification of eutectics. Author

N75-22753 Wiggin (Henry) and Co. Ltd., Hereford (England).
PRODUCTION OF SUPERALLOYS FROM POWDERS
F. A. Thompson and D. L. Williams *In* AGARD Advan. Manuf. Methods and their Econ. Implications Mar. 1975 15 p refs (For availability see N75-22749 14-37)

Powder metallurgical techniques are reported, when applied to superalloy production, overcome many of the problems facing the alloy developers for materials to use in the critical high temperature regions of aircraft gas turbine engines. It is shown not only do they overcome many technical problems, but in the future the powder techniques have the potential to increase material yields and processing efficiency thus leading to reduced costs. Author

N75-22754 Atomic Energy Research Establishment, Harwell (England). Process Technology Div.
TITANIUM POWDER METALLURGY
P. W. Sutcliffe and P. G. Mardon *In* AGARD Advan. Manuf. Methods and their Econ. Implications Mar. 1975 17 p refs (For availability see N75-22749 14-37)

The current technical and economic status of titanium powder metallurgy is surveyed. Relevant details of conventional wrought titanium route such as market size, distribution, scrap and loss generation and material utilization are summarized. Methods by which titanium and titanium alloy powders are presently produced such as sponge, fused salt electrolysis, hydride dehydride, rotating electrode and centrifugal shot casting processes are discussed together with typical powder properties. Possible ways of fabricating such powders from simple press and sinter route through to the variety of hot consolidation processes, now being employed to achieve properties equivalent to wrought material, are considered with examples of mechanical properties so far achieved. Some preliminary economic considerations are discussed including present and possible future powder costs; the fabrication costs available to date and their implications upon the likely level of finished part cost of a given quality are also noted. Author

N75-22755 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Paris (France). Lab. de la Direction Technique
WORK ON THE CALCINATION OF HEAT RESISTANT NICKEL BASED ALLOYS [MISE EN OEUVRE DES ALLIAGES FRITTES BASE NICKEL RESISTANT A CHAUD]
Pierre Lescop *In* AGARD Advan. Manuf. Methods and their Econ. Implications Mar. 1975 5 p In FRENCH (For availability see N75-22749 14-37)

The products obtained by powder metallurgy are reported showing that nickel based alloys possess good mechanical properties. The development of new techniques and the high cost of materials are discussed. Transl. by M.C.F.

38 QUALITY ASSURANCE AND RELIABILITY

Includes product sampling procedures and techniques, and quality control.

N76-16458# Advisory Group for Aerospace Research and Development, Paris (France).
NON-DESTRUCTIVE INSPECTION PRACTICES, VOLUME 1
Enrico Bolis, ed. Oct. 1975 470 p refs
(AGARD-AG-201-Vol-1, AGARDograph-201-Vol-1) Avail: NTIS HC $12.00

Nondestructive testing methods used to guarantee the safety of aircraft structures are reviewed. These methods are used in three areas: quality control, inspection of service aircraft, and as a basic element of design philosophies. Specific methods described include: magnetic particle inspection; liquid penetrant inspection, X-ray diffraction; gammagraphy, ultrasonic tests; and holographic methods. For individual titles, see N76-16459 through N76-16476.

N76-16459 Aeritalia, Turin (Italy).
PHILOSOPHY OF NON-DESTRUCTIVE INSPECTION
E. Bolis *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 1-10 refs (For availability see N76-16458 07-38)

The concept of nondestructive inspection of aircraft structures is discussed in terms of two philosophies: safe life and fail safe. Factors discussed include: structural design; tolerable defects; standards of acceptance; and selection of inspection methods. A survey of nondestructive inspection techniques is given. J.M.S.

N76-16460 George Washington Univ., Washington, D.C. School of Engineering and Applied Sciences.
BASIC CONCEPTS IN FRACTURE MECHANICS
J. Eftis, D. L. Jones, and H. Liebowitz *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 11-25 refs (For availability see N76-16458 07-38)

The linear elastic fracture mechanics approach to design against fracture of structural components, basically a stress intensity approach which establishes criteria for fracture instability in the presence of a crack, is presented. Emphasis is placed on design of aerospace structures. Factors discussed include: the fail-safe or fracture safe philosophy of damage tolerant structures, critical crack size; and fatigue crack growth under constant amplitude fatigue loading and variable amplitude fatigue loading. Examples are given. J.M.S.

N76-16461 British Aircraft Corp., Weybridge (England). Commercial Aircraft Div.
DESIGN FOR INSPECTION AND PLANNING FOR MAINTENANCE OF STRUCTURAL INTEGRITY
H. Tyrer *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 27-54 (For availability see N76-16458 07-38)

The role of the structural and systems designer in planning for inspection and maintenance of aircraft structures is discussed. A structural inspection program which verifies the structural integrity of all aircraft in a fleet by means of visual examination and nondestructive testing is described in detail. J.M.S.

N76-16462 Army Materials and Mechanics Research Center, Watertown, Mass.
STANDARDS OF ACCEPTANCE BY NON-DESTRUCTIVE INSPECTION FOR RAW MATERIALS AND COMPONENTS
Herbert F. Campbell *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 55-82 (For availability see N76-16458 07-38)

Nondestructive inspection (NDI) acceptance criteria to assure reliability of airframe materials and components are discussed. An overview is presented of responsibility, analysis requirements, and specification requirements. Materials and defect characterization, which together with service requirements form the basis for accept/reject criteria, is included. Based upon the materials and defect characterization, the action areas in the material life cycle for preparation of specifications and standards are discussed. General considerations and requirements for preparing specifications and standards are discussed. General considerations and requirements for preparing specifications and standards are presented and the various types of specifications and standards are described. Applicable specifications and standards are listed. The general formulation of the NDI program within the framework of life cycle management system is discussed together with scheduling considerations in relation to raw material, in process, final, and in service inspection. Author

N76-16463 Royal Netherlands Aircraft Factories Fokker, Amsterdam.
SURVEY OF PROBLEMS
R. J. Schliekelmann *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 83-90 (For availability see N76-16458 07-38)

Problems limiting the effectiveness of nondestructive inspection (NDI) are discussed. Areas considered include: inspection of raw materials, inspection of components, and inspection of assemblies. A need for established standards in the application of NDI methods as well as in qualification and certification of NDI inspectors is indicated. J.M.S.

N76-16464 Royal Netherlands Aircraft Factories Fokker, Amsterdam.
CRITICAL SURVEY OF METHODS
E. J. vanderSchee and P. F. A. Bijlmer *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 91-128 (For availability see N76-16458 07-38)

Various nondestructive test methods are described. These methods include basic techniques in the following areas: visual inspection, acoustic and ultrasonic methods, and electrical methods. The relations between the observed properties and the properties of interest are given with each method. J.M.S.

N76-16465 Royal Netherlands Air Force, The Hague.
QUALIFICATION OF PERSONNEL
R. Hilverdink *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 129-139 (For availability see N76-16458 07-38)

Requirements of trained and qualified personnel that determine to a considerable extent the successful accomplishment of nondestructive testing are presented. Only general requirements are given, as specific arrangements vary not only for each process, but also for each organization which works with the process, as well as the item to be tested. Author

N76-16466 Laboratori Centrali Fiat, Turin (Italy).
MAGNETIC PARTICLE INSPECTION
G. Magistrali *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 143-168 (For availability see N76-16458 07-38)

The magnetic or magnetic particle method of inspection which allows detection of surface and subsurface flaws by means of leakage magnetic fields appearing on the surface of test specimens is described. An accumulation of a particles clearly visible to the naked eye is produced, thus revealing defects not previously visible. This method is suitable only with ferromagnetic materials, such as steel, cast iron, nickel, and various ferromagnetic alloys. A summary of magnetization techniques and inspection methods is given. Author

N76-16467 Laboratori Centrali Fiat, Turin (Italy).
LIQUID PENETRANT INSPECTION
Giovanni Magistrali *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 169-180 (For availability see N76-16458 07-38)

Liquid penetrant inspection which is applicable to direct surface defects or surface defects with surface openings is described. Liquids of low surface tension and with the capability of penetrating by capillary action into cracks or openings are used giving a surface indication visible to the naked eye. Author

N76-16468 Brussels National Airport, Zaventem (Belgium).
EDDY CURRENT NDI IN AIRLINE MAINTENANCE
M. VanAverbeke *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 181-228 refs (For availability see N76-16458 07-38)

The theory of eddy current testing with the surface probe is discussed. Factors affecting the surface probe impedance include: conductivity variations; magnetic permeability variations; frequency variations; lift-off effect; edge effect, thinness effect, and hand capacitance effect. Other topics discussed are: sensitivity limit of eddy current testing; quantitative determination of defects; airframe holes inspection; miscellaneous airframe inspection, engine on-wing inspections; testing for corrosion; testing for conductivity; and testing of radome thickness. J.M.S.

N76-16469 Roentgen Technische Dienst N. V., Rotterdam (Netherlands). Research and Development Dept.
RADIOGRAPHY
A. deSterke *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 232-259 refs (For availability see N76-16458 07-38)

Application of X-radiography to nondestructive testing of aircraft structures is discussed. The principles of radiography are given and X-ray equipment and exposure techniques described. Topics considered include: difference between the examination and inspection, practical aspects of the inspection, cracks and their performance, examination of honeycomb structures, radiographic detection and evaluation of corrosion, and radiation safety. J.M.S.

N76-16470 Roentgen Technische Dienst N. V., Rotterdam (Netherlands).
RADIATION SAFETY
A. H. A. M. Roepke *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 260-267 refs (For availability see N76-16458 07-38)

The biological effects of handling the different radiation sources are discussed in terms of protection. The characteristics of radiation sources are given along with the maximum permissible doses for individuals. Other topics discussed include: personal dosimeters, monitoring; and shielding and protection. J.M.S.

N76-16471 Direzione Laboratori Aeronautici Militaire, Rome (Italy).
X-RAY DIFFRACTION
A. Tronca *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 271-292 refs (For availability see N76-16458 07-38)

The fundamental concepts of X-ray diffraction are discussed in terms of nondestructive testing of airframe materials to determine the cause of failure. The method is used to determine the amount of austenite in a hardened steel and the residual stress acting on the surface of a specimen. Other topics discussed include: determination of grain size by line-width analysis; immediate evaluation of the metallurgical state of a material; determination of preferred orientations; the use of electronic computers in processing X-ray diffraction data; and X-ray diffraction in relation to other methods of structural investigation. J.M.S.

N76-16472 Brussels National Airport, Zaventem (Belgium).
GAMMAGRAPHY IN AIRLINE MAINTENANCE
M. VanAverbeke *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 295-329 refs (For availability see N76-16458 07-38)

Gammagraphy a nondestructive inspection technique derived from X-ray radiography utilizing a compact source of radioactive material is examined in relation to application in aircraft maintenance. Topics discussed include: gamma-ray properties, sources, and energy; activity of a gamma-ray source; source activity decay, radiation quantity; specific radiation intensity; gamma-ray absorption, and compton scattering. Gammagraphic photography is described in detail along with equipment and safety rules. Applications in civil aviation are given. J.M.S.

N76-16473 Krautkraemer Branson, Inc., Stamford, Conn.
ULTRASONIC AND ACOUSTIC METHODS
K. G. Walther *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 331-385 refs (For availability see N76-16458 07-38)

Nondestructive test methods utilizing ultrasonics and acoustics are considered. Wall thickness measurements with ultrasonics on new material and measurement of remaining wall thickness in maintenance inspection are described along with ultrasonic inspection methods of forged parts, wrought material, and cast parts. Other topics discussed include: inspection of material connections; testing of brazed and soldered joints; ultrasonic inspection of laminates; ultrasonic inspection with surface waves, ultrasonic inspection with geometrically guided waves; ultrasonic inspection of nonmetallics, and continuous surveillance of structural members by means of ultrasonic techniques. J.M.S.

N76-16474 Aerojet Solid Propulsion Co., Sacramento, Calif.
DETECTION AND DETERMINATION OF FLAW SIZE BY ACOUSTIC EMISSION
C. E. Hartbower *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 387-447 refs (For availability see N76-16458 07-38)

The use of acoustic emission as a nondestructive inspection technique is discussed. Each stage of the failure process is detected in real time starting with deformation, crack propagation, and the onset of instability. Areas of application discussed include: low cycle high-stress-intensity fatigue; stress corrosion cracking and hydrogen embrittlement; strain-aging embrittlement; delayed weld cracking, and continuous in-service surveillance. Limitations of acoustic emission techniques are summarized. J.M.S.

N76-16475 RDE and Missile System Lab., Redstone Arsenal, Ala.
LIQUID CRYSTAL AND NEUTRON RADIOGRAPHY METHODS
Sheiba P. Brown *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 449-470 ref (For availability see N76-16458 07-38)

Nondestructive test methods using liquid crystals to test composite structures, electronic components, and for detection of cracks in welded areas are described along with the neutron radiographic method for providing quantitative information regarding flaw location, size, shape, and orientation. Areas of application are given. J.M.S.

N76-16476 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
HOLOGRAPHIC METHODS
G. E. Maddux *In* AGARD Non-Destructive Inspection Practices, Vol. 1 Oct. 1975 p 459-470 refs (For availability see N76-16458 07-38)

The principal features and aspects of the application of holography as a nondestructive test technique are considered. Methods of application examined include: surface recording, pulsed laser nondestructive inspection, ultrasonic holography, correlation methods, and speckle pattern interferometry. Holographic recording materials are briefly discussed. J.M.S.

N76-16477# Advisory Group for Aerospace Research and Development, Paris (France).
NON-DESTRUCTIVE INSPECTION PRACTICES, VOLUME 2
Enrico Bolis, ed. Oct. 1975 194 p refs
(AGARD-AG-201-Vol-2; AGARDograph-201-Vol-2) Avail: NTIS HC $7.50

Nondestructive testing methods used to guarantee the safety of aircraft structures are reviewed. Nondestructive inspection of welding, bonded structures, and composite materials is described along with measurement of residual stress and corrosion. For vol. 1, see N76-16458. For individual titles, see N76-16478 through N76-16482.

N76-16478 Technical Univ. of Denmark, Lyngby.
THE NON-DESTRUCTIVE MEASUREMENT OF RESIDUAL STRESSES
F. Rotvel *In* AGARD Non-Destructive Inspection Practices Oct. 1975 p 473-505 refs (For availability see N76-16477 07-38)

The effect of mean stress on fatigue strength and stress corrosion is discussed briefly. Processes by which residual stresses are created were studied; these include plastic deformation in regions with stress gradients, temperature gradients, chemical expansion or contraction surface material, and electroplating. X-ray stress measurement using the film method of the diffractometer method was investigated, and comparisons were made between the two methods. The ultrasonic stress measuring method and the Knoop hardness stress measuring method are considered. M.J.S.

N76-16479 Laboratori Centrali Fiat, Turin (Italy).
NDI OF WELDING
G. Fenoglio and G. Magistrali *In* AGARD Non-Destructive Inspection Practices Oct. 1975 p 507-528 (For availability see N76-16477 07-38)

Various types of welding techniques are briefly defined. The weldability and welding defects of titanium and its alloys, austenitic stainless steels, aluminum and its alloys, and nickel and its alloys are discussed. Typical welding defects and their detection by nondestructive testing are considered. M.J.S.

N76-16480 Societe Nationale Industrielle Aerospatiale, Suresnes (France).
NDI OF BONDED STRUCTURES
M. Trecu *In* AGARD Non-Destructive Inspection Practices Jan. 1975 p 529-577 refs (For availability see N76-16477 07-38)

Advantages of bonded structures are presented along with data on bonding adhesives, flaws in bonded structures, and inspection processes during product manufacture. Inspection methods which are discussed in detail include sonic inspection technique, vacuum cup inspection, ultrasonic techniques, sonic resonance, eddy sonic methods, holographic interferometry, thermal methods, and radiography. M.J.S.

N76-16461 Air Force Materials Lab., Wright-Patterson AFB, Ohio.
NDI OF COMPOSITE MATERIALS
W. L. Shelton *In* AGARD Non-Destructive Inspection Practices Oct. 1975 p 579-592 refs (For availability see N76-16477 07-38)

The general problem areas of composites, the defects which may occur in composite production and fabrication, and the nondestructive tests which are applicable for detection and measurement of such defects are reviewed. Methods discussed briefly include visual inspection, acoustic techniques, sonic methods, radiation methods, electrical methods, electromagnetic methods, and thermal methods. Author

N76-16462 British European Airways, London (England).
DETECTION AND MEASUREMENT OF CORROSION BY NDI
A. R. Bond *In* AGARD Non-Destructive Inspection Practices Oct. 1975 p 593-611 (For availability see N76-16477 07-38)

Nondestructive test methods for inspecting the corrosion of aircraft structures are reviewed. The method which gave the best results was the phase sensitive eddy current method; the detectors are described in detail along with their selection and testing. M.J.S.

N76-24602# Advisory Group for Aerospace Research and Development, Paris (France).
AVIONICS DESIGN FOR RELIABILITY
Mar. 1976 163 p refs
(AGARD-LS-81) Avail. NTIS HC $6.75

Problems of avionics reliability were discussed. Typical methods for forcing reliability into new design and development and into new procurement requirements were described, including a discussion of the relationship between life cycle costs as affected by the reliability achieved. The case for improving initial designs with more background experience, greater patience and thoroughness by the designer is viewed as perhaps the soundest and in the long run the most economical means for reliability attainment. Case histories involving both reliability testing and field reliability achievement are described. For individual titles, see N76-24603 through N76-24614.

N76-24603 Bird Engineering-Research Associates, Inc., Vienna, Va.
AVIONICS RELIABILITY CONTROL DURING DEVELOPMENT
George T. Bird and G. Ronald Herd *In* AGARD Avionics Design for Reliability Mar. 1976 11 p refs (For availability see N76-24602 15-38)

A comparison was made between actual reliability growth observed during recent years and the inherent reliability potential for avionics equipment. A method of control is presented integrating prediction procedures currently outlined in MIL-STD-756 and MIL-HDBK-217 with development testing. A nomograph is presented for determining the amount of design support testing which will be required to achieve a desired or specified value of avionics equipment reliability. It is shown how these control procedures are used for specification, design planning, testing, and monitoring high reliability achievement in avionics equipment. Author

N76-24604 Royal Radar Establishment, Malvern (England).
RELIABILITY GROWTH MODELLING FOR AVIONICS
J. E. Green *In* AGARD Avionics Design for Reliability Mar. 1976 12 p refs (For availability see N76-24602 15-38)

The factors which influence the reliability of avionics were reviewed, with emphasis on the development phase. A method for providing progressive estimates of reliability achievement during the development phase was presented. Reference is made to the use of computer programs for these purposes, and for estimating costs. The validity of the Duane Model is considered against practical experience gained during development of military avionics. Explanations are given for observed deviations in the short and long term periods, and the need to make adjustments for different environmental stress conditions is noted. Further verification of a mathematical law for the rate of appearance of types of systematic (pattern) failure is reported. A review of potential avionic reliability was also given in relation to the increased use of microelectronics and the eventual limiting factors were considered. Author

N76-24605 Sumerlin (W. T.), Hazelwood, Mo.
ILLUSORY RELIABILITY GROWTH
W. T. Sumerlin *In* AGARD Avionics Design for Reliability Mar. 1976 4 p refs (For availability see N76-24602 15-38)

The present meaning of reliability growth was identified and contrasted to earlier concepts. Present needs to devise effective means for administering the later phase of avionic development were recognized. It is during this development phase that an abundance of system failures caused by shortcomings of design, workmanship, and parts selection, mark more or less completely the inherent reliability achievable upon development completion. The mathematical uncertainty of prognosticating a valid schedule for elimination of all pattern failures and achievement of required reliability on the basis of early test experience is examined. It is concluded that accepted means must be used for quantitative MTBF measurement in the absence of pattern failures, and that quantitative values for MTBF produced by typical growth monitoring in the presence of an abundance of pattern failures can be dangerously misleading. Author

N76-24606 Bird Engineering-Research Associates, Inc., Vienna, Va.
EXPERIENCED IN-FLIGHT AVIONICS MALFUNCTIONS
George T. Bird and G. Ronald Herd *In* AGARD Avionics Design for Reliability Mar. 1976 10 p (For availability see N76-24602 15-38)

The status of current avionics reliability in the field has been evaluated by a study of 98 types of avionics equipment used in a variety of aircraft during a six-month period in 1970. The MTBFs were analyzed by aircraft type and by equipment category (i.e., communication, radar, flight controls, computers, etc.) to reveal correlations with functional complexity. About 4,000 in-flight malfunctions from one type of aircraft covering 28 different equipment types were investigated to show failure modes, repair actions, and probable design causes. Author

N76-24607 Service Technique des Telecommunications de l'Air, Paris (France).
FAILURES AFFECTING RELIABILITY OF AVIONIC SYSTEMS
J. A. Garnier *In* AGARD Avionics Design for Reliability Mar. 1976 11 p In FRENCH and ENGLISH (For availability see N76-24602 15-38)

An automatic system of technical information set up within the French Air Force in conjunction with a basic document, the technical action form, was described, and the principle and conditions of application of guaranteed reliability clauses were discussed. The objective of this system is to determine the actual reliability of a system under operational conditions and to detect the failures affecting reliability. This is not only indispensable in improving the reliability of the equipment considered, but also provides information that is essential in developing new generations of equipment. The main results obtained through this system regarding the actual reliability of equipment and the analysis of the failures affecting reliability were also reviewed. Author

N76-24608 General Dynamics/Fort Worth, Tex. Research and Engineering Dept.
IMPACT OF RELIABILITY IMPROVEMENT WARRANTY (RIW) ON AVIONIC RELIABILITY
C. A. Hardy *In* AGARD Avionics Design for Reliability Mar. 1976 12 p refs (For availability see N76-24602 15-38)

Incentives provided by the Air Force to contractors of new systems to design and produce electronic equipment with low failure rates and low repair costs in operational use were described. These incentives, which are included in procurement contracts as reliability improvement warranty (RIW) provisions, obligate the contractor to accomplish repair and replacement of failed equipment at a fixed price during operational use of the equipment by the Air Force. The contractor also guarantees the mean-time-between-failure of the equipment during the warranty period. The RIW provisions are projected to have a significant impact on avionic reliability. Author

N76-24609 Sumerlin (W. T.), Hazelwood, Mo.
HIGH RELIABILITY DESIGN TECHNIQUES
W. T. Sumerlin *In* AGARD Avionics Design for Reliability Mar. 1976 7 p ref (For availability see N76-24602 15-38)

The general situation between the following two extremes in design techniques was considered: (1) commonplace techniques, with the constraints of holding a normal cost ceiling and schedule, to provide higher reliability than would otherwise be expected, and (2) special and unusual techniques, with greatly extended costs and schedule, to produce much higher reliability. The objective under study was to attain a preferred balance between reliability and all competing factors such as performance, cost, schedule, etc. This requires a thorough understanding of the need for the desired reliability and the probability of its attainment under various trades and compromises. It was concluded that adherence to the discussed techniques and their intent will generally lead to the attainment of optimum reliability prior to the need for a quantitative reliability verification test, and the question of reliability growth during the development program becomes academic. Author

N76-24610 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany).
DESIGN OF ELECTRONIC CIRCUITS AND COMPONENT SELECTION FOR HIGH RELIABILITY
Walter Schambeck *In* AGARD Avionics Design for Reliability Mar. 1976 14 p refs (For availability see N76-24602 15-38)

Rules were given for the selection of components for high reliability applications. Determining the suitable technology, part derating factors and then the selection or writing of specifications for parts procurement are described. The necessity of precap visual inspection and screening of components as well as incoming inspection by the user for high reliability applications is emphasized. The use of plastic IC's for HI-REL applications and a new development in this field is discussed. The second part is concerned with the design of reliable circuits. Precautions to be taken against voltage and current overloading and the selection of the proper supply voltage are described. The use of MSI and LSI and synchronous operation is suggested to increase the reliability. Noise immunity and its influence on reliable operation is discussed. Finally redundancy versus screening and the cost of reliability are considered. Author

N76-24611 General Dynamics/Fort Worth, Tex. Research and Engineering Dept.
AVIONIC RELIABILITY AND LIFE-CYCLE-COST PARTNERSHIP
C. A. Hardy *In* AGARD Avionics Design for Reliability Mar. 1976 14 p (For availability see N76-24602 15-38)

The interface between the reliability and life-cycle cost of avionics weapon systems was discussed. The following areas were treated: (1) definition of life-cycle cost, (2) rationale for promoting the life-cycle cost concept, (3) analysis techniques used to evaluate the life-cycle cost, (4) the life-cycle-cost/design to cost requirements that are contained in present contracts, and (5) the interface between reliability and life-cycle cost during proposal, definition, and production phases Author

N76-24612 Service Technique des Telecommunications de l'Air, Paris (France).
CASE HISTORY OF SOME HIGH RELIABILITY DESIGNS FOR AVIONIC SYSTEMS
J. A. Garnier and D. Reneric *In* AGARD Avionics Design for Reliability Mar. 1976 23 p In FRENCH and ENGLISH (For availability see N76-24602 15-38)

Four methods developed to obtain high reliability with avionics equipment were described and illustrated. These methods deal with the following areas: (1)components, efforts are directed towards the achievement of manufacturing processes leading to high reliability devices, (2) reliability prediction: appropriate calculations are carried out to analyze the stresses to which components are submitted and to improve circuit design, (3) reliability and burn-in tests: their purpose is to reveal early operation defects and systematic failures, as well as to give an estimation of reliability close to the operational value, and (4) reliability clauses: guaranteed reliability or contractual maintenance clauses ensure that the aim in view has been reached. The main results of a study aimed at analyzing the efficiency of these methods were then presented, based on a cost-reliability standpoint, for a particular example. Finally, the essential lessons learned from the application of these methods to known equipment were brought out Author

N76-24613 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany).
RELIABILITY TESTING OF ELECTRONIC PARTS
Walter Schambeck *In* AGARD Avionics Design for Reliability Mar. 1976 18 p refs (For availability see N76-24602 15-38)

A survey of the environmental, physical and electrical tests, which are necessary to establish the reliability of electronic parts, is given. Special emphasis is placed on the testing of semiconductors. All the tests are described together with the failure they can detect in parts. Within these three categories of tests, nondestructive and destructive ones are distinguished. Although most popular tests are mentioned, special emphasis is placed on tests not so widely used yet, such as high stress tests, acoustical particle detection, thermal mapping by means of liquid crystals and the test of input protection circuits of MOS IC's. The need for visual inspection as a means of improving the quality of components is discussed. Product analysis as a means of evaluation of the parts manufacturer's capability is described in detail. Author

N76-24614* National Aeronautics and Space Administration, Washington, D.C.
AVIONICS DESIGN FOR RELIABILITY BIBLIOGRAPHY
In AGARD Avionics Design for Reliability Mar. 1976 12 p (For availability see N76-24602 15-38)

A bibliography with abstracts was presented in support of AGARD lecture series No. 81. The following areas were covered: (1) program management, (2) design for high reliability, (3) selection of components and parts, (4) environment consideration, (5) reliable packaging, (6) life cycle cost, and (7) case histories. Author

39 STRUCTURAL MECHANICS

Includes structural element design and weight analysis; fatigue; and thermal stress. For applications see *05 Aircraft Design, Testing and Performance* and *18 Spacecraft Design, Testing and Performance*.

N74-21549# Advisory Group for Aerospace Research and Development, Paris (France).
SURVEY OF ACTIVITIES IN THE FIELD OF LOW CYCLE HIGH TEMPERATURE FATIGUE. CRITICAL REPORT
J. M. Drapier (Centre de Recherch. Met., Liege, Belgium). Feb. 1974. 149 p. refs. Presented at the 37th Meeting of the AGARD Struct. and Mater. Panel, The Hague, 7-12 Oct. 1973 (AGARD-R-618). Avail: NTIS HC $10.50

Information on the activities in low cycle fatigue testing at high temperature (LCHTF) was gathered during the visit of 38 laboratories (industry and universities) from 7 NATO countries. It covers several facets of the LCHTF problem, namely: materials, testing equipments and conditions, types of data plots, latest developments in prediction laws for the fatigue behaviour of materials and design procedures for predicting lives in different engine components. Author

N74-23413# Advisory Group for Aerospace Research and Development, Paris (France).
FRACTURE MECHANICS OF AIRCRAFT STRUCTURES
Harold Liebowitz, ed. (George Washington Univ.) Jan. 1974. 624 p. refs.
(AGARD-AG-176; AGARDograph-176) Avail: NTIS HC $34.25

The proceedings of a conference on the structural analysis of airframes and aircraft components are presented. The subjects discussed include the following: (1) history of aircraft loading and examples of aircraft failure, (2) application of fracture mechanics principles in the design and analysis of damage tolerant aircraft structures, (3) fail safe design procedures, (4) experimental techniques for determining fracture toughness, and (5) flaw detection methods. For individual titles, see N74-23414 through N74-23445.

N74-23414 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
SPECTRUM OF LOADING OF AIRCRAFT
Howard A. Wood *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 3-7 refs (For availability see N74-23413 14-32)

A summary of airframe service loadings and experience is presented. The areas of concern are: (1) the structural environment, (2) the operational environment, (3) the internal airframe environment, and (4) frequency of occurrence and significance of airframe loadings. Diagrams are presented for typical load profile for tactical aircraft on a conventional delivery mission and the flight-profile for a transport aircraft wing root. Author

N74-23415 Royal Aircraft Establishment, Farnborough (England).
EXAMPLES OF AIRCRAFT FAILURE
W. T. Kirkby *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 8-13 (For availability see N74-23413 14-32)

Examples of structural failure of aircraft components are presented to show the importance of structural design and reliability engineering. Photographs of typical aircraft components are provided to show the type of failure and the degree of impairment. The examples include the following: (1) pressure cabin skin cracking, (2) landing gear door uplock failure, (3) rotor blade extrusion cracking, (4) wheel casting failure, and (5) typical defects in spar booms. Author

N74-23416 Army Materials and Mechanics Research Center, Watertown, Mass.
FRACTURE REGIMES
J. I. Bluhm *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 14-17 refs (For availability see N74-23413 14-32)

An analysis of the effects of ambient conditions on the fracture characteristics of materials is presented. A schematic diagram is provided to show range of applicable strength approaches. Stress-strain diagrams are developed of the limit stresses in notched plates and notched cylinders in tension. The considerations for fracture characteristics are examined with respect to: (1) linear fracture mechanics, (2) limit design for temperature extremes, and (3) transition approaches based on various structural analysis tests. The effect of superimposed hydrostatic pressure on strain to fracture and the effects of temperature and/or strain rate are illustrated. The variation in stress state in the vicinity of a notch in a thick plate is analyzed. Author

N74-23417 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
THE USE OF FRACTURE MECHANICS PRINCIPLES IN THE DESIGN AND ANALYSIS OF DAMAGE TOLERANT AIRCRAFT STRUCTURES
Howard A. Wood *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 18-31 refs (For availability see N74-23413 14-32)

The application of fracture control principles to aircraft design in order to produce safer structures is discussed. The mechanical and physical properties of the construction materials which are capable of modification to produce the desired strength are discussed. The selected of materials for airframes is based on requirements established through actual failure experience and service life data. The nature of the requirements and allowances in their application are defined. Tables of data are provided to show the inspection requirements for cases of: (1) slow crack growth structure, (2) crack arrest structure, and (3) fail-safe structure. Author

N74-23418 George Washington Univ., Washington, D.C.
BASIC CONCEPTS IN FRACTURE MECHANICS
John Eftis, Douglas L. Jones, and Harold Liebowitz *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 32-73 refs (For availability see N74-23413 14-32)

A review of fracture mechanics is presented highlighting the strengths and limitations and establishing dome perspective of its relationship to the general fracture process. The importance of nondestructive inspection as one of several potential safegurads against failure by fracture is stressed. The subjects discussed include: (1) macroscopic classification of fracture, (2) linear elastic fracture mechanics, (3) fracture toughness in semibrittle fracture, (4) applications of fracture mechanics concepts, and (5) fatigue crack growth characteristics. Author

N74-23419 Army Materials and Mechanics Research Center, Watertown, Mass.
RESISTANCE METHOD
J. I. Bluhm *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 74-88 refs (For availability see N74-23413 14-32)

A method of determining the strength of materials based on the resistance to fracture with increasing crack length is described. The criteria for stable crack growth for a variety of specimens for both load controlled and/or displacement controlled systems are expressed by a mathematical model. The various conditions which can affect the resistance to fracture of a material are analyzed. Curves are developed to show: (1) schematic resistance/energy release rate changes in crack length, (2) constant load/constant deflection energy release rate curves for a tension specimen, and (3) constant load/constant deflection energy release curves for a bending specimen. Author

N74-23420 Army Materials and Mechanics Research Center, Watertown, Mass.
THE KUHN-HARDRATH METHOD
J. I. Bluhm *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 89-94 refs (For availability see N74-23413 14-32)

A procedure for determining the residual strength of a structural member which contains a damaged area is discussed. The damage covers the spectrum from a notch to its degenerate and generally most severe configuration, which is a crack. The method starts with an expression for the elastic stress concentration and recognizes that the maximum effective stress from a fracture point of view is not merely the nominal stress multiplied by a stress concentration factor. Instead, a concept is introduced to attempt to account for the microscopic heterogeneity of the material. The theoretical considerations are supported by mathematical models. Curves are developed to show the energy relations for fast and slow crack growth and the relation between sheet width and residual strength. Author

N74-23421 Army Materials and Mechanics Research Center, Watertown, Mass.
CRACK PROPAGATION LAWS
J. I. Bluhm *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 95-109 refs (For availability see N74-23413 14-32)

A numerical analysis of the principles of crack propagation is presented. Mathematical models are developed to show the

relations between cyclic crack growth rates to various functions of the instantaneous crack length and the alternating stress. The effects of programmed and random loading on the stability of airframes are analyzed and mathematical dependences are reported. The influences of geometry and/or structural considerations on structural stability are investigated Author

N74-23422 Cornell Univ., Ithaca, N.Y.
ENVIRONMENTAL EFFECTS IN FRACTURE
H. H. Johnson *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 110-117 refs (For availability see N74-23413 14-32)

The characteristics of environmental cracking of aircraft structures are presented. A test method for evaluating the susceptibility of a structure to environmental cracking is described. The application of linear elastic fracture mechanics to predict and interpret environmental cracking phenomena when crack propagation is the controlling feature is discussed. Curves are developed to show (1) a comparison of threshold stress intensities for three specimen configurations (2) constant crack growth rate in a constant stress intensity test, (3) crack growth rate versus field intensity, and (4) correlation of hydraulic activator and surface flawed specimen results. Author

N74-23423 Army Materials and Mechanics Research Center, Watertown, Mass.
SUMMARY OF LIMITATIONS
J. I. Bluhm *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 118-120 refs (For availability see N74-23413 14-32)

The limitations affecting the applicability of mechanics to the fracture process are discussed. Methods for conducting stress state analysis are presented to include the following: (1) crack opening displacement, (2) resistance method, and (3) the Kuhn-Hadrath method. A list of factors which influence the crack propagation behavior is developed. Author

N74-23424 Technische Hogeschool, Delft (Netherlands).
FAIL-SAFE DESIGN PROCEDURES: BASIC INFORMATION
David Broek *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 121-166 refs (For availability see N74-23413 14-32)

The application of fail-safe concepts to the design of aircraft structures is discussed. The subjects considered are: (1) plane strain problems in heavy members with surface flaws, (2) plane stress and transitional modes in sheet structures, (3) fatigue crack propagation characteristics, and (4) the prediction of crack propagation. Graphs are developed to show residual strength characteristics in plane stress. Mathematical models are included to support the theoretical considerations. Author

N74-23425 Technische Hogeschool, Delft (Netherlands).
THE PREDICTION OF CRACK PROPAGATION
David Broek *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 167-180 (For availability see N74-23413 14-32)

The factors which affect the application of fail-safe techniques in aircraft design are discussed. The load-time histories and flight-load profiles are analyzed on the basis of the following: (1) gust, maneuvers, and taxiing loads were assumed to occur as one cycle, (2) the sequence of loads was assumed random without correlation, and (3) flight profiles may differ from flight to flight, especially with respect to the large cycles and the number of cycles. Methods for estimating fatigue crack propagation are analyzed. The crack propagation life for various materials is tabulated. Author

N74-23426 Technische Hogeschool, Delft (Netherlands).
BUILT-UP SHEET STRUCTURES
David Broek *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 181-193 refs (For availability see N74-23413 14-32)

The mechanical properties of built up sheet structures under conditions of crack propagation and stress intensity are discussed. The procedure to calculate the stress intensity factor of a reinforced panel is illustrated. Graphs are developed to show the fatigue crack growth rate in stiffened panels. The factors which affect the accuracy of crack growth prediction are analyzed. The effects of stop holes on the structural integrity of sheet structures are reported. Author

N74-23427 National Aerospace Lab., Amsterdam (Netherlands)
BUILT-UP SHEET STRUCTURES, WINGS
H. Vlieger and David Broek (Technische Hogeschool, Delft, Netherlands) *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 195-225 refs (For availability see N74-23413 14-32)

The residual strength of sheet structures under conditions of plane stress is discussed. The basic fracture behavior of a stiffened panel is explained. The principles for calculating the residual strength of aircraft structures are analyzed. Curves are developed to show the residual strength of stiffened and unstiffened panels for various configurations Mathematical models of the factors involved in residual strength calculations are provided Author

N74-23428 Douglas Aircraft Co., Inc., Long Beach, Calif
THE APPLICATION OF FRACTURE MECHANICS IN THE DEVELOPMENT OF THE DC-10 FUSELAGE
T. Swift *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 226-287 refs (For availability see N74-23413 14-32)

The degree of damage tolerance used in the design of the DC-10 fuselage pressure shell is discussed with reasons for its selection. Analysis methods are presented for the prediction of the residual strength of damaged, stiffened panels, based on the Matrix Force solution of an idealized structure combined with fracture mechanics equations. The effects of attachment flexibility, which play an important part in the residual strength of damaged structure, are accounted for. Crack growth retardation due to the plastic zone formed on high load cycles and its effect on propagation under spectrum loading is discussed. It is shown that the stress intensity at the threshold of slow stable growth is not only a material property but depends almost entirely on past load history. A description of the development test program to verify the analytical techniques and to substantiate the fail-safe strength of the fuselage shell is given together with the results of many of the tests. Author

N74-23429 Royal Aircraft Establishment, Farnborough (England).
HEAVY SECTIONS
W. T. Kirkby *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 288-293 refs (For availability see N74-23413 14-32)

Methods for predicting the residual strength of relatively thick structures under plane strain conditions are presented. The problems are discussed in relation to heavy members with surface flaws, corner cracks at holes, and other natural cracks. Practical examples of the application of the procedure are provided. Mathematical models are included to show the relation of the various parameters involved in the structural analysis. Author

N74-23430 Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
AEROSPACE PRESSURE VESSELS
C. F. Tiffany *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 294-313 refs (For availability see N74-23413 14-32)

During the development of the many pressure vessels used in the Apollo Program several serious failures were encountered. In some cases through-the-thickness cracks formed and the vessels leaked. In other cases, small surface or embedded flaws grew to critical size prior to growing through the thickness of the vessel wall and catastrophic failure. Several of the different types of pressure vessel failures which have been encountered are reviewed. A discussion of the important considerations and the general technical approach being used to prevent failures in the future are presented. This encompasses many considerations ranging from initial material selection through the final acceptance of individual batches of propellant based on the results of fracture specimen tests. Examples of static fracture toughness and subcritical flaw growth data, which have been obtained on various research programs are included. Cyclic lives, times to failure and flaw growth rates are discussed in the context of linear elastic crack tip stress intensity factors. It is shown how the proof test is used to provide assurance of subsequent service life for both thick and thin walled vessels, and test procedures are recommended which should minimize potential damaging effects of the test which can occur as a result of flaw growth. Author

N74-23431 National Engineering Lab., East Kilbride (Scotland)
AN EXAMPLE OF A METHOD FOR PREDICTING FAILURE
G. H. Haslam *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 314-324 refs (For availability see N74-23413 14-32)

A method is presented for estimating the life to failure of a cylindrical pressure vessel subjected to repeated internal pressure. Design curves are obtained by which the fatigue life of such a cylinder may be estimated from a knowledge of the transverse uniaxial fatigue limit and fracture roughness properties of the cylinder material, as well as the diameter ratio of the cylinder and the repeated pressure. Examples are given of the application of the method and close correlation is demonstrated between estimated and actual behaviour Author

N74-23432 Societe Nationale Industrielle Aerospatiale, Paris (France).
SERVICE FAILURES AND LABORATORY TESTS
W. Barrois *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 325-345 refs (For availability see N74-23413 14-32)

The significant differences between structural analyses conducted in the laboratory and those conducted under service conditions are compared. Low temperature brittleness and hydrogen embrittlement of steels are used as examples. Intergranular or stress corrosion of aluminum alloys are reviewed in relation to various causes of service or manufacturing damages. The main objectives of structural tests are defined. Curves are developed to show the fracture toughness of steel sheets as a function of treatment and test temperature. Photographic samples of specific types of structural failure are included. Author

N74-23433 Societe Nationale Industrielle Aerospatiale, Paris (France).
A SHORT SURVEY ON POSSIBILITIES OF FATIGUE LIFE ASSESSMENT OF AIRCRAFT STRUCTURES BASED ON RANDOM OR PROGRAMMED FATIGUE TESTS
W. Barrois *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 346-366 refs Repr. from AGARD Conf. Proc. No. 118 (For availability see N74-23413 14-32)

The various physical parameters which are significant in the fatigue behavior of specimens and structures are reviewed. Several types of fatigue tests are analyzed to show their applicability. A short survey is made of present prediction methods of structure fatigue life from fatigue tests of components, assemblies, and structures undergoing constant amplitude loadings. The case of random loadings is also discussed. The possibility of test acceleration by increasing general loading itensity is considered. Author

N74-23434 Technische Hogeschool, Delft (Netherlands).
OUTLOOK, FUTURE DEVELOPMENTS
David Broek *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 367-369 (For availability see N74-23413 14-32)

The factors which influence the design of fail-safe systems are discussed. It is stated that many of the shortcomings in fail-safe design are caused by insufficient knowledge of fracture and fatigue mechanisms. For successful fail-safe operation, the results of tests should be documented with respect to critical locations, crack propagation rates, and residual strength. The procedures for conducting tests which will provide the data required for fail-safe design are defined. Author

N74-23435 Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany).
EXPERIMENTAL TECHNIQUES FOR DETERMINING FRACTURE TOUGHNESS VALUES
Walter Schuetz and Wolfram Oberparleiter *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 371-394 refs (For availability see N74-23413 14-32)

The Standard Method of Test for Plane Strain Fracture Toughness of Metallic Materials and the Standard Method of Sharp Notch Tension Testing of High Strength Sheet Materials, are described and some details which are important for carrying out the test are discussed. A series of nonstandard test methods are explained which mainly use different specimen shapes. Advantages and disadvantages of these test methods are discussed and comparisons of the test results with results obtained from the ASTM standard specimen are made. Also test equipment for testing fracture toughness of weldments, under environmental conditions (low temperature, salt water corrosion) and high strain rates are described. Author

N74-23436 Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany).
RELIABILITY OF THE DETECTION OF FLAWS AND OF THE DETERMINATION OF FLAW SIZE
Ekkart Knorr *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 395-412 refs (For availability see N74-23413 14-32)

Laboratory investigations concerning reliability of crack detection and determination of crack size which represent the state of the art are described. All three are typical applications of nondestructive inspection to structural parts of aircraft: (1) inspection of flat surfaces with fatigue cracks, using ultrasonic, X-ray, dye penetrant, magnetic particle and eddy current methods, (2) crack detection below rivet heads with an ultrasonic shear wave technique, and (3) crack detection in bore holes of a forged part using a manual eddy current method. The second and the third one analyzed for statistical evaluation of probability of success. An evaluation of the conventional NDI-methods regarding reliability is performed. Author

N74-23437 Aeritalia, Turin (Italy).
NONDESTRUCTIVE TESTING (NDT) AND FRACTURE MECHANICS
Enrico Bolis *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 413-417 refs (For availability see N74-23413 14-32)

The basic concepts of nondestructive testing (NDT) are reviewed in relationship with fracture mechanics concepts. The necessity of correlating basic differences between ordinary destructive mechanical tests and NDT is considered. The use of NDT for assessment of integrity of aircraft components and structures, after fabrication and during service life is discussed. Inherent limitations of NDT and necessity of interdepartmental team work are reviewed. General information on routine and advanced methods is included. Author

N74-23438 Aerojet Solid Propulsion Co., Sacramento, Calif.
DETECTION AND DETERMINATION OF FLAW SIZE BY ACOUSTIC EMISSION
C. E. Hartbower *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 419-473 refs (For availability see N74-23413 14-32)

Available acoustic emission instrumentation systems are so sensitive that it is possible to detect each stage of the failure process starting with deformation (dislocation pileups), crack propagation and, finally, the onset of instability all in real time. In the second and third stage of the failure process, it is possible by triangulation to locate the source of the signal. In some applications, the practical limitation for use of acoustic emission as a nondestructive inspection method has been and will continue to be extraneous noise. However, most noise problems are solved by the effective use of band-pass filters or special isolation techniques involving computer solutions. The use of acoustic emission as a nondestructive inspection technique has been under development for over a decade. The technique is based upon the elastic energy which is spontaneously released when a material undergoes plastic deformation and/or cracking. Thus, acoustic emission constitutes a unique nondestructive inspection method in that the material defect when propagating, transmits its own signal, with the sensor acting as the receiver. The material undergoing crack growth both generates and transmits the signal (acoustic emission) which then can be detected by suitable instrumentation and the source located using seismic techniques. Author

N74-23439 Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
SURFACE DYE PENETRANTS
Wolfgang Hansen *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 474-484 refs (For availability see N74-23413 14-32)

The detection of surface cracks in metal sheets using a penetrant dye technique is discussed. The preparation of the specimen for inspection is described. The subjects covered include the following: (1) applicability and limitations of the process, (2) intensifying the sensitivity of the dye, (3) the difference between red and fluorescent penetrants and (4) qualification of inspection materials. Author

N74-23440 Motoren- und Turbinen-Union Muenchen G.m.b.H (West Germany).
MAGNETIC PARTICLE TESTING

Eberhard Dickhaut *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 485-493 refs (For availability see N74-23413 14-32)

Nondestructive tests of ferritic materials using magnetic particle techniques are described. The magnetizing methods are discussed. Illustrations of the various methods are provided. The procedure for preparing the specimen for testing is reported. Comments concerning the application and usefulness of the process are included. Author

N74-23441 Dornier-System G.m.b.H., Friedrichshafen (West Germany).

FLAW DETECTION BY MEANS OF HOLOGRAPHIC INTERFEROMETRY

Klaus Gruenewald *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 494-502 refs (For availability see N74-23413 14-32)

Nondestructive tests to detect flaws using holographic interferometry techniques are discussed. Descriptions of the optical measuring principles of holography are provided. The theoretical and experimental aspects of holographic interferometry are examined. References are made with respect to quantitative interpretation of interferograms. The possibilities of flaw detection are illustrated by some experimental examples. Author

N74-23442 Royal Aircraft Establishment, Farnborough (England).

AN ANALYSIS OF A TEST FATIGUE FAILURE BY FRACTOGRAPHY AND FRACTURE MECHANICS

C. J. Peel *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 503-508 refs (For availability see N74-23413 14-32)

The fracture surfaces of two fatigue cracks, that had caused the failure of an engine impeller during a fatigue substantiation test, were examined by electron microscopy to find the number of fatigue crack growth cycles. This was done by measuring the spacings of fatigue striations on the fracture surface as a function of crack depth and by subsequent integration of the striation spacing versus crack depth expression. The measured striation spacings were compared with laboratory crack growth data to determine the fatigue stress intensity range as a function of crack depth and hence the fatigue stress range. The number of crack initiation cycles was then found by comparing the fatigue stress range and number of crack growth cycles with further laboratory data and the total fatigue life was calculated to have been approximately 50,000 cycles. This identified the fatigue loading that had caused the failure as having been the 29179 cycles of engine acceleration and deceleration that had been applied during the test. Author

N74-23443 Army Materials and Mechanics Research Center, Watertown, Mass.

TYPICAL PLANE STRAIN FRACTURE TOUGHNESS OF AIRCRAFT MATERIALS

W. T. Matthews *In* AGARD Fracture Mechanics of Aircraft Structure Jan. 1974 p 509-579 refs (For availability see N74-23413 14-32)

The fracture toughness values of aircraft metals are expressed in terms of linear elastic fracture mechanics. The general tabulation includes only values measured under plane strain conditions. These plane strain K sub IC values have been obtained by the ASTM E399-72 Standard Method of Test for Plane Strain Fracture Toughness Testing of Metallic Material or a similar method. This data compilation includes materials manufactured in the U.S.A. and Europe. Factors involved in the selection and interpretation of the K sub IC values will be discussed in the latter sections of this introduction. Author

N74-23444 Royal Aircraft Establishment, Farnborough (England).

FRACTURE TOUGHNESS TEST RESULTS

W. T. Kirkby *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 580-591 refs (For availability see N74-23413 14-32)

Fracture toughness test results for various metal alloys and compounds are tabulated. Data for titanium alloys, steels, and aluminum alloys have been collated. The composition of the alloys, their form, and the fracture plane orientation of the fracture toughness test pieces are given. Tensile test results for the various heat treatments are included. The results have been obtained from room temperature tests. Author

N74-23445 Royal Aircraft Establishment, Farnborough (England).

STRESS INTENSITY FACTOR SOLUTIONS

D. P. Rooke and D. J. Cartwright (Southampton Univ.) *In* AGARD Fracture Mechanics of Aircraft Structures Jan. 1974 p 592-600 refs (For availability see N74-23413 14-32)

The titles and references of approximately 140 configurations for which stress intensity factors have been determined, are presented. Section 1 gives the titles of the various configurations together with reference numbers, which are detailed in section 2. The solutions are given in graphical form together with relevant formulas. Author

N75-10487# Advisory Group for Aerospace Research and Development, Paris (France).

LOW CYCLE HIGH TEMPERATURE FATIGUE

Aug. 1974 149 p refs In FRENCH and ENGLISH Presented at the 38th meeting of the Struct. and Mater. Panel, Washington, D. C., 21-26 Apr. 1974

(AGARD-CP-155) Avail: NTIS HC $6.75

The operating conditions of aircraft are discussed in terms of propulsive efficiency, especially insofar as fatigue and creep phenomena affect the performance of engines operating at high and variable temperatures, and under cyclic stresses. Low cycle high temperature fatigue studies were conducted to obtain data related to these questions. For individual titles, see N75-10488 through N75-10494.

N75-10488 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Corbeil (France).

PROBLEMS OF LOW CYCLE HIGH TEMPERATURE FATIGUE IN AIRCRAFT JET ENGINES

R. Brunetaud and J. Thiery *In* AGARD Low Cycle High Temp. Fatigue Aug. 1974 11 p In FRENCH; ENGLISH summary (For availability see N75-10487 01-39)

Low cycle fatigue resistance problems related to aircraft engine operating cycles were examined in terms of the possibility of using calculation methods in elastic and plastic ranges for testing the condition of engine parts. Metallurgical aspects of the problem are also briefly considered. Author

N75-10489* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

AN OVERVIEW OF HIGH TEMPERATURE METAL FATIGUE: ASPECTS COVERED BY THE 1973 INTERNATIONAL CONFERENCE ON CREEP AND FATIGUE

S. S. Manson (Case Western Reserve Univ.) and G. R. Halford *In* AGARD Low Cycle High Temp. Fatigue Aug. 1974 47 p refs (For availability see N75-10487 01-39)

A summary of papers is presented which covers the following broad aspects of high temperature metal fatigue: (1) materials development and characterization; (2) environmental factors, including air, vacuum, helium, iodine, sodium, and radiation environments; (3) general fatigue life relationships; (4) crack growth laws; (5) design code activities; and (6) design and service experience. Illustrative tables accompany the summary. A.A.D.

N75-10490 Newcastle-upon-Tyne Univ. (England). Dept. of Mechanical Engineering.

PRECISION IN LCHTF TESTING

E. M. Smith *In* AGARD Low Cycle High Temp. Fatigue Aug. 1974 19 p refs (For availability see N75-10487 01-39)

Fast and accurate temperature control in low cycle high temperature fatigue (LCHTF) testing depends on an accurate sensitivity to changes in stress and temperature levels, oxidation, direction, and rates of loading. Extremities of the possible test spectrum are described in terms of constitutive testing and component testing. An evaluation of thermal and stress fields within the specimen geometry, selection of appropriate heating and cooling methods, and assessment of precision of measurement under thermal and mechanical transients were all involved in the constitutive behavior testing. Coupon testing, utilizing precisely controlled thermal shocks, was used to measure component response to LCHTF conditions. Author

N75-10491 National Gas Turbine Establishment, Pyestock (England). Materials Science Dept.

THE EFFECT OF CYCLE PARAMETERS ON HIGH TEMPERATURE LOW CYCLE FATIGUE

G. F. Harrison and M. G. Cockcroft *In* AGARD Low Cycle High Temp. Fatigue Aug. 1974 15 p refs (For availability see N75-10487 01-39)

The types of information required by engine designers in the area of high temperature low cycle fatigue engine parameters are summarized, particularly concerning temperature effects, frequency and hold-time effects, and the effects of strain cycling and stress cycling. The choice of testing method is dependent on the type of analysis employed when making use of the data and the various possible approaches are compared. It is suggested that in high temperature situations there is often advantage in regarding fatigue as a creep-dominated process. Some gaps in the present state of knowledge are indicated. Author

N75-10492 Rensselaer Polytechnic Inst., Troy, N.Y. Mechanics Div.
MULTIAXIAL FATIGUE: PRESENT AND FUTURE METHODS OF CORRELATION
Erhard Krempl *In* AGARD Low Cycle High Temp. Fatigue Aug. 1974 13 p refs (For availability see N75-10487 01-39)

Multiaxial fatigue fracture criteria are viewed as surfaces in stress (strain) space which can exhibit isotropy or anisotropy. A quadratic form of the proposed equation includes the von Mises, the Sines and the Gough criteria. It is shown how this criterion can be fitted to low-cycle fatigue data, and specific methods are suggested for the experimental determination of these constants. The criterion exhibits a linear mean stress (strain) effect and the tension-torsion ratio must be less than two. Tests necessary for the determination of the orthotropic constants are outlined. A possible extension to variable amplitude loading is suggested. Author

N75-10493 Connecticut Univ., Storrs. Dept. of Metallurgy.
LIFETIME PREDICTION METHODS FOR ELEVATED TEMPERATURE FATIGUE
A. J. McEvily and S. R. Crosby *In* AGARD Low Cycle High Temp. Fatigue Aug. 1974 18 p refs (For availability see N75-10487 01-39)

Methods for lifetime prediction at elevated temperatures can be categorized as either: (1) parametric; (2) damage summation; (3) strainrange partitioning; or (4) frequency modification. The capabilities and limitations of these various approaches are discussed, and the problem of extrapolation beyond laboratory experience is considered. Author

N75-10494 Pratt and Whitney Aircraft, Middletown, Conn. Materials Engineering and Research Lab.
DESIGN PROCEDURES FOR ELEVATED TEMPERATURE LOW-CYCLE FATIGUE
C. H. Wells *In* AGARD Low Cycle High Temp. Fatigue Aug. 1974 17 p refs (For availability see N75-10487 01-39)

The state of the art review of component design against low-cycle fatigue failure at elevated temperature, covers the areas of failure criteria, nondestructive inspection, constitutive behavior, prediction of crack initiation and propagation lifetime, applicability of linear elastic fracture mechanics, and structural verification. Special problems posed by gas turbine applications are discussed, along with major gaps in understanding and techniques. Chief among these are the nondestructive characterization of surfaces and internal flaws, definition of the limitations of fracture mechanics in the regime of intergranular cracking, the prediction of mean stress and cyclic creep, and the experimental verification of analytical procedures at high temperature. Author

N75-12357# Advisory Group for Aerospace Research and Development, Paris (France).
STRUCTURAL OPTIMIZATION
Sep. 1974 94 p refs Lecture series presented at Hampton, Va., 10-11 Oct. 1974, Duesseldorf, 14-15 Oct. 1974, and London, 17-18 Oct. 1974
(AGARD-LS-70) Avail: NTIS HC $4.75

A series of reports are presented to inform structural design engineers on the latest developments in partical design optimization methods. Emphasis is placed on the applications and use of these methods in practical design organizations. The subjects considered include the following: (1) use of optimality criteria methods for large scale systems, (2) approximation concepts for structural synthesis, (3) geometric programming methods for structural optimization, and (4) sizing of complex structure by the integration of several different optimal design algorithms. For individual titles, see N75-12358 through N75-12362.

N75-12358 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
USE OF OPTIMALITY CRITERIA METHODS FOR LARGE SCALE SYSTEMS
L. Berke and N. S. Khot *In* AGARD Structural Optimization Sep. 1974 29 p refs (For availability see N75-12357 03-39)

The development of finite element techniques enabled the structural engineer to analyze to analyze the extremely complex structural systems typical of modern aerospace vehicles. The trend now is towards automated design methods. In the case of large structural systems, optimality criteria methods, now in an advanced stage of development, appear to be the most practical for the problem of automated sizing. A brief historical review of optimality criteria methods is given. The general optimality criteria of equal cost of improvement for every active design variable is derived. The problem of multiple active constraints is discussed and solution alternatives are pointed out. As special cases, optimality criteria for generalized deflection constraints, general instability and dynamic response are derived and examples given. Author

N75-12359* California Univ., Los Angeles.
SOME APPROXIMATION CONCEPTS FOR STRUCTURAL SYNTHESIS
L. A. Schmit, Jr. and B. Farshi *In* AGARD Structural Optimization Sep. 1974 8 p refs Repr. from AIAA J., v. 12, no. 5, May 1974 p 692-699 Presented at the AIAA/ASME/SAE 14th Struct., Structural Dyn., and Mater. Conf., Williamsburg, Va., 20-22 Mar. 1973 (For availability see N75-12357 03-39)
(Grant NGR-05-007-337)
(NASA-CR-140937; Paper-73-341) CSCL 13M

An efficient automated minimum weight design procedure is presented which is applicable to sizing structural systems that can be idealized by truss, shear panel, and constant strain triangles. Static stress and displacement constraints under alternative loading conditions are considered. The optimization algorithm is an adaptation of the method of inscribed hyperspheres and high efficiency is achieved by using several approximation concepts including temporary deletion of noncritical constraints, design variable linking, and Taylor series expansions for response variables in terms of design variables. Optimum designs for several planar and space truss examples problems are presented. The results reported support the contention that the innovative use of approximation concepts in structural synthesis can produce significant improvements in efficiency. Author

N75-12360 Liverpool Univ. (England).
THE USE OF GEOMETRIC PROGRAMMING METHODS FOR STRUCTURAL OPTIMIZATION
Andrew B. Templeman *In* AGARD Structural Optimization Sep. 1974 17 p refs (For availability see N75-12357 03-39)

Structural design problems may be classified into two types, (1) the detailed design of components and (2) the design of assemblages of idealised components. The paper demonstrates that geometric programming is suitable for a wide range of optimum design problems in both these classes. The mathematics of the geometric programming method is explained with the aid of a simple example and a computer program for large problems is described. It is shown that component design characteristically gives rise to the type of functions best suited to geometric programming. Examples are presented of the use of geometric programming for the optimum design of several kinds of structural components. The design of an integrally stiffened compression panel is examined in more detail. The paper demonstrates that geometric programming can also be used for the optimum design of complete idealised assemblages of components. Examples are given of the minimum weight design of trusses. Author

N75-12361* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
SIZING OF COMPLEX STRUCTURE BY THE INTEGRATION OF SEVERAL DIFFERENT OPTIMAL DESIGN ALGORITHMS
Jaroslaw Sobieszczanski *In* AGARD Structural Optimization Sep. 1974 19 p refs (For availability see N75-12357 03-39)
(L-9738)

Practical design of large-scale structures can be accomplished with the aid of the digital computer by bringing together in one computer program algorithms of nonlinear mathematical programing and optimality criteria with weight-strength and other so-called engineering methods. Applications of this approach to aviation structures are discussed with a detailed description of how the total problem of structural sizing can be broken down into subproblems for best utilization of each algorithm and for efficient organization of the program into iterative loops. Typical results are examined for a number of examples. Author

N76-12362 Bell Aerosystems Co., Buffalo, N.Y. Structural Systems Dept.

A DISCRETIZED PROGRAM FOR THE OPTIMAL DESIGN OF COMPLEX STRUCTURES

James R. Batt and Ronald A. Gellatly *In* AGARD Structural Optimization Sep. 1974 15 p refs (For availability see N75-12367 03-39)

More economical and more flexible procedures for structural optimization of large scale systems have been sought. A new approach to determine the minimum weight of such systems has been developed, is discrete in nature, and is labeled the sieve-search technique. An essential element of the technique is the use of data banks which contain minimum weight and associated geometry of structural components. These banks are generated using classical methods of optimization. An additional facet of the technique is the use of simplified engineering analysis methods during the redesign phase of the optimization cycle. Herein lies the efficiency of the sieve-search technique. The method was successfully applied to the design of an extensive class of surface effect vehicles and is shown through application to the design of thermal protective systems and associated wing substructure. Author

N76-18623# Advisory Group for Aerospace Research and Development, Paris (France).

ACOUSTIC FATIGUE DESIGN DATA, PART 4

A. G. R. Thomson (ESDU) and R. F. Lambert (ESDU) Jan. 1975 48 p refs

(AGARD-AG-162-Pt-4; AGARDograph-162-Pt-4) Avail: NTIS HC $3.75

Acoustic fatigue test procedures, methods of calculation, and results for various structural elements are presented. The methods of calculation given are: (1) a method to determine the natural frequencies of initially unstressed box structures that are rectangular in section; (2) a method of estimating the R.M.S. stress in internal plates of a box structure subjected to random acoustic loading; and (3) a method of estimating the sound pressure levels within the intake duct of a supersonic fan or compressor due to buzz saw noise. Author

N76-11454# Advisory Group for Aerospace Research and Development, Paris (France).

STRUCTURAL RESPONSE TO IMPACT DAMAGE

Juergen Massmann Sep. 1975 21 p

(AGARD-R-633) Avail: NTIS HC $3.50

The complex problem of designing an aircraft structure in a manner to minimize its vulnerability to the impact damage of projectiles has always been a major concern of aircraft builders. A description of the vulnerability assessment of aircraft structures to projectile threats, including high explosive munitions is presented. The major elements of a structural vulnerability assessment are discussed, including development of a damage model, and strength model. Considerable experimental verification is included. Author

N76-16492# Advisory Group for Aerospace Research and Development, Paris (France).

MECHANICAL PROPERTY TESTING OF HIGH TEMPERATURE MATERIALS

R. W. Davidge and J. Massmann Dec. 1975 34 p refs

(AGARD-R-634) Avail: NTIS HC $4.00

The Structures and Materials Panel recently initiated a new activity dealing with the field of high temperature materials. Several exploratory papers were heard covering various aspects of this field, to aid in determining the desired direction of the new activity. Two of these papers were considered particularly noteworthy. The first deals with the mechanical properties and design data of ceramic components for engineering applications. Materials science considerations are emphasized with brief reference being made to the engineering aspects. Areas requiring further development are also covered. The second paper, dealing with stress and strain calculations, shows the application of the finite element method to a structural analysis and lifetime prediction problem, and includes the calculation of stress and strain distribution at critical locations. Stress concentration factors in specimens of linear and nonlinear material, different types of yield criteria, use of Neuber and the Hardrath and Ohman Theories are examined and results are compared with the finite element method. Plasticity and creep influences are considered. For individual titles, see N76-16493 through N76-16494.

N76-16493 Atomic Energy Research Establishment, Harwell (England). Materials Development Div.

THE MECHANICAL PROPERTIES AND DESIGN DATA FOR ENGINEERING CERAMICS

R. W. Davidge *In* AGARD Mech. Property Testing of High Temp. Mater. Dec. 1975 p 1-9 refs (For availability see N76-16492 07-39)

Developments in understanding the mechanical properties of ceramics from a materials science viewpoint, and in the generation of design data for ceramics of direct applicability to engineering applications are discussed. General recommendations for further research are made. Author

N76-16494 Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany)

CALCULATION OF STRESS AND STRAIN DISTRIBUTION AT CRITICAL LOCATIONS, TAKING INTO ACCOUNT PLASTICITY AND CREEP

Juergen Massmann *In* AGARD Mech. Property Testing of High Temp. Mater. Dec. 1975 p 10-29 (For availability see N76-16492 07-39)

The finite element method was applied to a particular structural analysis problem, the calculation of the stress and strain distribution at critical locations, which occurs in life time prediction. Some of the types of elements currently available, the selection of economical elements, and the required accuracy of the calculated results are discussed. The calculated stress concentration factor of a specimen containing a hole is presented for linear and nonlinear materials and different types of yield criteria are briefly discussed. The use of the Neuber and the Hardrath and Ohman Theories to determine the stress and strain concentration factor for nonlinear material behavior is examined, and a comparison of the results of these different theories and the Finite Element Method is given. The influence of plasticity and creep is also considered and the stress and strain concentration factor is shown as a function of creep time. Author

N76-19471# Advisory Group for Aerospace Research and Development, Paris (France).

SPECIALISTS MEETING ON IMPACT DAMAGE TOLERANCE OF STRUCTURES

Jan. 1976 202 p refs In ENGLISH and FRENCH Paper presented at 41st Meeting of the Struct. and Mater. Panel, Ankara, 28 Sep. - 3 Oct. 1975

(AGARD-CP-188 ISBN-92-835-0154-3) Avail: NTIS HC $7.75

Among the subjects covered in this exploratory conference were: blast effects, the type of damage produced by different projectiles, the failure characteristics of the structure under load and its residual strength and life after damage; the relationship between spread of damage, materials used, and detail design features; the degree of projectile penetration and the related hydraulic ram effect in fuel tanks, and distribution of size, velocity and direction of engine debris fragments and their effect on structure. The relationship to improved aircraft damage tolerance of such factors as the use of armor and deflectors, the employment of modified engine design (to cause blade failure to be more likely than disc failure and to contain a large portion of the resultant debris), the effectiveness of analysis of damaged structures, and the utilization of methods of improvement of overall aircraft layout are also considered. For individual titles, see N76-19472 through N76-19482.

N76-19472 Boeing Aerospace Co., Seattle, Wash. Research and Engineering Div.

STRUCTURAL INTEGRITY REQUIREMENTS FOR PROJECTILE IMPACT DAMAGE; AN OVERVIEW

J. G. Avery, T. R. Porter, and R. W. Lauzze (AFFDL) *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 30 p refs (For availability see N76-19471 10-39)

Aircraft can be exposed to projectile impacts from several sources, including military weapons, hailstones, pebbles, and debris from engine failures. In spite of the importance of the projectile damage threat to many types of aircraft, this category of damage is addressed in only a limited degree by existing design guidelines and specifications. There is a growing body of research results becoming available, and attention is being directed toward making this information usable to designers. The only means of doing this is to integrate projectile damage tolerance considerations within the existing structural design process. A design methodology for projectile damage tolerance and some of the research results available for implementing the methodology are summarized. Author

N76-19473 Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany)

STRUCTURAL ANALYSIS OF IMPACT DAMAGE ON WINGS

Juergen Massmann *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 27 p refs (For availability see N76-19471 10-39)

A recently-developed structural strength model is described, and the functions and characteristics of a damage model are examined. A shock wave model and how it analytically determines the dynamic response of a pressurized flat plate is also presented. Test and finite element results are compared with model-predicted results in order to determine model credibility. The pressures resulting from the detonation of ammunition are discussed, and the contributions of each of the pressure components to the entire response are illustrated. Some advantages of an advanced fragment model are mentioned, and the results from such a model are compared with appropriate test data. Applications of the different damage submodels with respect to a honeycomb structure are shown. Author

N76-19474 Naval Weapons Center, China Lake, Calif.
FLUID DYNAMIC ANALYSIS OF HYDRAULIC RAM
Eric A. Lundstrom and Wallace K. Fung *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 10 p refs (For availability see N76-19471 10-39)

A model was developed for predicting fluid pressure fields generated by tumbling military ammunition. Derivation of the model is described, and comparison with experimental data is shown. Agreement of the model was quite good with shots fired into a test cell with 0-degree obliquity. Significant deviation of the model from experiment was obtained with 30- and 45-degree obliquity shots. Author

N76-19475 Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
STUDY OF CERTAIN IMPACT PROBLEMS ON AIRCRAFT STRUCTURES [CALCUL DE QUELQUES PROBLEMES D'IMPACT SUR DES STRUCTURES AERONAUTIQUES]
C. Petiau *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 14 p In FRENCH (For availability see N76-19471 10-39)

After reviewing some of the finite elements, methods used for calculating impacts and transitory responses, the possibilities of application in the following cases are examined: (1) response of structure upon impact of a projectile on an armor-plate, (2) response of structures to forces due to explosion blast, and (3) calculation of hard landings, catapulting and taxiing. Practical calculation of the residual strength of locally damaged structures is also considered. Author

N76-19476 Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany).
COMPUTER METHOD FOR AIRCRAFT VULNERABILITY ANALYSIS AND THE INFLUENCE OF STRUCTURAL DAMAGE ON TOTAL VULNERABILITY
Dieter Kardels *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 21 p refs (For availability see N76-19471 10-39)

Methodology consists of two basic computer models, the socalled ammunition and target models. These models are so constructed that the evaluation of ammunition types such as AP, API, HEI with both impact and proximity fuzes, and fragmenting warheads is possible, as is a detailed vulnerability assessment of a particular aircraft. Various submodels interact in order to show the different types of possible outputs. A special emphasis is given to the influence of structural damage and aerodynamic capabilities on total aircraft vulnerability. Some test data and model prediction results are also graphically presented. Author

N76-19477 Ballistic Research Labs., Aberdeen Proving Ground, Md.
DAMAGE TOLERANCE OF SEMIMONOCOQUE AIRCRAFT
Donald F. Haskell *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 12 p ref (For availability see N76-19471 10-39)

The simple theoretical method which was developed may be used to predict deformation, strain, and fracture of aircraft skin subjected to blast attack. Test results and predictions of the theory compare favorably. The method is used to analytically delineate the factors that significantly affect skin damage tolerance. For the conditions studied, these factors, in decreasing order of influence, are standoff distance, panel width, skin thickness, aspect ratio, skin ultimate strength, rivet spacing, and rivet hole diameter to skin thickness ratio. Test results of two types of semimonocoque helicopter tail booms damaged by bare explosive charges and small-caliber, high-explosive projectiles while under simulated maximum flight load show that both skin and the skin stiffening system are important in the damage tolerance of these structures. Damage tolerance of these structures is proportional to the section modulus of the undamaged section and inversely proportional to the amount of skin removed from the structure by the damaging agent. It is also demonstrated that large increases in damage tolerance can be achieved by increasing longitudinal stiffness. Author

N76-19478 Rolls-Royce, Ltd., Derby (England). Engine Div.
DEFINITION OF ENGINE DEBRIS AND SOME PROPOSALS FOR REDUCING POTENTIAL DAMAGE TO AIRCRAFT STRUCTURE
D. McCarthy *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 10 p (For availability see N76-19471 10-39)

From an analysis of a large sample of past noncontained engine failures in commercial service, parameters were established for any given engine. Protection of sensitive parts of an aircraft beyond that implicit in the aircraft/engine layout could be provided by recently developed deflector systems capable of deflecting high energy fragments in a harmless direction. Author

N76-19479 Societe Nationale Industrielle Aerospatiale, Toulouse (France).
PROBABILITY OF PERFORATION OF AIRCRAFT STRUCTURES BY ENGINE FRAGMENTS [PROBABILITE DE PERFORATION D'UNE STRUCTURE D'AVION PAR DES DEBRIS DE MOTEURS]
Michel Huret *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 12 p In FRENCH (For availability see N76-19471 10-39)

An analytical approach was presented by which the probability of perforation of aircraft structures by engine fragments may be determined, given a specific fragment ejection model provided by engine designers. Simplifying, realistic assumptions were made to keep the implementation practical. A mathematical model was derived, taking into account the geometry of the situation, the energy of the fragment and that of the target, and the contact relationship between the fragment and the target.
Transl. by Y.J.A.

N76-19480 British Aircraft Corp. (Operating) Ltd., Bristol (England). Commercial Aircraft Div.
STRUCTURAL EFFECTS OF ENGINE BURST NON CONTAINMENT
T. W. Coombe and D. F. Vowles *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 10 p refs (For availability see N76-19471 10-39)

The requirements and the specified acceptable levels of risk are outlined, as applied to a large subsonic transport aircraft. The resultant damage forms are discussed and some test details given to illustrate the problems. Examples of engine fragment damage potentials are given with an empirically based equation relating fragment energy to target resistance for light alloy, titanium, and steel targets. Two types of design solution are discussed as applied to a large subsonic jet transport. Author

N76-19481 Naval Air Propulsion Test Center, Trenton, N.J.
STUDIES OF ENGINE ROTOR FRAGMENT IMPACT ON PROTECTIVE STRUCTURE
G. J. Mangano *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 24 p refs (For availability see N76-19471 10-39)

Data compilations on aircraft gas turbine engine rotor failures that occurred in U.S. commercial aviation in 1973; the results of exploratory and systematic experimentation conducted to provide design guidelines for turbine rotor burst fragment containment; and an overview of the analytical effort directed toward rotor fragment containment are presented. Author

N76-19482 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Corbeil (France).
BEHAVIOR OF ENGINE CASES ASSOCIATED WITH BLADE RUPTURES [TENUE DES CARTERS MOTEURS LORS DES RUPTURES D'AUBES]
J. Thiery *In* AGARD Specialists Meeting on Impact Damage Tolerance of Struc. Jan. 1976 10 p In FRENCH (For availability see N76-19471 10-39)

The way in which a ruptured blade impacts an engine case was analyzed. A simple test bench, which projects bullets at a variable speed on a small target representative, is described. Tests on various materials such as aluminum, titanium, iron, nickel, and cobalt base alloys in wrought or cast form were

conducted at room as well as at elevated temperatures. This test is also able to show the influence of the stiffness, thickness, and mass of the target. Author

N76-19487# Advisory Group for Aerospace Research and Development, Paris (France)
THE DEVELOPMENT OF FATIGUE/CRACK GROWTH ANALYSIS LOADING SPECTRA
J. E. Holpp (Aeron. Systems Div., Wright-Patterson AFB, Ohio) and M. A. Landy (Aeron. Systems Div., Wright-Patterson AFB, Ohio) Jan. 1976 36 p refs
(AGARD-R-640; ISBN-92-835-1202-2) Avail: NTIS HC $4.00

A description is given of the processes involved in the development of realistic loading spectra for aircraft structures. These processes are presented in the order in which they would normally be implemented, accompanied by an example that is representative of loading spectra developed for fighter aircraft. The example is included for illustrative purposes only. Criteria are suggested that will help the designer choose the most appropriate methods consistent with his situation. Author

N76-25580# Advisory Group for Aerospace Research and Development, Paris (France)
STRAIN GAUGE MEASUREMENTS ON AIRCRAFT, VOLUME 7 AGARD Flight Test Instrumentation Series
E. Kottkamp (VFW-Fokker Test Labs.), H. Wilhelm (VFW-Fokker Test Labs.), and D. Kohl (VFW-Fokker Test Labs.) Apr. 1976 147 p refs
(AGARD-AG-160-Vol-7; ISBN-92-835-1215-4) Copyright. Avail: NTIS HC $8.00

Various subjects related to the application of strain gauges to aircraft structures were presented. These include: (1) introductory discussion, (2) physical properties of strain gauges, (3) measurement of resistance changes in strain guages, (4) error estimation for strain gauges with metallic measuring grids, (5) types of strain guages, (6) applications of strain gauges for static and dynamic short and long term measurements under normal conditions, (7) strain gauges for special applications, (8) use of strain gauges under extreme environmental conditions, (9) instrumentation of two VAK 191 B aircraft with flight load measuring systems. For individual titles, see N76-25581 through N76-25589.

N76-25581 Advisory Group for Aerospace Research and Development, Paris (France)
STRAIN GAUGE MEASUREMENTS ON AIRCRAFT INTRODUCTION
In its Strain Gauge Meas. on Aircraft, Vol. 7 Apr. 1976 p 1-4
(For availability see N76-25580 16-39)

A comprehensive description of the different aspects of strain and load measurements on aircraft was given. After discussion of possible errors, the various types of strain gauges and adhesives are described. Practical advice is given on their application, including a discussion on special cases. This is followed by a consideration of the strain gauge behavior under adverse environmental conditions (extremely low and high temperatures). Finally, an example is given of equipping an aircraft with a flight load measuring system. Author

N76-25582 Advisory Group for Aerospace Research and Development, Paris (France)
PHYSICAL BACKGROUND
In its Strain Gauge Meas. on Aircraft, Vol. 7 Apr. 1976 p 5-18
(For availability see N76-25580 16-39)

The physical background of the strain gauge system was presented. One part of this system is the material to be tested. The elementary laws of the behavior of metallic materials under load are described. The other important part is the measuring grid of the strain gauge. The fundamental correlations between the load on the measuring grid and its electrical behavior is described. Metallic as well as semi-conductor measuring grids are both discussed. Author

N76-25583 Advisory Group for Aerospace Research and Development, Paris (France)
THE MEASUREMENT OF THE RESISTANCE CHANGES OF STRAIN GAUGES
In its Strain Gauge Meas. on Aircraft, Vol. 7 Apr. 1976 p 18-29
(For availability see N76-25580 16-39)

Selection of the most appropriate method of recording small resistance changes in strain gauges when loads are applied was discussed. The basic equations underlying the electrical circuits involved were given and discussed. Special emphasis was placed on the Wheastone bridge circuit, which is the predominant measuring circuit for strain gauge measurements. The following aspects were elaborated: (1) current and voltage distribution, (2) choice of the supply voltage with respect to power dissipation, (3) choice of the output signal conditioning equipment, (4) power dissipation in the bridge resistors, (5) behavior of the Wheastone bridge in unbalanced conditions, and (6) bridge balancing and compensation. Y.J.A.

N76-25584 Advisory Group for Aerospace Research and Development, Paris (France)
ERROR ESTIMATION FOR STRAIN GAUGES WITH METALLIC MEASURING GRIDS
In its Strain Gauge Meas. on Aircraft, Vol. 7 Apr. 1976 p 29-33
(For availability see N76-25580 16-39)

The various factors that must be considered in error estimation for strain gauges with metallic measuring grids were discussed. These include: (1) resistance tolerances, (2) gauge factor tolerances and transverse strain sensitivity, (3) error caused by hysteresis and non-linearity, (4) maximum static elasticity of strain gauges, (5) creep effects, (6) temperature coefficient, (7) fatigue strength, (8) thickness of the adhesive layer, (9) angular errors during application of the strain gauge, (10) stiffening effect due to bonding, (11) insulation resistance effect, and (12) averaging effect of the strain gauge over the entire measuring grid area. Estimates of the total error are given. Y.J.A.

N76-25585 Advisory Group for Aerospace Research and Development, Paris (France).
TYPES OF STRAIN GAUGES
In its Strain Gauge Meas. on Aircraft, Vol. 7 Apr. 1976 p 33-37
(For availability see N76-25580 16-39)

The various types of strain gauges were classified and described. The several hundred different strain gauge configurations were assigned to one of the following basic types: (1) wire-grid strain gauges, (2) flat-coil gauges, (3) cross-bridge gauges, (4) metal-foil guages, and (5) strain gauges with metal supporting materials. The following supporting materials, their configuration, and properties were also discussed: paper, epoxy or phenolic resin, polyimidefoil, glass-fiber reinforced material, cellulose and metal foil (for large strains). Typical properties of some strain gauge groups were given. The new technology of vapor-depositing strain gauges was briefly mentioned. Y.J.A.

N76-25586 Advisory Group for Aerospace Research and Development, Paris (France).
APPLICATION OF STRAIN GAUGES TO STATIC AND DYNAMIC SHORT AND LONG TERM MEASUREMENTS UNDER NORMAL CONDITIONS
In its Strain Gauge Meas. on Aircraft, Vol. 7 Apr. 1976 p 37-45
(For availability see N76-25580 16-39)

The following factors that must be considered in the application of strain gauges to static and dynamic short and long term measurements under normal conditions were discussed: (1) technical and organizational boundary conditions, (2) material selection, (3) pretreatment of bonding areas (precleaning, mechanical, chemical), (4) adhesives (cold and hot setting), (5) special procedures (flame spraying, welding), (6) wiring technique, (7) protective materials, and (8) general instructions. Y.J.A.

N76-25587 Advisory Group for Aerospace Research and Development, Paris (France)
STRAIN GAUGES FOR SPECIAL APPLICATION
In its Strain Gauge Meas. on Aircraft, Vol. 7 Apr. 1976 p 45-72
(For availability see N76-25580 16-39)

Various special applications for strain gauges, involving multi-axial measurements, were described. These include: (1) measurements of multi-axial strain conditions and the determination of mechanical stress conditions (using various rosettes), (2) measurement of strain behavior by means of strain gauge chains, (3) strain gauges for flexural strain measurements, (4) strain gauges for membrane stress measurements, (5) strain gauges for the determination of residual streses, (6) stress gauges, (7) measurement of material fatigue, (8) measurement of large strains, (9) special procedures for strain gauge applications, (10) strain transformers, (11) geometrical arrangement and electrical interconnections to realize special measuring effects, (12) measurement of strain on and in fiber-reinforced components, (13) interconnection of strain gauge bridges for the measurement of defined load elements(structural measurements), (14) high-frequency strain measurement, (15) strain gauges of excessive length, and (16) interferometric strain gauges. Y.J.A.

N76-25588 Advisory Group for Aerospace Research and Development, Paris (France)
USE OF STRAIN GAUGES UNDER EXTREME ENVIRONMENTAL CONDITIONS
In its Strain Gauge Meas. on Aircraft, Vol. 7 Apr. 1976 p 72-78 (For availability see N76-25580 16-39)

A survey of the possibilities and limits of the strain gauge technique under extreme environmental conditions was given. This includes (1) Use at extreme temperatures, (2) use under hydrostatic pressure, (3) use under nuclear radiation, (4) use in magnetic fields, and (5) use under vacuum conditions. YJA

N76-25589 Advisory Group for Aerospace Research and Development, Paris (France).
INSTRUMENTATION OF TWO VAK 191 B AIRCRAFT WITH FLIGHT LOAD MEASURING SYSTEMS
In its Strain Gauge Meas. on Aircraft, Vol. 7 Apr. 1976 p 78-138 refs (For availability see N76-25580 16-39)

The instrumentation of the VAK 191 B STOL aircraft with strain gauge systems was described in some detail. The following measuring sections were planned for each aircraft: 4 measuring sections in the wing (2 port and 2 starboard), 2 measuring sections in the horizontal tail (1 port and 1 starboard), 1 measuring section in the vertical tail, 1 measuring section in the rear fuselage, and a number of measuring points on the landing gear and flight controls. A requirement of approximately 2,000 single strain gauges (or correspondingly smaller quantities of biaxial rosettes), including certain reserve quantities, was estimated for the two aircraft. The following aspects were discussed: selection of components, installation technique, location of strain gauges, installation of the strain gauge bridges, installation time requirements, calibration, and results. YJA

N76-29656# Advisory Group for Aerospace Research and Development, Paris (France).
STRUCTURAL IDENTIFICATION ON THE GROUND AND IN FLIGHT INCLUDING COMMAND AND STABILITY AUGMENTATION SYSTEM INTERACTION
Jun. 1976 57 p refs Partly in ENGLISH and FRENCH Presented at 42nd Struct. and Mater. Panel Meeting, Ottawa, Apr. 1976 (AGARD-R-646) Avail: NTIS HC $4.50

Papers are presented which deal with vibration testing of aircraft and rocket vehicles, flutter analysis, particularly of the MRCA aircraft, digital techniques for flutter analysis, and interactions between aircraft structures and the command and stability augmentation system of the MRCA. For individual titles, see N76-29657 through N76-29660.

N76-29657 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NEW STRUCTURAL TESTING METHODS BASED ON NON-APPROPRIATED EXCITATION
Gerard Piazzoli *In* AGARD Structural Identification on the Ground and in Flight Including Command and Stability Augmentation System Interaction Jun. 1976 p 1-6 refs In FRENCH; ENGLISH summary (For availability see N76-29656 20-39)

After recalling the classical methods for determining the vibratory characteristics of an aircraft or rocket structure by a test with appropriated excitation, the paper presents two new methods that do not deliver appropriation. In the Angelini method, independent excitations are located at significant points, that may number up 20 for a military aircraft with external stores. In the Dat-Meurzec method, the structure transfer functions obtained from a single, localized excitation configuration are smoothed; it is particularly convenient for the study of rockets. Both methods were implemented with the computer installed in the ONERA mobile laboratory. They permit a considerable gain of time, and give results comparable to those provided by the classical method. Author

N76-29658 Air Force Flight Test Center, Edwards AFB, Calif.
DIGITAL TIME SERIES ANALYSIS OF FLUTTER TEST DATA
Russell W. Lenz and David A. Foreman *In* AGARD Structural Identification on the Ground and in Flight Including Command and Stability Augmentation System Interaction Jun. 1976 p 7-24 refs (For availability see N76-29656 20-39)

A minicomputer based digital time series analysis system is used at the Air Force Flight Test Center to provide near real time estimates of modal parameters during flight flutter testing. Since the test data acquired often contains noise which distorts the transfer function or autospectrum results, data smoothing algorithms are employed. These algorithms, as well as algorithms for performing multimodal analyses, have been found to be useful when analyzing noisy aircraft data. Use of digital techniques has been beneficial both in terms of saving time and in improving accuracy when compared with more traditional flutter testing approaches. Author

N76-29659 British Aircraft Corp., Warton (England)
INFLIGHT FLUTTER IDENTIFICATION OF THE MRCA

D. K. Potter and A. Lotze (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich) *In* AGARD Structural Identification on the Ground and in Flight Including Command and Stability Augmentation System Interaction Jun. 1976 p 25-39 refs (For availability see N76-29656 20-39)

Flutter investigations were performed prior to flight testing and during flight flutter testing of the MRCA. Because the aircraft is equipped with fast responding power control systems which could produce undesirable structural motion, flutter investigations had to be accomplished with consideration of the command and stability augmentation system (CSAS). Analysis and test results for structural mode coupling with the CSAS are demonstrated for the aircraft on ground which proved to be the condition for the lowest stability margin. It was shown that there is practically no influence of CSAS on flutter behavior. The flutter speed with the lowest flutter margin was predicted for an antisymmetrical taileron mode which is modified by fuselage influences. The coupling mechanism of this mode was investigated and the effect of apex balance weight on the taileron inboard leading edge was demonstrated. Author

N76-29660 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
INTERACTION BETWEEN AIRCRAFT STRUCTURE AND COMMAND AND STABILITY AUGMENTATION SYSTEM

O. Sensburg *In* AGARD Structural Identification on the Ground and in Flight Including Command and Stability Augmentation System Interaction Jun. 1976 p 41-53 refs (For availability see N76-29656 20-39)

The multi role combat aircraft - MRCA - has a fly-by-wire control system and automatic stabilization. The sensors for the command and stability augmentation system - CSAS - are attached to the flexible aircraft structure and may therefore pick up signals which are detrimental to the stability. This paper describes the method which was used on the MRCA to avoid CSAS- structural mode coupling effects. Author

N77-17527# Advisory Group for Aerospace Research and Development, Paris (France).
SUMMARY OF THE DISCUSSIONS ON STRUCTURAL DESIGN TECHNOLOGY
R. B. Baird (Headquarters US AF, Pentagon, Washington, D. C.) Dec. 1976 13 p refs
(AGARD-AR-99; ISBN-92-835-1236-x) Avail: NTIS HC A02/MF A01

Structural design and questions created by improved technology are presented. Composite structures, fracture and fatigue mechanics, aeroelasticity and loads, and optimum and computer aided design are discussed along with USAF safety design philosophies. M.C.F.

44 ENERGY PRODUCTION AND CONVERSION

Includes specific energy conversion systems, e.g., fuel cells and batteries; global sources of energy; fossil fuels; geophysical conversion; hydroelectric power; and wind power. For related information see also *07 Aircraft Propulsion and Power*, *20 Spacecraft Propulsion and Power*, *28 Propellants and Fuels*, and *85 Urban Technology and Transportation*.

N75-16977# Advisory Group for Aerospace Research and Development, Paris (France).
THE 1974 AGARD ANNUAL MEETING: THE ENERGY PROBLEM: IMPACTS ON MILITARY RESEARCH AND DEVELOPMENT
Dec. 1974 84 p refs In ENGLISH and partly in FRENCH Meeting held at Paris, 26 Sep. 1974
Avail: NTIS HC $4.75

The proceedings of a conference on the impact of the energy problem on military research and development projects are presented. Some of the subjects discussed are as follows: (1) energy problems in a global context, (2) energy related research and development in the U.S. Air Force, (3) alternate fuels for aviation purposes, (4) the impact of future fuels on military aircraft engines, and (5) energy resources and utilization. For individual titles, see N75-16978 through N75-16983.

N75-16978 Ministry of Defence, Paris (France).
ENERGY PROBLEMS IN A GLOBAL CONTEXT
Jacques-emile Dubois *In* AGARD The 1974 AGARD Ann. Meeting Dec. 1974 p 6-20 refs In ENGLISH and FRENCH (For availability see N75-16977 08-44)

An analysis of the world-wide problems created by the consumption of non-renewable sources of energy is presented. The energy system of an industrial society is described by a diagram. A correlation between the energy consumption per individual of a given country and the gross national product of the company is developed. A chart of prospective sources of energy to meet future requirements is provided. Methods for obtaining additional energy by methods which do not consume fossil fuels are explained. The characteristics of an energy system based on the use of hydrogen as the primary energy sources are defined. Author

N75-16979 Air Force Dept., Washington, D.C.
ENERGY-RELATED RESEARCH AND DEVELOPMENT IN THE UNITED STATES AIR FORCE
Michael I. Yarymovych *In* AGARD The 1974 AGARD Ann. Meeting Dec. 1974 p 21-30 (For availability see N75-16977 08-44)

The requirements for petroleum based energy sources by the Department of Defense of the United States are analyzed. In addition to the requirements of the military forces, the logistic requirements are also examined. The impact of the energy crisis on military research and development programs to develop new energy sources for military use is examined. Methods of reducing fuel consumption by aircraft design and structural modification are proposed. The effectiveness of a campaign to reduce energy requirements and expenditures is documented. Author

N75-16980 Pinkel (I. Irving), Fairview Park, Ohio.
ALTERNATIVE FUELS FOR AVIATION
I. Irving Pinkel *In* AGARD The 1974 AGARD Ann. Meeting Dec. 1974 p 31-36 (For availability see N75-16977 08-44) CSCL 21D

The status of energy programs to provide hydrocarbon fuels from new sources is examined. Experience in the United States with non-hydrocarbon fuels for turbine powered aircraft is analyzed. The various alternate sources of hydrocarbon fuels are defined. The use of metals and metal slurries as turbine fuels is proposed. The advantages and disadvantages of liquid hydrogen as an aircraft fuel are discussed. A specific example of an aircraft operating on liquid hydrogen is described. Author

N75-16981 National Aerospace Lab., Amsterdam (Netherlands).
IMPACT OF FUTURE FUELS ON MILITARY AERO-ENGINES
F. Jaarsma *In* AGARD The 1974 AGARD Ann. Meeting Dec. 1974 p 37-46 refs (For availability see N75-16977 08-44)

The expected impact of the fossil fuel shortage on the design and operation of aircraft engines is discussed. Alternate fuels such as cryogenic fluids and synthetic fuels are proposed. Various aspects related to combustion of cryogenic and synthetic fuels are analyzed to examine the effects on seals, pumps, contamination, and engine operating procedures. Author

N75-16982 Technische Hochschule, Darmstadt (West Germany). Inst. fuer Flugtechnik.
IMPACT ON AERODYNAMIC DESIGN
X. Hafer *In* AGARD The 1974 AGARD Ann. Meeting Dec. 1974 p 47-55 refs (For availability see N75-16977 08-44)

The impact of fossil fuel consumption and anticipated shortages on aircraft design for improved efficiency is examined. Aerodynamic possibilities for improved efficiency are as follows: (1) aerodynamic configuration optimization, (2) boundary layer suction, (3) the oblique wing, and (4) supercritical airfoils. Aerodynamic improvements using active controls are as follows: (1) relaxed static stability, (2) maneuver load control, (3) active flutter control, and (4) gust alleviation and fatigue damage control. Changes in aircraft aerodynamics design resulting from the use of hydrogen fuel are analyzed. Author

N75-16983 National Gas Turbine Establishment, Pyestock (England).
ENERGY RESOURCES AND UTILIZATION
M. C. Neale *In* AGARD The 1974 AGARD Ann. Meeting Dec. 1974 p 56-66 refs (For availability see N75-16977 08-44)

An analysis of the world situation with respect to fossil fuels is presented. The impact of the fuel shortage on military aviation in European countries is examined. The availability and utilization of fuels other than petroleum are discussed. Charts are developed to show the following conditions: (1) world crude oil production and proven reserves, (2) world energy production and consumption, (3) total energy consumption per capita for the major nations, (4) outlets for refinery products, and (5) estimated coal reserves. Author

45 ENVIRONMENT POLLUTION

Includes air, noise, thermal and water pollution; environment monitoring, and contamination control

N74-26104# Advisory Group for Aerospace Research and Development, Paris (France).
THE FLUID DYNAMICS ASPECTS OF AIR POLLUTION RELATED TO AIRCRAFT OPERATIONS
P. Libby, ed. (California Univ., San Diego) Feb. 1974 53 p refs
(AGARD-AR-55) Avail: NTIS HC $5.75

The proceedings of the round table discussion are presented and include: (1) aircraft dispersion of pollutants, (2) air pollution characteristics of aircraft engines, (3) research in Germany on air pollution related to aircraft operations, (4) large scale mass transport, and (5) air pollution from aircraft. For individual titles, see N74-26105 through N74-26109.

N74-26105* Massachusetts Inst. of Tech., Cambridge. Dept. of Mechanical Engineering.
THE DISPERSION OF PROPELLANTS FROM AIRCRAFT

James A. Fay and John B. Heywood *In* AGARD The Fluid Dynamics Aspects of Air Pollution Related to Aircraft Operations Feb. 1974 p 5-16 refs (For availability see N74-26104 15-20)
(Grant NGR-22-009-378)
CSCL 21B

Two aspects of the dispersion of pollutants from aircraft are reviewed. The first is the dispersal of aircraft exhaust emissions in the vicinity of airports; the second is the dispersal of exhaust trails in the upper atmosphere. Techniques available for modeling this dispersal and how they might be applied to the airport problem are discussed. Field studies of airport pollution are then reviewed to assess current pollutant levels around airports and the aircraft's contribution to those levels. The possibility of contrail formation from jet emissions at high altitude is then considered and the effect of uncertainties in the trial mixing processes evaluated. Author

N74-26106 California Univ., Berkeley. Dept. of Mechanical Engineering.
AIR POLLUTION CHARACTERISTICS OF AIRCRAFT ENGINES
Robert F. Sawyer *In* AGARD The Fluid Dynamics Aspects of Air Pollution Related to Aircraft Operations Feb. 1974 p 17-26 (For availability see N74-26104 15-20)

Some results are presented of a survey on aircraft air pollution. The findings indicate that: (1) Aircraft are significant contributors to air pollution. (2) The engine is the primary source of aircraft air pollution. (3) Carbon monoxide and hydrocarbon emissions at low power and nitric oxide emissions at high power are the most important immediate engine pollution problems D.L.G

N74-26107 Technischen Universitaet, Munich (West Germany).
RESEARCH IN GERMANY ON FLUID-DYNAMICS OF AIR POLLUTION RELATED TO AIRCRAFT OPERATIONS
Franz Hindelang, J. *In* AGARD The Fluid Dynamics Aspects of Air Pollution Related to Aircraft Operations Feb. 1974 p 27-30 (For availability see N74-26104 15-20)

An overview is presented, based on a literature survey and a questionnaire, of German research on air pollution related to aircraft operation. The literature survey revealed that while there exists an abundance of material on air pollution in general, none was found to relate to aircraft operation. The questionnaire was sent to meteorologists, aerodynamicists, and aircraft companies. The answers obtained indicate a tremendous interest in the subject area with some research being conducted but not yet at the conclusive reporting stage D.L.G

N74-26108 Norwegian Inst. for Air Research, Kjeller.
PRELIMINARY NOTES ON LARGE SCALE MASS TRANSPORT
J. Nordo *In* AGARD The Fluid Dynamics Aspects of Air Pollution Related to Aircraft Operations Feb. 1974 p 33-40 (For availability see N74-26104 15-20)

The following areas of interest are discussed: (1) mesoscale transport of pollutants, (2) use of precipitation and flow patterns in Europe as a guide in designing a network of stations to measure air pollution, (3) acid precipitation in South Norway due to long range transport of sulfur from the industrial centers of Western Europe, (4) meteorological data analysis required for air pollution monitoring network, and (5) studies of air pollution in Europe during varying weather conditions D.L.G

N74-26109 Department of Trade and Industry, London (England) Civil Aviation
AIR POLLUTION FROM AIRCRAFT
R. A. Mangiarotty *In* AGARD The Fluid Dynamics Aspects of Air Pollution Related to Aircraft Operations Feb. 1974 p 41-54 refs (For availability see N74-26104 15-20)
Avail: NTIS

The current work being conducted in the UK in three specific areas of atmospheric pollution related to aircraft operations is summarized. The three areas are: (1) jet engine pollution in the neighborhood of airports including its generation, its reduction by proper combustion design, and its dispersal by winds; (2) smoke trails. (3) Pollution at high altitudes due to jet engine discharge, with its special problems of chemistry and dispersion. Author

N75-26343# Advisory Group for Aerospace Research and Development, Paris (France).
A GUIDE TO MICROFICHE EQUIPMENT AVAILABLE IN EUROPE
Apr. 1975 112 p
(AGARD-R-628) Avail: NTIS HC $5.25

A guide, composed of six sections listing equipment in each section alphabetically by manufacturer, with the names and addresses of their distributors in the appendix, alphabetically listed per European country is presented. The kinds of equipment illustrated are: (1) cameras and camera-processors; (2) processors; (3) duplicators and printer-processors; (4) reader-printers (at the back of the section are included two enlargers), (5) readers; (6) cutters, reader-fillers, strip-up systems, inspection devices, densitometers, and the two most commonly used test targets. Author

46 GEOPHYSICS

Includes aeronomy; upper and lower atmosphere studies, ionospheric and magnetospheric physics; and geomagnetism. For space radiation see *93 Space Radiation*

N76-29815 Advisory Group for Aerospace Research and Development, Paris (France).
OPTICAL PROPAGATION IN THE ATMOSPHERE
May 1976 625 p refs Present..d at the Electromagnetic Wave Propagation Panel Symp., Lyngby, Denmark, 27-31 Oct. 1975
(AGARD-CP-183) Copyright. Avail NTIS HC $16.25

Atmospheric effects are reported on the propagation of optical systems emphasizing high power lasers and adaptive optical correction procedures. For individual titles, see N76-29816 through N76-29859

N76-29816 Air Force Cambridge Research Labs., L. G. Hanscom Field, Mass.
OPTICAL MODELLING OF THE ATMOSPHERE
Robert A. McClatchey, John E. A. Selby, and John S. Garing *In* AGARD Opt. Propagation in the Atmosphere May 1976 21 p refs (For availability see N76-29815 20-46)

Optical atmospheric modelling requires both the knowledge of the physical properties of the atmosphere as well as the spectroscopic properties of the gases and particulates of which it is composed. The atmospheric absorption line parameter compilation system is discussed and requirements for such a data compilation are indicated. The line-by-line transmittance calculation technique is described, indicating the capability of this technique for use in laser propagation studies as well as low spectral resolution applications. The LOWTRAN computer model is presented together with an indication of its limitations. Author

N76-29817 Air Force Cambridge Research Labs., L. G. Hanscom Field, Mass.
MODELS OF THE ATMOSPHERIC AEROSOLS AND THEIR OPTICAL PROPERTIES
Eric P. Shettle and Robert W. Fenn *In* AGARD Opt. Propagation in the Atmosphere May 1976 16 p refs (For availability see N76-29815 20-46)

Aerosol models have been developed for the boundary layer, the upper troposphere, the stratosphere, and mesosphere. In the boundary layer they describe three different environments: rural, urban and maritime. In the upper troposphere and stratosphere two different models represent spring-summer and fall-winter conditions. In the stratosphere they describe several levels of volcanic dust concentrations and the background conditions. For each model the coefficients for extinction, scattering and absorption, the angular scattering distribution and other optical parameters have been computed for wavelengths between 0.2 and 40 micrometer. The aerosol models are being presented along with a discussion of their experimental basis. The optical properties of these models are being discussed and some examples of their effects on the overall atmospheric transmission properties and atmospheric contrast reduction are presented. Author

N76-29818 Plessey Radar Ltd., Cowes (England).
A COMPARATIVE STUDY OF ATMOSPHERIC TRANSMISSION AT THREE LASER WAVELENGTHS IN RELATION TO THE METEOROLOGICAL PARAMETERS
P. J. Wright *In* AGARD Opt. Propagation in the Atmosphere May 1976 10 p refs (For availability see N76-29815 20-46)

Experimental and theoretical studies are reported on the atmospheric transmission of laser radiation at 0.63 micrometer, 1.03 micrometer and 10.6 micrometer. A transmissometer continuously measured the attenuation of the three wavelengths simultaneously over a common path length. Results were compared with deduction from the theory of scattering of electromagnetic radiation due to Mie. Author

N76-29819 Fraunhofer-Gesellschaft, Garmisch-Partenkirchen (West Germany).
REMOTE AEROSOL SENSING WITH AN ABSOLUTE CALIBRATED DOUBLE FREQUENCY LIDAR
R. Reiter, W. Carnuth, M. Littfass, and N. C. Varshneya (Roorkee Univ.) *In* AGARD Opt. Propagation in the Atmosphere May 1976 15 p refs (For availability see N76-29815 20-46)

A two frequency lidar system, using a Q-switched ruby laser transmitter with frequency doubler and a 52 cm dia receiving telescope, for remote aerosol sensing up to more than 30 km altitude is described. The system includes electronic data acquisition and processing. Sufficient sensitivity for high altitude stratospheric measurements is provided by ten channel photon counting combined with range gating of the photomultiplier tube, and a mechanical chopper for rejection of the non-coherent ruby fluorescence. The system is now being absolutely calibrated by comparison between lidar backscatter profiles on the one hand, and theoretical backscatter functions calculated from experimental aerosol and aerological data, using Rayleigh and Mie scattering theories, on the other. The experimental data are acquired at mountain stations at 740, 1,800 and 3,000 m altitude by means of five stage impactors and of cable car probes and radiosondes. Examples of tropospheric lidar backscatter profiles, together with aerosol and aerological profiles, as well as stratospheric lidar measurements are presented. Author

N76-29820 Norwegian Defence Research Establishment, Kjeller.
ATMOSPHERIC EFFECTS RELEVANT TO LASER SPECTROSCOPY
T. Lund and A. G. Kjelaas *In* AGARD Opt. Propagation in the Atmosphere May 1976 8 p refs (For availability see N76-29815 20-46)

A qualitative discussion pointing out some of the sources of error and fluctuations in a long path laser differential absorption system measuring the concentration of atmospheric gaseous pollutants, is given. Except for single gas detectors using narrow optical frequency ranges, the unpredictable or unknown spread in the dispersive properties of the extinction caused by continuum absorption and scatter, is of major concern. In addition, the limitations of fast cross correlation of signals to compensate for turbulence induced fluctuation are discussed. Author

N76-29821 California Univ., Los Angeles.
THE FLUID MECHANICS AND COMPUTER MODELING OF ATMOSPHERIC TURBULENCE CAUSING OPTICAL PROPAGATION FLUCTUATIONS
William C. Meecham *In* AGARD Opt. Propagation in the Atmosphere May 1976 9 p refs (For availability see N76-29815 20-46)

Optical refractive index fluctuation are examined from the viewpoint of what is known by fluid dynamicists about atmospheric turbulence effects. Various field quantities (temperature, velocity and pressure) are written in terms of their averages and their fluctuations from those averages. The variations of the index of refraction with the fluid variables are discussed. The cross correlations of fluid velocity, of temperature, and of velocity with temperature are presented. A new, modified discussion of the Kolmogoroff cascade theory of turbulence is presented and its consequences analyzed for their bearing upon correlation functions and energy spectra. Using this fluid mechanical information, the modeling of propagation fluctuation problems is reported using computer generated realizations of index variations, with given statistical properties. Author

N76-29822* Texas A&M Univ., College Station. Dept. of Physics.
CALCULATIONS OF POLARIZATION AND RADIANCE IN THE ATMOSPHERE
Gilbert N. Plass *In* AGARD Opt. Propagation in the Atmosphere May 1976 20 p refs (For availability see N76-29815 20-46)
(Grant NGR-44-001-117)
CSCL 04A

Two different methods for the solution of radiative transfer problems, matrix operator and Monte Carlo, are discussed. As an example of the use of the method, results are given for the radiance and polarization of the radiation scattered from haze layers as well as from models of the real atmosphere. The variation of the radiance, polarization, and ellipticity with the aerosol amount in the real atmosphere model is presented. The Monte Carlo method is applied to the problem of calculation of the radiance and polarization of the photons in the atmosphere when there is an ocean as the lower surface. It is found that the turbidity of the ocean can be deduced from the upwelling radiance measured at some height in the atmosphere. The downwelling radiation just beneath the ocean surface is elliptically polarized at those angles where it is derived from the total internal reflection of the upwelling radiation at the ocean surface. Author

N76-29823 Utah Univ., Salt Lake City Dept. of Meteorology.
RADIATIVE TRANSFER IN CLOUDY ATMOSPHERES
K. N. Liou *In* AGARD Opt. Propagation in the Atmosphere May 1976 12 p refs (For availability see N76-29815 20-46)
(Contract F19628-75-C-0107, Grant NSF DES-75-05216)

Band-by-band calculations have been carried out to evaluate the reflection, absorption and transmission of solar radiation by cloud layers and model cloudy atmospheres in the entire solar spectrum. The radiation transfer program is based on the discrete ordinate method with applications to inhomogeneous atmospheres. The gaseous absorption in scattering atmospheres is taken into account by means of exponential fits to the total band absorption based on laboratory measurements. Thick clouds such as nimbostratus and cumulonimbus reflect 80-90% and absorb 10-20% of the solar radiation incident upon them. The reflection and absorption of a fairweather cumulus with a thickness of 0.45 km are about 68-85% and 4-9% respectively. Comparisons with aircraft observations reveal that within the uncertainties of the thickness and cloud particle characteristics theoretical computations yield higher reflection and lower absorption values for most of the water clouds. These comparisons indicate that clouds in the atmosphere are likely to consist of absorbing particles. Author

N76-29824* Massachusetts Univ., Amherst Dept. of Physics and Astronomy
MULTIPLE SCATTERING IN PLANETARY ATMOSPHERES
William M. Irvine *In* AGARD Opt. Propagation in the Atmosphere May 1976 11 p refs (For availability see N76-29815 20-46)
(Grant NGL-22-010-023)
CSCL 03B

Certain simple procedures for solving radiative transfer problems in planetary atmospheres are reviewed: the similarity relations relating isotropic to anisotropic scattering, asymptotic results relating known solutions for semi-infinite layers to desired solutions for optical depths, and expansions relating known solutions for conservative scattering to desired solutions for the nearly conservative case. The complications introduced by atmospheric inhomogeneity, surface reflection, and spectral features are also discussed. Author

N76-29825 Universite des Sciences et Techniques de Lille (France)
METHODS FOR SOLVING THE EQUATION OF RADIATIVE TRANSFER THROUGH FINITE THICKNESS LAYERS
J. Lenoble *In* AGARD Opt. Propagation in the Atmosphere May 1976 9 p refs In FRENCH, ENGLISH summary (For availability see N76-29815 20-46)

After recalling the general problem of radiative transfer, the methods of solution for a plane parallel horizontally homogeneous atmosphere are briefly reviewed and a few numerical comparisons are shown. Then the more difficult problems of horizontal inhomogeneities and of sphericity are considered. Author

N76-29826* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena
REMOTE PROBING OF ATMOSPHERIC PARTICULATES FROM RADIATION EXTINCTION EXPERIMENTS: A REVIEW OF METHODS
Alain L. Fymat *In* AGARD Opt. Propagation in the Atmosphere May 1976 30 p refs (For availability see N76-29815 20-46)
(Contract NAS7-100)
CSCL 04A

The existing methodology for reconstructing the particle size distribution and inferring the refractive index of absorbing and scattering atmospheric particulates is critically reviewed. Emphasis is placed on method capabilities and shortcomings and, wherever possible, on achievable accuracy. The nature of the associated remote probing problem is analyzed with regard to the effects of the particulates on EM wave propagation in the atmosphere. The parameterization of size distribution is studied within the unifying framework of Pearson's distribution curves. The inversions of extinction measurements and their ratios are considered separately, and the potentialities of each type of measurement are identified. Work lacking in each of the methods reviewed is indicated. A method of determining both the effective complex refractive index and size distribution model parameters from the same data is also presented. Lastly, determination from extinction ratio data of the complex refractive index independent of size distribution is discussed and error analyzed. Author

N76-29827 Cologne Univ. (West Germany). Inst. fuer Geophysik und Meteorologie.
THEORETICAL STUDIES OF THE TRANSFER OF SOLAR RADIATION IN THE ATMOSPHERE
M. J. Kerschgens, E. Raschke, and U. Reuter *In* AGARD Opt. Propagation in the Atmosphere May 1976 10 p refs (For availability see N76-29815 20-46)

The transfer of solar radiation in one dimensional model atmospheres has been computed for the wavelength range from 0.2 to 3.58 micrometer with an iterative solution of the radiative transfer equation. Absorption by O3, H2O, CO2, O2 and aerosols has been taken into account. The transmission in near infrared bands of CO2 and H2O is approximated by exponential series derived from spectral measurements. Various vertical distributions of H2O and aerosols are considered and also two different boundaries are used: a rough ocean surface and a bright sandy desert. It is shown, for instance that as a result of the higher albedo of the sand surface, the absorption increases by 5 to 7% depending on the solar height. Aerosol layers in the lower troposphere are much more effective respective to absorption. They may alter by almost 40% the radiative heating. Author

N76-29828 Physics Lab. RVO-TNO, The Hague (Netherlands).
THE MEASUREMENT PROGRAMME OPAQUE OF AC/243 (PANEL IV/RSG.8) ON SKY AND TERRAIN RADIATION
T. Baker *In* AGARD Opt. Propagation in the Atmosphere May 1976 10 p (For availability see N76-29815 20-46)

A measurement program on optical parameters of the atmosphere and environmental characteristics is reported. The aim of the project is to develop a data base of those parameters of the atmosphere and the environment that affect the performance of optical and electro-optical sensors during military operations. From the correlation with the meteorological data, the possibilities of forecasting the performance of the above mentioned sensors will be studied. The program consists of a minimum required set of parameters, to be measured at fixed times (every hour on the hour, local mean time) on all sites during a period of at least two years. At some of the sites a program of recommended additional measurements will be carried out during limited time periods. Author

N76-29829 Forschungsinstitut Fuer Optik, Tuebingen (West Germany).
EXPERIMENTAL AND COMPUTATIONAL COMPARISON OF DIFFERENT METHODS FOR DETERMINATION OF VISUAL RANGE
W. Buechtemann, H. Hipp, W. Jessen, and R. Neuwirth *In* AGARD Opt. Propagation in the Atmosphere May 1976 15 p refs (For availability see N76-29815 20-46)

Three visibility meters of different type have been run simultaneously over several weeks. At the same time aerosol spectra were collected using an optical counter. The visibility readings were compared under several meteorological conditions and a Junge distribution or a modified gamma - distribution has been fitted to the experimental aerosol size distribution. Using Mie's theory and the data recorded, the readings of the instruments have been compared with the computed total extinction and the values computed based on actual instrument parameters, i.e. especially the angular response in the case of two scattering type instruments. A good agreement between the observational visibilities is obtained, except under particular meteorological conditions. Computed visibilities give a generally correct prediction of the measured extinction. Author

N76-29830 Universite des Sciences et Techniques de Lille (France).
RADIATIVE TRANSFER IN A SCATTERING ABSORBING MEDIUM
Y. Fouquart and J. C. Buriez *In* AGARD Opt. Propagation in the Atmosphere May 1976 14 p refs In FRENCH; ENGLISH summary (For availability see N76-29815 20-46)

The computation of radiative transfer in a scattering and absorbing atmosphere is particularly complicated because absorption by gases and scattering by particles occur simultaneously. The most suitable method is to use the distribution of phonon optical path to disjoin absorption and scattering. The phonon optical path distribution is computed for a given scattering medium by means of Pade approximation. The solution of the transfer equation is found by any approximate or accurate method and absorption by gases is computed by means of band models. The method is presented and applied to calculate the intensity reflected by an inhomogeneous cloud. Author

N76-29831 Clarkson Coll. of Technology, Potsdam, N.Y.
FLUORESCENT AND RAMAN SCATTERING IN PARTICLES
M. Kerker, P. J. McNulty, and H. Chew *In* AGARD Opt. Propagation in the Atmosphere May 1976 8 p refs (For availability see N76-29815 20-46)

When inelastically scattering molecules are distributed within a small particle, they respond to the local nonuniform electromagnetic field within the particle. The outgoing inelastic field is obtained by matching at the boundary the dipole field of the emitting molecules plus an internal field with the outgoing field. In this way, it is possible to express the inelastic radiances in terms of the geometry and optical properties of the particle, of the distribution of inelastically scattering molecules within the particle, and of the molecular polarizability, for both coherent and incoherent scattering. Author

N76-29832 Aerospace Corp., Los Angeles, Calif. Electronics Research Lab.
PHYSICAL MODEL FOR STRONG OPTICAL WAVE FLUCTUATIONS IN THE ATMOSPHERE
H. T. Yura *In* AGARD Opt. Propagation in the Atmosphere May 1976 24 p refs (For availability see N76-29815 20-46)

Elementary physical arguments are used to deduce the qualitative functional dependence of amplitude and phase statistics on the optical wave number, propagation distance and the parameters that describe the turbulent medium. An attempt is made to delineate the underlying physical mechanisms which produce such fluctuations and as such the derivations presented here complement the more rigorous analysis presented elsewhere. Although the discussion is limited to the basic plane- and spherical-wave amplitude and phase statistics for constant turbulence conditions, the extension to the case of inhomogeneous turbulence conditions is straightforward. Finally, the propagation of beam waves in a turbulent medium is determined from a knowledge of the propagation characteristics of spherical waves via the extended Huygens-Fresnel principle. As a result, the qualitative dependance of the characteristics of beam waves can be obtained directly from the spherical wave coherence length discussed above. Author

N76-29833 Defence Research Establishment Valcartier (Quebec).
LOG-NORMAL PROBABILITY DISTRIBUTION OF STRONG IRRADIANCE FLUCTUATIONS: AN ASYMPTOTIC ANALYSIS
Luc R. Bissonnette *In* AGARD Opt. Propagation in the Atmosphere May 1976 10 p refs (For availability see N76-29815 20-46)

The asymptotic solutions for the first- and second-order statistical moments of the amplitude of a plane optical wave propagating in a turbulent atmosphere are derived from Maxwell's equations. These solutions show that the irradiance variance diverges to infinity if the irradiance probability distribution is everywhere log-normal. Therefore, the widely used log-normal hypothesis is incompatible with the observation of the saturation of the irradiance variance. Using the same asymptotic solutions, it is shown that the irradiance variance tends to unity if, alternately, the wave amplitude has a normal distribution in the saturation region. The latter result is much more consistent with the measured saturation levels. Finally, direct probability measurements in a simulated atmosphere tend to confirm that the actual distribution is close to normal at saturation distances. Author

N76-29834 Oregon Graduate Center for Study and Research, Beaverton.
TURBULENCE EFFECTS ON TARGET ILLUMINATION BY LASER TRANSMITTER: UNIFIED ANALYSIS AND EXPERIMENTAL VERIFICATION
J. Richard Kerr *In* AGARD Opt. Propagation in the Atmosphere May 1976 27 p refs Sponsored in part by DARPA and AFSC (For availability see N76-29815 20-46)

A phenomenological and analytical description is given of atmospheric turbulence effects on laser beam waves, including the improved target irradiance characteristics resulting from cancellation of turbulence induced beam wander through reciprocity tracking. The mechanisms related to the mean irradiance include diffraction, wander, and wavefront distortion (beamspread), while irradiance fading is caused by wander, first order scintillation, and coherent fading. The phenomenological description unifies the often fragmentary and inconsistent treatment of beam wave phenomena found in the literature, and is sufficiently accurate for engineering purposes. It was shown that wander cancellation and control of the transmitter beam diameter results in substantial improvements in target illumination. The analyses are compared with experimental data for the detailed statistical and spectral characteristics of on-axis target irradiance. Author

N76-29835 Forschungsinstitut Fuer Optik, Tuebingen (West Germany).
PROPAGATION OF FOCUSED LASER BEAMS IN THE TURBULENT ATMOSPHERE
H. Raidt *In* AGARD Opt. Propagation in the Atmosphere May 1976 12 p refs (For availability see N76-29815 20-46)

Experimental results from investigations of instantaneous intensity distributions in focused laser beams at 0.63 micrometer and 10.6 micrometer at distances of approximately 1.3 km, 5 km and 8.6 km are presented and discussed. At 0.63 micrometer the beam pattern is broken up into several diffraction scale spots because focusing is saturated, except for weak turbulence and short propagation distance. At 10.6 micrometer the beam pattern is almost uniform, as long as the beam dimensions are smaller than the correlation length of the amplitude. Author

N76-29836 Pacific Sierra Research Corp., Santa Monica, Calif.
PROPAGATION OF FOCUSED TRUNCATED LASER BEAMS IN THE ATMOSPHERE
R. F. Lutomirski *In* AGARD Opt. Propagation in the Atmosphere May 1976 14 p refs (For availability see N76-29815 20-46)

A formula is derived for the mean intensity distribution from a finite beam in terms of the complex disturbance in the aperture and the mutual coherence function (MCF) for a spherical wave in the medium. The formula is used to examine the effects of turbulence on the long term average intensity produced by a focused, truncated Gaussian aperture distribution. It is shown that while the vacuum focal point intensity will increase as the degree of truncation decreases for a given laser output power, the effect of turbulence limits this increase, and that the turbulence can virtually eliminate the vacuum advantage of visible over infrared wavelengths in focusing the beam at practical ranges. Transverse beam patterns and the on-axis intensity are shown for CO2 wavelength, and a criterion is established for the condition under which the turbulence prevents effective focusing. Author

N76-29837 Queen Elizabeth Coll., London (England). Dept. of Physics.
MEASUREMENTS OF THE ATMOSPHERIC TRANSFER FUNCTION
J. C. Dainty and R. J. Scaddan (Imperial Coll. of Sci. and Technol.) *In* AGARD Opt. Propagation in the Atmosphere May 1976 14 p refs (For availability see N76-29815 20-46)

A wavefront folding interferometer has been constructed with which the long time averaged modulation transfer function, MTF, of the atmosphere can be measured. The instrument was used to determine the MTF over 10 nights in June 1974 at Mauna Kea Observatory, Hawaii, using bright stars as sources. The form of the MTF at separations of a few centimeters in the pupil agreed with that predicted on the basis of a Kolmogorov spectrum of turbulence, but there was a departure at larger separations. The MTFs were highly variable both from hour-to-hour and night-to-night, the wavefront correlation region varying from approximately 4 to 20 cm. Increasing the zenith angle generally decreased the correlation region, but no exact relationship was observed. Author

N76-29838 Rome Univ. (Italy).
INTENSITY CORRELATION OF RADIATION SCATTERED ALONG THE PATH OF A LASER BEAM PROPAGATING IN THE ATMOSPHERE
M. Bertolotti, M. Carnevale (Fondazione Ugo Bordoni, Rome, Italy), B. Crosignani (Fondazione Ugo Bordoni, Rome, Italy), B. Daino (Fondazione Ugo Bordoni, Rome, Italy), and P. DiPorto (Fondazione Ugo Bordoni, Rome, Italy) *In* AGARD Opt. Propagation in the Atmosphere May 1976 9 p refs (For availability see N76-29815 20-46)

Correlation properties of the electromagnetic field scattered away from the direction of propagation of a laser beam are studied. The correlation could be used for whenever a direct measurement of the scattered intensity is difficult due to background radiation. Correlation measurements are also connected with the scale of atmospheric turbulence. Author

N76-29839 Rome Univ (Italy)
MEASUREMENT OF ATMOSPHERIC ATTENUATION AT 6328 A
M Bertolotti, M Carnevale (Fondazione Ugo Bordoni, Rome, Italy), B Daino (Fondazione Ugo Bordoni, Rome, Italy), M Galeotti (Fondazione Ugo Bordoni, Rome, Italy), and D Sette *In* AGARD Opt Propagation in the Atmosphere May 1976 7 p (For availability see N76-29815 20-46)

The influence of the free atmosphere on the propagation properties of laser beams has been studied for a communication link through the determination of atmospheric attenuation statistics, and for the effects of turbulence and atmospheric conditions. Author

N76-29840 Consiglio Nazionale delle Ricerche, Frascati (Italy). Ist di Ricerca sulle Onde Elettromagnetiche
MEASUREMENTS OF ANGLE OF ARRIVAL FLUCTUATIONS OF A LASER BEAM DUE TO TURBULENCE
Anna Consortini *In* AGARD Opt Propagation in the Atmosphere May 1976 8 p refs (For availability see N76-29815 20-46)

The angles of arrival fluctuations were measured for a diverging laser beam after propagation through turbulence, firstly through a thin layer of artificial turbulence, then through the atmosphere at near ground levels. In the first case the influence of the position of the layer is put in evidence. In the case of the atmosphere approximate values of the inner scale of turbulence and the structure constant are derived by a comparison with the theory of Tatarski. Author

N76-29841 Plessey Radar Ltd., Cowes (England)
A MULTIPLE SCATTERING CORRECTION FOR LIDAR SYSTEM
J V Winstanley and C. Wigmore *In* AGARD Opt. Propagation in the Atmosphere May 1976 13 p refs (For availability see N76-29815 20-46)

Multiple scattering phenomena are treated as effective beam broadening mechanisms. At any given range the amount of beam overlap was greater in the cases of fog and smoke than in clear air. In addition, the amount of beam overlap increased as the optical density increased. A beam broadening correction factor was therefore defined as the ratio of beam overlap in poor visibility conditions to that in clear air, measured at the same range. Experimental measurements were made of the beam broadening factors, using a GaAc lidar system. The results obtained were expressed as a graph of correction factor versus extinction coefficient for each range element, and were in fair agreement with the theoretical models of Chu and Hogg and Kunkel.
Author

N76-29842 Societe Anonyme de Telecommunications, Paris (France)
MEASUREMENT OF ATMOSPHERIC ABSORPTION BY UTILIZATION OF AN INFRARED SOLAR RADIATION RECEIVER [MESURES DE L'ABSORPTION ATMOSPHERIQUE PAR UTILISATION D'UN RADIOMETRE HETERODYNE INFRA-ROUGE SOLAIRE]
B Christophe and M. Comus *In* AGARD Opt Propagation in the Atmosphere May 1976 13 p refs In FRENCH (For availability see N76-29815 20-46)

The physical principles underlying the coherent and incoherent heterodyne detection technique in the middle infrared region were described. The application of this technique to the measurement of atmospheric transparency was illustrated, including presentation of the first results so far available. Transl by Y J A

N76-29843 Naval Research Lab., Washington, D C
PROPAGATION OF HIGH POWER LASER BEAMS THROUGH THE ATMOSPHERE: AN OVERVIEW
John N Hayes *In* AGARD Opt Propagation in the Atmosphere May 1976 15 p refs (For availability see N76-29815 20-46)

The major categories of the thermal blooming phenomena encountered in the propagation of high power laser beams in the open atmosphere are developed. The basic physical ideas behind each type of blooming phenomenon are discussed, experimental data and theoretical formulation are briefly presented that show the present state of knowledge. Author

N76-29844 Lincoln Lab., Mass. Inst. of Tech., Lexington
AN OVERVIEW OF THE LIMITATIONS ON THE TRANSMISSION OF HIGH ENERGY LASER BEAMS THROUGH THE ATMOSPHERE BY NONLINEAR EFFECTS
S Edelberg *In* AGARD Opt Propagation in the Atmosphere May 1976 15 p refs Sponsored by ARPA (For availability see N76-29815 20-46)

The important nonlinear effects which limit high energy laser propagation through the atmosphere are reviewed. The two most important effects are thermal blooming (or thermal defocussing) and air breakdown within the beam. A third, less important effect is stimulated raman scattering. The possibility of transmitting laser beams through fogs, clouds or haze by boring holes through these atmospheric media with the laser beam is also reviewed. The laser's waveform is considered to be a train of pulses. It is shown that the waveform design and other important parameters such as range to the focal plane, aperture and focal spot size, pulse intensity, etc., can be chosen to avoid the thermal blooming of individual pulses and air breakdown. The limit on beam propagation is then caused by thermal blooming due to the cumulative heating by the pulses in the train. An added set of parameters then controls this multipulse blooming including beam slew rate, cross wind velocity, and interpulse spacing. Parametric tradeoffs required to satisfactorily control thermal blooming and quantitative results for several parametric choices are summarized. Author

N76-29845 Naval Research Lab., Washington, D.C
NUMERICAL METHODS IN HIGH POWER LASER PROPAGATION
Peter B. Ulrich *In* AGARD Opt. Propagation in the Atmosphere May 1976 19 p refs (For availability see N76-29815 20-46)

Numerical solutions to the complex nonlinear problems of the interaction of high energy lasers with the atmosphere have played an important role in the understanding and development of this important and interesting field. Summarized are the relevant partial differential equations that apply, the kinds of numerical algorithms employed in their solution and representative results of a variety of cases of interest. Comparison with experiment is made wherever possible. Other effects which impact the thermal blooming phenomena are also addressed. Author

N76-29846 Lincoln Lab., Mass. Inst. of Tech., Lexington
THE LIMITATIONS IMPOSED BY ATMOSPHERIC BREAKDOWN ON THE PROPAGATION OF HIGH POWER LASER BEAMS
D. E. Lencioni *In* AGARD Opt. Propagation in the Atmosphere May 1976 12 p refs Sponsored by ARPA (For availability see N76-29815 20-46)

The results of a series of experiments on laser induced air breakdown at 10.6 and 1.06 micrometers are reported. Threshold intensities for breakdown were determined for clean air, aerosols, and single particles. The clean air threshold was found to be in good agreement with microwave breakdown theory. The presence of aerosol particles was found to lower the threshold by an amount which depended mainly on particle size and laser pulse length. Only a slight material dependence was found with the one exception of water particles which had the least effect on threshold. The particle induced thresholds were found to scale as wavelength to the minus two power for 100 nsec pulse lengths. The dynamics of the particle initiated thresholds were studied. For intensities slightly above threshold the plasma grew within the beam as an axisymmetric volume surrounding the particle. At higher intensities the plasma formed as a highly absorbing thin disk which grew radially and propagated back towards the laser. Author

N76-29847 Lincoln Lab., Mass. Inst. of Tech., Lexington
EXPERIMENTAL DETERMINATION OF SINGLE AND MULTIPLE PULSE PROPAGATION
R W. ONeil, H. Kleiman, and H. R. Zwicker *In* AGARD Opt. Propagation in the Atmosphere May 1976 13 p refs Sponsored by ARPA (For availability see N76-29815 20-46)

Thermal blooming of focused single and multiple pulse lasers is considered. Experimental procedures are described to characterize the reduction in far field irradiance observed for pulses whose duration is comparable to and shorter than the acoustic transit time across a focal radius. Experimental measurements of short pulse blooming are compared with a scalar wave theoretical computer model embodying the medium hydrodynamics. Agreement with the short pulse theory is generally good. An experiment was designed to test the quantitative predictive capability of a steady state multiple pulse computer code. Blooming of a multiple pulse beam was measured as a function of absorbed energy and spatial overlap of successive pulses. Agreement between the actual measurements and those predicted by theory was very good. Author

N76-29848 Defense Advanced Research Projects Agency, Arlington, Va.
COMPENSATED IMAGING
James W. Justice and Raymond P. Urtz, Jr. (RADC, Griffiss AFB, N. Y.) *In* AGARD Opt. Propagation in the Atmosphere May 1976 17 p refs (For availability see N76-29815 20-46)

The presence of the atmosphere degrades the imaging performance of large telescopes. Optical phase distortion imposed by atmospheric turbulence causes a loss in resolution capability of from 10 to 30 times a system's theoretical performance. A compensated imaging approach is reported which allows the retrieval of low contrast information by active adaptation of the telescope system to atmospheric conditions. This is accomplished through the use of real time wavefront sensing coupled with fast response deformable optics. In practice, the wavefront entering the telescope is measured to determine its wavefront deformation (optical path length difference across the aperture) and a mirror is then deformed to the conjugate of the deformations, producing a near diffraction limited image on a sensor. Analysis of the wavefront correction capabilities has been completed. Author

N76-29849 Consiglio Nazional delle Ricerche, Bologna (Italy)
DETERMINATION OF SLANT VISUAL RANGE FROM LIDAR SIGNATURES. ANALYSIS OF SIMULATED SIGNATURES

Mario Gazzi, Vittorio Vicentini, Luca Pantani, Bruno Radicati, Leopoldo Stefanutti, and Christian Werner (DFVLR) *In* AGARD Opt. Propagation in the Atmosphere May 1976 19 p refs (For availability see N76-29815 20-46)

The measurement of the slant visual range by means of lidars involves two main problems: the extraction of the atmospheric extinction coefficient from the lidar signature and the calculation of the slant visual range from the extinction coefficient. These problems were solved for the particular situation of a landing in low visibility conditions. An equation was obtained which allows the computation of the visual range from the extinction coefficient in every hour of the day both for extended and point sources. In order to compare the different methods for the extraction of the extinction coefficient from the lidar signatures some atmospheric situations were simulated on a computer, and the lidar equation was calculated. The simulated signatures were then processed by different methods and the results were collated. A new procedure for the processing of lidar signatures was introduced. Author

N76-29850 California Univ., San Diego.
COMPUTER SIMULATION OF ATMOSPHERIC TURBULENCE AND COMPENSATED IMAGING SYSTEMS
B. L. McGlamery *In* AGARD Opt. Propagation in the Atmosphere May 1976 17 p refs (For availability see N76-29815 20-46)

The earth's turbulent atmosphere severely limits the resolution of conventional ground based telescopes. Methods of reducing this limitation for ground based telescopes include post detection processing in which the blurred recorded image is processed to extract information not discernable to the human visual system, and pre-detection compensation in which the wave front deformations are dynamically corrected in the optical system before the image is recorded. Computer simulations of both of these methods are presented. The simulations demonstrate that the post detection processing method produces only moderate improvement in resolution due to signal to noise limitations while the pre-detection method gives very significant improvements. As a part of the simulations, techniques of generating instantaneous realizations of wave fronts deformed by atmospheric turbulence and their corresponding point spread functions are presented. Author

N76-29851 Optical Science Consultants, Yorba Linda, Calif.
HOW MANY PICTURES DO YOU HAVE TO TAKE TO GET A GOOD ONE?
David L. Fried *In* AGARD Opt. Propagation in the Atmosphere May 1976 11 p refs (For availability see N76-29815 20-46)

In short exposure imaging through turbulence, there is some probability that the image will be nearly diffraction limited because the instantaneous wave front distortion over the aperture was negligible. It is shown that the probability of obtaining a good short exposure image corresponds to a hyperspace integral in which the spatial dimensions are the independent random coefficients in an orthonormal series expansion. It is equal to the probability that a randomly chosen point in the hyperspace will lie within a hypersphere of unit radius, the points in the hyperspace being randomly chosen in accordance with the product of independent Gaussian probability distributions - one distribution for each dimension. The variances of these distributions are directly proportional to the eigenvalues of the Karhunen-Loeve equation. This hyperspace integral (involving up to several hundred dimensions) has been evaluated using Monte Carlo techniques. Author

N76-29852 National Oceanic and Atmospheric Administration, Boulder, Colo.
REMOTE PROBING OF WINDS AND REFRACTIVE TURBULENCE USING OPTICAL TECHNIQUES
S. F. Clifford *In* AGARD Opt. Propagation in the Atmosphere May 1976 10 p refs (For availability see N76-29815 20-46)

Techniques of measuring wind and refractive turbulence by using both active and passive optical sources are considered. A passive wind sensor was developed that requires no active light source; it responds to fluctuations of light reflected from a target to determine the average crosswind. Finally, progress was made in the application of horizontal path techniques to the problem of remotely sensing wind and refractive turbulence profiles aloft from observations of stellar scintillations. The operational principles of these devices are analyzed and their performances compared to more conventional meteorological instruments. Author

N76-29853 California Univ., La Jolla.
MEASURED VISIBLE SPECTRUM PROPERTIES OF REAL ATMOSPHERES
S. Q. Duntley *In* AGARD Opt. Propagation in the Atmosphere May 1976 14 p ref (For availability see N76-29815 20-46)

Measurements of the visible spectrum properties of the atmosphere which govern the apparent contrast of distant objects have been made from aircraft, spacecraft, and ground stations in various parts of the world throughout the past thirty years. Samples of these data are presented and the techniques of measurement that were used are described. Examples are given to illustrate how the data can be used to predict the limiting ranges of detection, recognition, classification, and identification of any specific object by airborne, spaceborne, and ground based observers or imaging devices. Author

N76-29854 Forschungsinstitut Fuer Optik, Tuebingen (West Germany).
PASSIVE AND ACTIVE ATMOSPHERIC VISION
D. H. Hohn *In* AGARD Opt. Propagation in the Atmosphere May 1976 8 p refs (For availability see N76-29815 20-46)

The main features of a unique theory of atmospheric passive and active vision for 0.25 micrometer to 14 micrometers are discussed. The signal-to-noise ratio corresponding to the detection of the vision signal, i.e. the apparent radiance of the observation site, is used as the basic physically limiting magnitude. It establishes a general vision formula. Different noise limitations (detector, device radiation, signal photon noise) were used to derive special, more applicable equations. The theoretical results were applied numerically to passive thermal vision. The optimization of optoelectronic vision systems was considered by approaching signal limited photon noise conditions in contradiction to blip conditions, and by using reduced wavelength bands for atmospheric vision. Finally, the problem of defining and measuring characteristic lengths comparable to the visual range 5 was considered. Author

N76-29855 Physics Lab. RVO-TNO, The Hague (Netherlands).
DECREASE OF CONTRAST IN THE ATMOSPHERE: STATISTICAL PRESENTATION OF THE RESULTS OF DAYTIME AND NIGHT-TIME MEASUREMENTS
J. VanSchie and J. Rogge (Roy. Mil. Acad., Breda, Netherlands) *In* AGARD Opt. Propagation in the Atmosphere May 1976 16 p refs (For availability see N76-29815 20-46)

An outline is given of the model in which the decrease of contrast in the atmosphere in the visible region is described with two parameters: the extinction coefficient and the luminance of the atmosphere; also the distance over which the initial contrast is halved, is introduced. The results of a number of measurements of these parameters, both at day and at night, are presented in the form of several histograms. Some comments concerning the results of the various measurements are given. Author

N76-29856 Norwegian Defence Research Establishment, Kjeller.
BENDING OF RAYS OF LIGHT ABOVE THE SEA SURFACE
P. A. Stokseth and A. Nordbryhn *In* AGARD Opt. Propagation in the Atmosphere May 1976 14 p refs (For availability see N76-29815 20-46)

A temperature difference between the sea and the air above it sets up a stable vertical air temperature gradient in the first few meters above the sea surface. This temperature inhomogeneity causes a similar refractive index gradient. Rays of light passing through this optical inhomogeneous medium are bent, and imaging of objects through this medium may be subject to strong distortion. Such image distortion has been investigated, theoretically and experimentally. The main experimental results were obtained by taking pictures of a suitable test object with a photographic camera and a telephoto lens at 8.2 km range just above the sea surface. From these pictures typical forms and magnitudes of the distortion were found. A mathematical model tracing rays of light through a vertically varying optical medium was used to predict image distortions. The theoretical results have been compared with the experimental results, and good similarity has been found. Author

N76-29857 Marconi-Elliot Avionic Systems Ltd., Basildon (England).
ATMOSPHERIC LIMITATIONS OF ACTIVE AND PASSIVE NIGHT VISION SYSTEMS
E. G. D. Youngs *In* AGARD Opt. Propagation in the Atmosphere May 1976 7 p refs (For availability see N76-29815 20-46)

The ways in which the earth's atmosphere effect the image quality of night vision devices are discussed, and of particular interest here is the effect on apparent contrast. Atmospheric problems are considered that are associated with the use of supplementary illumination. Continuously emitting searchlights are briefly outlined, and techniques associated with pulsed illuminators are considered. A summary is given of a basic mathematical model for such a system. Author

N76-29858 Eltro G.m.b.H., Heidelberg (West Germany).
USING LIDAR FOR MEASURING VISIBILITY
James F. Ruger *In* AGARD Opt. Propagation in the Atmosphere May 1976 8 p refs (For availability see N76-29815 20-46)

The performance of slant visibility equipment and the data processing techniques used, are described. Special attention is given to the correlation data which compares the accuracy of the slant visibility system to that of a recognized transmissometer. Approximately 800 slant visibility readings were compared with the transmissometer visibility data at three different airports in order to obtain the correlation function. The results show that in slant visibility readings, although consistently higher than the transmissometer visibility reading, the factor is always approximately two. Therefore the correlation factor is a constant, and the visibility data plots of the two systems lie exactly parallel to one another. Author

N76-29859 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany).
THE INFLUENCE OF THE ATMOSPHERE BETWEEN HELICOPTERS AND GROUND-TARGETS ON THE DOWNWARD AND UPWARD VISIBILITY
H.-E. Hoffmann *In* AGARD Opt. Propagation in the Atmosphere May 1976 16 p refs (For availability see N76-29815 20-46)

During some preliminary visibility air-to-ground and ground-to-air tests in autumn 1974, the maximum detection range and the maximum recognition range were determined. A Leopard tank, a 1.5 t military truck and a special test board were observed from air to ground. The experiments took place only at standard visibilities between 36 and 57 km - the maximum detection range ground-to-air was between 8 and 12 km larger than the maximum detection range air-to-ground. The maximum recognition range air-to-ground was up to 2 km smaller than the maximum detection range. The maximum detection range for observations of a special test board was smaller than that for observations of the 1.5 t military truck. The maximum recognition ranges, however, determined at observations of the test board and of the 1.5 t military truck did not differentiate significantly from each other. Author

51 LIFE SCIENCES (GENERAL)

Includes genetics

N75-23084# Advisory Group for Aerospace Research and Development, Paris (France).
MEDICAL REQUIREMENTS AND EXAMINATION PROCEDURES IN RELATION TO THE TASKS OF TODAY'S AIRCREW: EVALUATION OF THE SPECIAL SENSES FOR FLYING DUTIES
G. Perdriel, ed. Feb. 1975 94 p refs In ENGLISH, partly in FRENCH Presented at Aerospace Med Panel Meeting, Naples, 16-20 Sep. 1974
(AGARD-CP-152) Avail: NTIS HC $4.75

Medical requirements and examination procedures in relation to sensory tasks of aircrews are reported. For individual titles, see N75-23085 through N75-23097.

N75-23085 Advisory Group for Aerospace Research and Development, Paris (France).
MEDICAL REQUIREMENTS AND EXAMINATION PROCEDURES IN RELATION TO THE TASKS OF TODAY'S AIRCREW: INTRODUCTORY REMARKS
Aristice Scano *In its* Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 3 p refs (For availability see N75-23084 14-51)

The medical and aptitudinal selection of aircrew and periodical examinations of their physiopsychological efficiency are necessary to define better fitness in relation to perceptive capacities, to standards for visual and hearing devices, and to intelligibility of speech transmitted to the aircrew in flight. G.G.

N75-23086 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
EVALUATION OF ROLL AXIS TRACKING AS AN INDICATOR OF VESTIBULAR/SOMATO SENSORY FUNCTION

A. M. Junker and C. R. Replogle *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 8 p refs (For availability see N75-23084 14-51)

To learn more about the effects of vestibular/somato sensory information upon visual motor control, a roll axis tracking simulator was developed. A description of this simulator, including the ability to run with and without motion cues, is given. Large amplitude roll angle motion cues were used. The effects of various plant dynamics, relating to plant complexity on tracking performance, are discussed. For a particular set of plant dynamics requiring a considerable amount of lead compensation, it is shown that subjects perform significantly better with the presence of motion cues. It has been suggested that primarily vestibular system contributions allow motion cues to aid pilot performance.
Author

N75-23087 Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).
THE EFFECTS OF PURE TONE HEARING LOSSES ON AVIATORS' SENTENCE INTELLIGIBILITY IN QUIET AND IN AIRCRAFT NOISE
G. R. Froelich *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 4 p (For availability see N75-23084 14-51)

Pure tone audiometry remains the basis for the acceptance of applicants as well as the annual follow-ups of rated pilots. Speech audiometry in quiet is very efficient for the assessment of disability for compensation and the selection of hearing aids, but not for decisions on deafened aircrew. Present audiometric standards for rated aircrew make sure that aviators with hearing losses admitted by standards have no difficulties with inflight voice communication. The decision on the disposal of experienced but deafened aircrew should be based on the discrimination of connected speech in the presence of a background aircraft noise. Author

N75-23088 Naval Aerospace Medical Research Lab., Pensacola, Fla. Acoustical Sciences Div.
ASSESSING AN AVIATOR'S ABILITY TO HEAR SPEECH IN HIS OPERATIONAL ENVIRONMENT
Carl E. Williams, James D. Mosko, and James W. Greene *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 10 p refs (For availability see N75-23084 14-51)

The use of multiple word test items is analyzed whether it influences the intelligibility function of test words relative to their presentation as single word test items and whether such items provide a sensitive measure of an individual's ability to hear speech in aircraft acoustical environments. High quality tape recordings were constructed of single, double, and triple word test items from six monosyllabic word lists of the Modified Rhyme Test (MRT), a multiple choice intelligibility test. The test words were incorporated in a carrier phrase somewhat analogous to typical aircraft radio messages. The recorded lists were mixed with shaped noise and played back to a group of listeners at three signal-to-noise ratios. At the two best signal-to-noise ratios (+4 db and 0 db), there was little difference in overall listener performance for the single, double, and triple word test items.
Author

N75-23089 Army Aeromedical Research Lab., Fort Rucker, Ala.
CHARACTERISTICS OF NEW GENERATION MILITARY NOISE CANCELING MICROPHONES
Robert T. Camp, Jr., Ben T. Mozo, and James H. Patterson *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 6 p (For availability see N75-23084 14-51)

Military voice communication systems have two undesirable characteristics: (1) they have excessive distortion that causes low intelligibility; and (2) they emit excessive noise which constitutes an acoustic hazard to military personnel. A prototype voice communication system is developed that includes a new generation noise cancelling microphone. Results of a test are presented to show that near field linearity and improved noise cancelling characteristics are the desired characteristics of future noise cancelling microphones. Author

N75-23090 Centre Principal d'Expertises Medicales du Personnel Navigant, Paris (France).
THE ROLE OF VOCAL AUDIOMETRY IN THE SELECTION OF NAVIGATION PERSONNEL [LA PART DE L'AUDIOMETRIE VOCALE DANS LA SELECTION DU PERSONNEL NAVIGANT]
P. Blanc and J. D. P. Bastien *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 3 p In FRENCH (For availability see N75-23084 14-51)

Different clinical procedures and functions of examining and diagnosing hearing problems of navigation personnel are discussed. Data are given on localization of deafness, physiological surveillance of navigation personnel problems, and standards for normal aerial security. The application of these methods to personnel selection are also examined. Transl. by E.H.W.

N75-23091 Erlangen-Nuremberg Univ. (West Germany). Dept. of Physiology.
OBJECTIVE ELECTROPHYSIOLOGICAL MEASUREMENTS OF EAR CHARACTERISTICS, INTELLIGIBILITY OF VOWELS AND JUDGEMENT OF THE STAGE OF ATTENTION
Manfred Spreng *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 10 p refs (For availability see N75-23084 14-51)

The influence of short time annoying noise upon evoked human responses can be demonstrated if the noise reaches intensities around 70 db. Ear characteristics measured show objectively the behavior of the individual ear in the range above the increased thresholds. Based upon their course compensating hearing aids can be adapted which do not only amplify in a variable degree but also may show even a range of attenuation with increasing sound pressure levels in some special cases of recruitment. Using computer generated vowels as exactly triggered stimuli evoked responses have been recorded with a 16 to 37% increase compared with speech noise stimulation of equal intensity near threshold. First trials are reported to select the single responses corresponding to the FFT-EEG spectra, thus, overcoming the influence of different stages of attention. By this means new data may be gathered concerning the change of evoked potentials from change of attention doing additional tasks, having multisensory input or succumbing sedation. Author

N75-23092 Italian Air Force Medico-Legal Inst., Milan.
THE IMPORTANCE OF THE DOSAGE OF THIOCYANATES IN URINE AND BLOOD OF FLYING PERSONNEL FOR THE PREVENTION OF DISEASES OF VISUAL FUNCTION
G. Durazzini, F. Zazo, and G. Bertoni (Milan Univ.) *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 5 p refs (For availability see N75-23084 14-51)

The relationship between the quantity of cyanides introduced into the organism with smoke, the increase of thiocyanides in organic fluids (blood and urine) and any impairment of the multiple and complex functions of the optic nerve was considered. The amount of thiocyanides present was measured in a group of healthy non-smokers and no significant increase of thiocyanides was found, either in the urine or in the blood and for comparative purposes on another group of healthy smokers in whom a clear increase in the average thiocyanide values was found, especially in urine and in proportion to the number of cigarettes smoked, in comparison with non-smokers. Particular tests of central and peripheric visual function showed slight impairments or results at the lower limits of the normal score (particularly in the test of visual acuteness in reduced lighting and in mesopic campimetry) in 50% of the subjects smoking more than 10 cigarettes (average quantity of thiocyantes in urine : 9.3 mg/l). Author

N75-23093 Dunlap and Associates, Inc., la Jolla, Calif.
EVALUATION OF THE SPECIAL SENSES FOR FLYING DUTIES: PERCEPTUAL ABILITIES OF LANDING SIGNAL OFFICERS (LSOS)
C. A. Brictson *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 8 p refs (For availability see N75-23084 14-51)

The job of the landing signal officer is to provide for the safe and expeditious recovery of aircraft aboard ship. Perceptual abilities related to job performance were identified and used as a basis to select a preliminary battery of perceptual tests which was administered to qualified LSOs and trainees. Results indicate that LSOs may be differentiated on the basis of perceptual style on a field independence dimension. Suggestions for validation of the test battery against LSO performance criteria are presented and reviewed. Author

N75-23094 Naval Aerospace Medical Research Lab., Pensacola, Fla. Aerospace Psychology Dept.
AIR-TO-AIR VISUAL TARGET ACQUISITION
James E. Goodson *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 9 p refs (For availability see N75-23084 14-51)

A most critical element of tactical advantage in the air combat environment is the early visual acquisition and continued visual tracking of airborne targets. Little data are available which relate specific visual functions or tests to air-to-air performance ability. Initial visual acquisition of airborne targets usually occurs at distances far less than calculated visibility ranges. Further, many targets go undetected even though they pass well within the acquisition range. There appears to be great variability among aviation personnel in visual acquisition performance. However, potential procedures for either selecting or training personnel for this special ability have not been validated against inflight performance criteria. Author

N75-23095 Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome (Italy).
VISUAL ACUITY OF ASTIGMATIC SUBJECTS AND FITNESS TO AIR FORCE SERVICE
Paolo Rota and Carlo Terrana *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 3 p refs (For availability see N75-23084 14-51)

Visual acuity in different axes was studied in astigmatic subjects, and its importance is considered, in view of fitness in flight and on ground special tasks. The research was carried out by means of optotypes made with Landolt rings, on purpose redesigned, for distant and near vision. Author

N75-23096 School of Aerospace Medicine, Brooks AFB, Tex. Ophthalmology Branch.
MICROSTRABISMUS IN FLYING PERSONNEL (DIAGNOSIS AND DISPOSITION)
Thomas J. Tredici *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb. 1975 10 p refs (For availability see N75-23084 14-51)

It is considered of paramount importance for the aviator to have the ability to accurately perceive depth and judge distances. One of the important elements contributing to his depth perception is stereopsis. The United States Air Force (USAF) depth perception tests are in reality tests of stereopsis. Examiners are aware that a number of trained aviators always have difficulties in passing these stereoscopic tests. In the past those who failed these tests but had straight eyes and normal visual acuity were thought to have idiopathic partial lack of stereoacuity, most likely on a central basis. Recently developed subtle diagnostic motility techniques have revealed that many of these airmen in reality have a small degree of strabismus (crossed eyes). Presently, this condition is known as microstrabismus or microtropia. Author

N75-23097 Amsterdam Univ. (Netherlands).
LINEAR ACCELERATION PERCEPTION THRESHOLD DETERMINATION WITH THE USE OF A PARALLEL-SWING
A. J. Greven, W. J. Oosterveld, and W. J. A. C. Rademakers *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Feb 1975 4 p refs (For availability see N75-23084 14-51)

The perception of linear acceleration in humans is discussed. The parallel swing -as a tool to collect data on the functioning of the otolithic system- is described. In twelve human subjects experiments were conducted with the parallel swing in order to determine the threshold of perception for movements of this swing. The effect of different body positions on this threshold was also determined. In another series of experiments the amplitude of the sinusoidal compensatory eye movements was investigated when the swing was oscillating with an amplitude of 12.5 cm, as well as with an amplitude of 25 cm. Author

N75-24297# Advisory Group for Aerospace Research and Development, Paris (France).
MEDICAL REQUIREMENTS AND EXAMINATION PROCEDURES IN RELATION TO THE TASKS OF TODAY'S AIRCREW: COMPARISON OF EXAMINATION TECHNIQUES IN NEUROLOGY, PSYCHIATRY AND PSYCHOLOGY WITH SPECIAL EMPHASIS ON OBJECTIVE METHODS AND ASSESSMENT CRITERIA
H. Oberholz, ed. (Flugmedizinisches Inst der Luftwaffe, Fuerstenfeldbruck, West Germany) Mar 1975 100 p refs In ENGLISH; partly in FRENCH Presented at the Aerospace Medical Panel Meeting, Naples, 16-20 Sep. 1974
(AGARD-CP-153) Avail: NTIS HC $4.75

Papers presented at the conference are given. Topics discussed include Rorschach tests, computer measurement of complex performance, nonvisual task processing, pulse wave velocity and psychophysiological reaction patterns, catecholamine excretion from air cadets, flight fitness, fast analytical techniques for the EEG, impact of multivariate analysis on the aviation selection, psychic health and flying fitness examinations, and military aviation psychiatry and neurology. For individual titles, see N75-24298 through N75-24309

N75-24298 Advisory Group for Aerospace Research and Development, Paris (France).
TEST FOR QUICK AND EARLY DETECTION OF PSYCHIC SYNDROMES MORE FREQUENT IN THE AIR FORCE PERSONNEL
Luigi Longo (Italian Air Force Appeal Medical Board) *In its* Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 4 p refs (For availability see N75-24297 15-51)

Results and observations are presented which are derived from a test known as a 'test of three random dots'. The test was used to detect early symptoms and psychopathological tendencies in order to prevent their development. The following points were considered in analyzing the results of the tests: the order of distribution of the 3 dots, the type of figure gained by joining the 3 dots, the maximum distance between the lateral dots, and the quadrant of paper in which the center of the figure appears. M.J.S.

N75-24299 Advisory Group for Aerospace Research and Development, Paris (France).
ADMINISTRATION OF THE RORSCHACH TESTS TO A SAMPLE OF STUDENT PILOTS TRAINING APPRENTICESHIP [COMPORTEMENT AU TEST DE RORSCHACH D'UN ECHANTILLON D'ELEVES PILOTES EN PHASES SUCCESSIVES D'APPRENTISSAGE]
Fabrizio Spurieri (Schools of the Italian Air Force) *In its* Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar 1975 3 p refs In FRENCH (For availability see N75-24297 15-51)

The Rorschach Test was administered to 138 student pilots, 77 were in academic training and 61 were in flying training. Stress and fatigue effects on the quality of student response were compared. It was determined that students in flying training supplied more answers, but of less quality than those in academic training. It was suggested increased psychological stress and fatigue induced by flight situations was the cause of such responses. Transl by E.H.W.

N75-24300 Naval Aerospace Medical Research Lab., Pensacola, Fla.
COMPUTER MEASUREMENT OF COMPLEX PERFORMANCE
Richard S. Gibson *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 7 p refs (For availability see N75-24297 15-51)

A series of computer controlled performance measurement tests using response latency measures were developed. Three types of performance tasks were used in these tests: an experimenter paced complex discrimination task, a subject-paced complex discrimination task, and an experimenter paced stress task. Each task is capable of being presented separately or in conjunction with other tasks. This quality permits the assessment of performance changes as the test environment is changed from a simple single task situation to an increasingly complex multiple task situation. The results indicate that response times under complex conditions are much longer than under simpler task conditions. Task interactions and the need to divide attention greatly increase the time required to respond to any test situation. Some individuals appear to be more able to cope with time-shared conditions than others. In general, the data indicate that much of the traditional human performance data may grossly overestimate performance levels obtainable under real-world conditions.
Author

N75-24301 Organization for Health Research, TNO, Amsterdam (Netherlands). Lab. for Ergonomic Psychology.
CHANGES IN VISUAL EVOKED RESPONSE BY NON-VISUAL TASK PROCESSING
J. L. Blom *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 11 p refs (For availability see N75-24297 15-51)

The influence of an auditory binary choice task on the visual evoked response (VER) in man is analyzed. The separation of task and test stimulus and the processing techniques used enabled the demonstration of a significant difference between task and resting conditions, especially in the amplitude levels of wave IV. These observations, together with data from literature form the basis of a neurophysiological hypothesis advanced to explain the responsible mechanisms. It is postulated that, in the waking state, the reticular formation can only be in two states designated resting and busy, which are responsible for the cortical processing of information. The busy state occurs when information is processed and is maintained by cortico-reticular activity during this state. If this activity has been maintained during a certain period of time, return to the resting state is delayed, changing the VER in the period immediately following mental activity.
Author

N75-24302 Organization for Health Research, TNO, Amsterdam (Netherlands). Lab. for Ergonomic Psychology.
PULSE WAVE VELOCITY OVER THE VASCULAR WALL AS A MEANS FOR DISTINGUISHING BETWEEN DIFFERENT PSYCHOPHYSIOLOGICAL REACTION PATTERNS TO A MENTAL TASK
C. H. J. M. Opmeer *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 7 p refs (For availability see N75-24297 15-51)

The influence of a quantitative task of a predominantly mental nature on pulse wave velocity (PWV) was investigated. The time which the pulse wave (caused by the pumping action of the heart) needed to travel along the vascular wall (from heart to right ear lobe) generally decreased (i.e. PWV increased) during a 75 choices per min - task. It seems possible to distinguish two groups: those subjects showing a decreased PWV (supposed to indicate arterial vasoconstriction), and those showing an increased PWV (supposed to be caused by vasodilatation). The continuous PWV-time series appears to be quite irregular (mean SD 16 ms). A Fourier-analysis performed on these data indicates that the observed increase in the number of oscillations during a heavy task is due to an influence of augmented respiratory rate during this task.
Author

N75-24303 Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome (Italy).
CATECHOLAMINE EXCRETION FROM AIR CADETS
G. Paolucci and G. Biundo *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 3 p refs (For availability see N75-24297 15-51)

As every stress can produce rise on catecholamine rate (as adrenal gland response), these substances in aviators during training were analyzed. In order to establish whether the flight could have some influence in their output. The assessment of the data obtained results in the conclusion that, in air cadets, first flying missions act as a stress, since the catecholamine excretion increases 4 times in comparison with basic values, collected during nonflying duty.
Author

N75-24304 Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome (Italy).
FLIGHT FITNESS AND PSYCHO-PHYSIOLOGICAL BEHAVIOR OF APPLICANT PILOTS IN THE FIRST FLIGHT MISSIONS
Cesare A. Ramacci and Paolo Rota *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 8 p refs (For availability see N75-24297 15-51)

The psycho-physiological behavior of 73 applicant pilots was studied during the flights of a basic training course. On ground and during the 1st, 7th, and 15th mission, the trainees carried out arithmetic calculation consisting of progressive subtractions, and tracked a given outline. In the same missions, in a few trainees, heart rate was continuously recorded with magnetic tape electrocardiograph, and related to flight tasks. The data obtained are discussed with respect to the results of flight final tests, preliminary psychological selection, and previous flight experience, in order to evaluate their importance to flight fitness assessment.
Author

N75-24305 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
SOME FAST ANALYTICAL TECHNIQUES FOR THE EEG
G. H. Byford *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 10 p refs (For availability see N75-24297 15-51)

Three fast single or multichannel techniques were developed and investigated. The shape and size of an electrical signal may be described by means of the amplitude probability density. This statistical characteristic can be calculated on-line for several channels simultaneously, and techniques are available to detect significant differences between one epoch and another of the same channel, or between epochs from different channels. Using a small analogue computer, the signal from a single channel may be divided into 5 frequency bands approximating the accepted physiological definitions; for each, the time course of the integral of signal variance is then plotted automatically at up to 16 times real-time, and the slopes of the curves used to obtain numerical indices of change in eeg activity. It is intuitively satisfactory to describe the eeg in terms of amplitude, frequency and time, but no simple graph will display the interrelationship between these 3 variables. The power spectral density describes the relationship between frequency and amplitude in one epoch; successive spectra can be organized so as to produce a 3 dimensional display, and a technique based on the fast Fourier transform was devised which will satisfactorily decrease the spectral density computer time, by a factor of up to 100. In order to carry out these calculations with adequate speed, a hybrid computing system was developed which may be controlled either from an on-line experiment or from an index placed on one track of an analog FM recording; results are presented as graphs or printed tables.
Author

N75-24306 Naval Aerospace Medical Research Lab., Pensacola, Fla.
IMPACT OF MULTIVARIATE ANALYSIS ON THE AVIATION SELECTION AND CLASSIFICATION PROCESS
Norman E. Lane and Rosalie K. Ambler *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 7 p refs (For availability see N75-24297 15-51)

Continuous quality control which has evolved from the massive use of multivariate statistical techniques made possible by modern computer technology is described along with the selection and classification process from the first coarse screen at widely separated procurement points through the first fleet assignment. Emphasis is on the role of multivariate analysis in the development of statistical forecasts of performance for various points in time within each training option. Among the multivariate techniques that were employed are factor analysis, multiple group discriminant function, and multiple regression analysis. Multiple regression analysis is the most productive and is the principal technique currently used to produce the many series of successive prediction equations which combine quantitative and qualitative data from numerous sources. Comparisons of the multiple regression prediction model with other techniques are made and refinements developed in use of this technique are discussed. These

refinements are concerned with minimizing the impact of sampling error on validity, the handling of potential suppressors, and the development of decision rules for variable selection. These decision rules encompass the practical demands of the training situation as well as the mathematical properties of the potential predictors. Author

N75-24307 Direction des Recherches et Moyens d'Essais, Paris (France)
STANDARDIZATION OF OBJECTIVE MEDICO-PSYCHIATRIC QUESTIONNAIRE IN THE FRENCH ARMY [UN QUESTIONNAIRE MEDICO-PSYCHIATRIQUE OBJECTIF STANDARDISE DANS L'ARMEE FRANCAISE]

Louis Crocq *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 7 p in FRENCH (For availability see N75-24297 15-51)

An objective questionnaire based on data from the psychiatric, neurological, medical, and social history was developed and administered to French Army personnel. Upon completion and verification, the questionnaire is used for initial selection, facilitation of clinical examination and psychological interview, for prognosis of later adaptation, and for easier statistical evaluation and computerization of data. The possible development of a mental hygiene data storage bank from such material was examined. Data are also used to select personnel for specific missions and jobs. Transl. by E.H.W.

N75-24308 Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).
PSYCHIC HEALTH: A QUANTITE NEGLIGEABLE IN FLYING FITNESS EXAMINATIONS
H. P. Goerres *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 6 p refs (For availability see N75-24297 15-51)

After a comparative analysis of possibilities and results of aptitude diagnoses so far applied to applicants by aviation psychologists, experiences gained in routine and psychological follow-up examinations are reported. Various suggestions for the accomplishment of periodic psychologic examinations in the German Air Force are offered and discussed, emphasizing practicability and effectiveness of the different possibilities in detail. It is shown that examinations of this kind could be conducted by the German Air Force without additional expenditures in personnel, provided certain organizational prerequisites are met. Author

N75-24309 Royal Air Force Central Medical Establishment, London (England).
SIXTEEN YEARS EXPERIENCE IN MILITARY AVIATION PSYCHIATRY AND NEUROLOGY
P. J. OConnor *In* AGARD Med. Requirements and Exam. Procedures in Relation to the Tasks of Today's Aircrew Mar. 1975 3 p refs (For availability see N75-24297 15-51)

The wastage of aircrew due to psychiatric causes is discussed. One approach to psychiatric selection is to forecast how a cadet will withstand the stress of flying on the evidence of his previous life history, the approach was investigated. Two ways of tackling psychiatric wastage are found to be the physiological measurement of the cadet's ability to adapt to stress, and the acceptance of the fact that the only test for fitness for flying is the flying itself. It is found that neurological wastage of aircrew is much smaller than psychiatric wastage, and that routine electroencephalography may further reduce neurological wastage by identifying those likely to develop epilepsy. Author

N75-26778# Advisory Group for Aerospace Research and Development, Paris (France).
ELECTRO-OPTICAL SYSTEMS
May 1975 142 p refs
(AGARD-LS-76) Avail: NTIS HC $5.75

Military applications of optic-electronics are reported. The design and application of display devices including helmet mounted devices are discussed. The design and limitations of cockpit and display devices are described for human factors engineering. For individual titles, see N75-26779 through N75-26787.

N75-26779 Hughes Aircraft Co., Culver City, Calif.
LASER AND LOW LIGHT LEVEL TELEVISION SYSTEMS

Richard D. Hudson, Jr. and Jacqueline W. Hudson (Arjay Associates, Encino, Calif.) *In* AGARD Electro-Opt. Systems May 1975 14 p refs (For availability see N75-26778 17-70)

A system-oriented discussion is presented of the design of typical electro-optical systems. Laser rangefinders, laser target designators, and low light level television systems are described as examples of active and semiactive systems. Design equations are developed from first principles but in a way that emphasizes the physical nature of the quantities involved. Several examples of designs are carried out in detail so as to illustrate the manner in which a typical system design proceeds. Author

N75-26780 Marconi-Elliott Avionic Systems Ltd., Rochester (England)
THE APPLICATION OF DISPLAYS IN NAVIGATION/ATTACK SYSTEMS
J. T. Shepherd *In* AGARD Electro-Opt. Systems May 1975 19 p (For availability see N75-26778 17-70)

The use of display systems during the navigation/attack phase of an aircraft mission is outlined. The types of display used and their advantages and limitations are discussed. Author

N75-26781 Hughes Aircraft Co., Culver City, Calif.
FORWARD LOOKING INFRARED SYSTEMS
Richard D. Hudson, Jr. and Jacqueline W. Hudson (Arjay Associates, Encino, Calif.) *In* AGARD Electro-Opt. Systems May 1975 12 p refs (For availability see N75-26778 17-70)

A system-oriented discussion is provided of the design of typical electro-optical systems. Forward looking infrared systems, unlike those described earlier, are an example of a passive sensor system. Design equations are developed from first principles but in a way that emphasizes the physical nature of the quantities involved. The system design process is described and analyzed with emphasis on the tradeoffs that can be made during a design. The advantages of designing with background-limited (Blip) detectors are described. A sample design is provided so as to illustrate the manner in which a typical system design proceeds. Author

N75-26782 Marconi-Elliott Avionic Systems Ltd., Rochester (England).
HELMET MOUNTED SIGHTS AND DISPLAY SYSTEMS

J. T. Shepherd *In* AGARD Electro-Opt. Systems May 1975 13 p (For availability see N75-26778 17-70)

The design and capabilities are reviewed of helmet mounted sights and display systems in the context of a modern navigation/attack. Author

N75-26783 EMI Electronics Ltd., Feltham (England). Ergonomics Lab.
OPTO-ELECTRONIC SYSTEMS: PERCEPTUAL LIMITATIONS AND DISPLAY ENHANCEMENT
A. A. Clarke *In* AGARD Electro-Opt. Systems May 1975 12 p refs (For availability see N75-26778 17-70)

Sensor-display combinations are described which show how they may be designed to extend the limits imposed by the operators perceptual capabilities and environment. It is shown that CRT displays are the most appropriate and a discussion of the various display enhancement techniques are included. Author

N75-26784 Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
TOTAL COCKPIT IMPLICATIONS OF ELECTRO-OPTICAL DISPLAYS
John M. Reising *In* AGARD Electro-Opt. Systems May 1975 16 p refs (For availability see N75-26778 17-70)

The implications for using electro-optical displays to replace many of the electro-mechanical instruments are discussed. A short history of cockpit development is given to show the growth of cockpit instrumentation. After discussing the F-111 as an example of a modern electro-mechanical cockpit, the question is asked, 'Where do we go from here?' Early developments in electro-optical cockpits are reviewed and current research programs are discussed. The unique impacts of electro-optical displays in the design of both close air support and air superiority aircraft are examined in detail. Finally, the future of the electro-optical cockpit is discussed and conclusions reached as to its viability. Author

N75-26785 EMI Electronics Ltd., Feltham (England). Ergonomics Lab.
TWO WORLD DISPLAYS: HUMAN ENGINEERING ASPECTS

A. A. Clarke *In* AGARD Electro-Opt. Systems May 1975 8 p refs (For availability see N75-26778 17-70)

The known information requirements are described for aircrew under three particular mission constraints and shows possible display formats and illustrates applications. Author

N75-26786 Naval Research Lab., Washington, D.C.
OPTICAL FIBER APPLICATIONS
A. Fenner Milton *In* AGARD Electro-Opt. Systems May 1975 21 p (For availability see N75-26778 17-70)

Optical fibers for communication and data transmission are reported. Military applications of the fiber optic links are shown. The principal methods of making optical fibers with a lower index cladding are included. M.C.F.

N75-26787 British Aircraft Corp., Warton (England). Military Aircraft Div.
AIRCRAFT DESIGN IMPLICATIONS OF OPTO-ELECTRONIC SYSTEMS
W. I. McFarlane *In* AGARD Electro-Opt. Systems May 1975 22 p (For availability see N75-26778 17-70)

The application of electro-optical systems to low level aircraft and helicopters is discussed with particular emphasis on the installational problems of weight, drag, the need for transparencies, and power and cooling requirements. In addition the need for integration and matching of these systems with other equipments, weapons and each other is illustrated from the point of view of optimizing the overall weapon system. Finally an objective is stated whereby these new developments can be integrated to maximize the usefulness of the crew by providing them with the right information from the right sensor on the right display at the right time for them to take executive action. Author

N75-27685# Advisory Group for Aerospace Research and Development, Paris (France).
VIBRATION AND COMBINED STRESSES IN ADVANCED SYSTEMS
Henning E. VonGierke, ed. (AFSC) Mar. 1975 272 p refs In ENGLISH; partly in FRENCH Presented at the Aerospace Med. Panel Specialists Meeting, Oslo, 22-23 Apr. 1974
(AGARD-CP-145) Avail: NTIS HC $8.50

Operational vibration environments and their psychophysiological effects on performances of crews of aircraft, land vehicles, and ships are studied. For individual titles, see N75-27686 through N75-27713.

N75-27686 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
AIRCREW ASSESSMENT OF THE VIBRATION ENVIRONMENT IN HELICOPTERS
B. H. Rance and J. W. Chappelow *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 7 p refs (For availability see N75-27685 18-51)

A survey of military helicopter crews was carried out to determine the scope and nature of problems due to vibration. Three hundred questionnaires were completed. The chief consequences of vibration were discomfort and difficulty in reading displays. The occurrence of these effects was associated with significant increases in reported fatigue. The major effects were, mainly confined to the larger aircraft. Most of the reports from Royal Navy helicopters were associated with hovering or transition to or from the hover; turbulence was found to increase the number of reports of vibration effects. Loading of the aircraft was not found to cause any increase in the number of reports. Author

N75-27687 Max-Planck-Institut fuer Landarbeit und Landtechnik, Bad Kreuznach (West Germany).
HUMAN EXPOSURE TO WHOLE-BODY VIBRATION IN MILITARY VEHICLES AND EVALUATION BY APPLICATION OF ISO/DIS 2631
Heinrich Dupuis *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 7 p refs (For availability see N75-27685 18-51)

The vibration strain of soldiers and test drivers in military vehicles concerns mainly those reactions which, by the way of influencing the sensation and motoric coordination, can decrease the human performance when operating vehicles and carrying out military tasks. So especially visual sensation will be influenced by vibration stress. Furthermore, vibration at high amplitude in certain frequency ranges may lead to injuries to health. Results of vibration measurements in 13 wheeled vehicles, 3 tanks and 2 ambulances show that the vibration stress under certain conditions may be very high. By the use of national and international standards the measured vibration stress is evaluated. As consequences of these results technical improvements and daily exposure time limits are proposed. Author

N75-27688 Surface Effects Ship Project Office, Bethesda, Md.
CREW PERFORMANCE REQUIREMENTS IN THE VIBRATION ENVIRONMENTS OF SURFACE EFFECT SHIPS
Alfred Skolnick *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 22 p refs (For availability see N75-27685 18-51)

Basic requirements and habitability standards are studied for designing surface effect ships employing a self generated cushion of air for lift support with vertical motion centering in the 0.2 to 3.0 Hz region. Emphasis is placed on vibratory loads and crew performance. Using empirical data from 100-ton testcraft and motion predictions from a 2000-ton SES math model, a simulated pilot house is stimulated to portray ship response characteristics at various speeds in diverse sea states. Results of these motion simulations and selected critical crew tasks conducted during the tests for up to four hour intervals are discussed. Author

N75-27689 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE TRANSMISSION OF ANGULAR ACCELERATION TO THE HEAD IN THE SEATED HUMAN SUBJECT
G. R. Barnes and B. H. Rance *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 7 p refs (For availability see N75-27685 18-51)

Sinusoidal angular oscillation in yaw of seated human subjects, both restrained and unrestrained, has demonstrated that responses of significant amplitude may be elicited in all three head axes. In the unrestrained condition, the torso appeared to absorb the input acceleration, the response of the head in the yaw axis exhibiting very rapid attenuation and large phase lags at frequencies above 4 Hz. In the restrained condition, the transmission to the yaw axis of the head was much less severely attenuated with smaller phase lags above 4 Hz. The yaw responses in the unrestrained condition exhibited a resonant peak at 2 Hz. In both experimental conditions there was a significant response in both the roll and pitch axes of the head. The response in pitch exhibited significant 2nd harmonic components which were manifested as a frequency doubling effect between 1 and 6 Hz. Author

N75-27690 Naval Air Development Center, Warminster, Pa. Air Vehicle Technology Dept.
THE EFFECT OF THE INDIVIDUAL AND COMBINED STRESSES OF VIBRATION AND SUSTAINED G ON PILOT PERFORMANCE
A. G. Piranian *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 13 p refs (For availability see N75-27685 18-51)

The human centrifuge was used to evaluate the relative influences of sustained normal accelerations, combined vertical and lateral buffet loads, and basic aircraft flying qualities on air-to-air tracking performance in air combat maneuvering flight. Performing the simulation in an actual F-4B cockpit, 11 pilots were tasked with tracking a moving target with a fixed reticle sight presented in visual display. Sustained accelerations from 1.3 to 5.0 g's, buffet intensity levels from buffet free to + or - .5 g, and lateral directional flying qualities were varied independently in several combinations to assess their individual and combined influences on tracking precision. Results show that for the buffet frequency used (10 cps), intensities up to + or - .5 g have negligible effects on performance. Sustained accelerations up to 5.0 g's have appreciable effects, degrading tracking by 10 mils over the 1.0 g level. Flying qualities' influences were substantial, and greater than those of either buffet or acceleration. Decreased dutch roll frequency and/or damping, adverse aileron yaw, and proverse aileron yaw were seen to have degrading effects on performance. Author

N75-27691 Deutsche Versuchsanstalt fuer Luft- und Raumfahrt, Bad Godesberg (West Germany). Acceleration Physiology Dept.
EFFECTS OF TRANSIENT VIBRATIONS ON HUMAN SAFETY AND PERFORMANCE
Lorenz H. Vogt *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 10 p refs (For availability see N75-27685 18-51)

Transient vibrations and impact forces represent possible hazards in underground personnel shelters when subjected to pressure waves from nuclear blasts. Calculated and simulated acceleration time relationships are compared to safety limits for humans. By way of an existing nonlinear model for supine humans, the application of a general model for transient and steady state conditions is proposed. Performance limits for transient conditions are scarce. Some information may be gained by applying the results from steady state experiments to transient conditions.
Author

N75-27692 Centre d'Essais en Vol, Bretigny-sur-Orge (France) Lab. de Medecine Aerospatiale.
ACTION OF LOW VIBRATION FREQUENCIES ON THE CARDIOVASCULAR SYSTEM OF MAN [ACTION DES VIBRATIONS DE BASSES FREQUENCES SUR LE SYSTEME CARDIO-VASCULAIRE DE L'HOMME]
J. Demange, R. Auffret, and B. Vettes *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 5 p refs In FRENCH (For availability see N75-27685 18-51)

Cardiac variability in subjects exposed to low frequency mechanical vibrations was studied. Vascular response to these vibrations was also measured. Particular attention was given to physiological disorders, especially in the case of vibration effects on sick or wounded subjects. Measurements were made of circulation and human performance after exposure to the vibrations; some subjects were required to perform complex tasks. Transl. by E.H.W.

N75-27693 Kentucky Univ., Lexington. Wenner-Gren Research Lab.
EFFECTS OF VIBRATION STRESS ON THE CARDIOVASCULAR SYSTEM OF ANIMALS
Ernest P. McCutcheon *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 13 p refs (For availability see N75-27685 18-51)

Results from a recent series of investigations on the mechanisms and pathways involved in the two major types of physiological responses to mild to moderate levels of vibration exposure are reported. The majority of these studies are based on the chronically instrumented animal preparation. In addition to representative cardiovascular and mechanical variables, many of the studies include hormonal, metabolic, hematological, and psychological measurements in order to quantify the vibration parameters, estimate the overall stress level, identify specific response patterns, and evaluate the relative dependence of cardiovascular changes on these factors. Author

N75-27694 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
LABORATORY STUDIES ON CHRONIC EFFECTS OF VIBRATION EXPOSURE
D. V. Sturges, D. W. Badger (Natl. Inst. for Occupational Safety and Health, Cincinnati), R. N. Slarve, and D. E. Wasserman (Natl. Inst. for Occupational Safety and Health, Cincinnati) *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 2 p refs (For availability see N75-27685 18-51)

Rhesus monkeys were chronically exposed to sinusoidal vibration in the Z axis. Gastrointestinal bleeding and lowered hematocrits were noted during exposure. Multiple lesions of the gastric mucosa were seen at necropsy. The impression is one of early erosive hemorrhaging gastric lesions with subsequent adjustment to the stress and resultant healing of the lesions.
Author

N75-27695 National Inst. for Occupational Safety and Health, Cincinnati, Ohio.
SERUM AND URINE CHANGES IN MACACA MULATTA FOLLOWING PROLONGED EXPOSURE TO 12 Hz, 1.5 g VIBRATION
D. W. Badger, D. V. Sturges (Aerospace Med. Res. Lab.), R. N. Slarve (Aerospace Med. Res. Lab.), and D. E. Wasserman *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 3 p refs (For availability see N75-27685 18-51)

Serum and urine changes in male rhesus monkeys were measured before, during, and after exposure to 12 Hz, 1.5 g vibration 5 hours daily for 130 hours. Marked erythrocyte loss occurred in 10 exposed animals within 3 weeks, probably as a result of extensive gastrointestinal lesions. Serum albumin globulin ratios decreased. Similar values for 13 controls were unchanged during this time. No evidence of renal impairment was seen since serum creatinine was unchanged and hematuria, increased proteinuria and urine sediment morphology were either absent or not changed. Author

N75-27696 Centre d'Essais en Vol, Bretigny-sur-Orge (France) Lab. de Medecine Aerospatiale.
RAPID FLIGHT VIBRATION PHENOMENA AND SPINE FRACTURES [PHENOMENES VIBRATOIRES RAPIDES EN VOL ET FRACTURES DU RACHIS]
R. Auffret, R. P. Delahaye, and J. Salvagniac *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 5 p refs In FRENCH (For availability see N75-27685 18-51)

Severe vibrations leading to vertebral fractures to pilots of high performance jet aircraft are examined. Specifically two cases were studied: sudden intensive accelerations causing ejection from seats, and aircraft malfunctions or sudden movements as caused by turbulence, pilot correction procedures, aircraft control, or servomechanism malfunctions. Transl. by E.H.W.

N75-27697 Army Aeromedical Research Lab., Fort Rucker, Ala.
EFFECTS OF VIBRATION ON THE MUSCULOSKELETAL SYSTEM
Walter M. Braunohler *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 7 p refs (For availability see N75-27685 18-51)

No significant change occurs in bone mineral density after short term helicopter flying. However, the impact conditions of basic physical training induce 10% demineralization of the distal ulna. It is our impression that this is a transient phenomenon. Long term follow-up of helicopter pilots flying 6.5 hours/week over two years reveals no evidence of musculoskeletal strain; however, there appears to be a trend towards demineralization of the distal radius. Continued monitoring of this population group is recommended to determine when pathological changes may be expected to occur. Author

N75-27698 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE RESPIRATORY AND METABOLIC EFFECTS OF CONSTANT AMPLITUDE WHOLE-BODY VIBRATION IN MAN
G. R. Sharp, G. A. Patrick, and W. R. Withey *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 6 p refs (For availability see N75-27685 18-51)

Nine human subjects were exposed to constant amplitude whole body, G sub z vibration, for 10 minutes, at frequencies of 2, 4, 6, 8 and 10 Hz. It was found that at 2 and 4 Hz pulmonary ventilation, oxygen uptake, and tidal carbon dioxide tension and heart rate were unchanged. At frequencies of 6, 8 and 10 Hz, however, there was an increase in pulmonary ventilation and in oxygen uptake. Pulmonary ventilation was increased in excess of the oxygen uptake, resulting in hyperventilation. There were no qualitative or quantitative differences in values of pulmonary ventilation or oxygen uptake between subjects when unrestrained and when fully restrained on the vibrator. Most subjects experienced discomfort or pain during exposure to frequencies of 6, 8 and 10 Hz. It is considered that this pain induced the observed hyperventilation. The increase in oxygen uptake is thought to be related to the tensing of musculature.
Author

N75-27699 Southampton Univ. (England). Human Factors Research Unit.
A STUDY OF VIBRATION, PILOT VISION AND HELICOPTER ACCIDENTS
Michael J. Griffin *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 16 p refs (For availability see N75-27685 18-51)

A series of experiments has been conducted to investigate the hypothesis that the occurrence of helicopters flying into wires is associated with vibration having a detrimental effect on pilot visual acuity. The research commenced with an investigation of the evidence for the problem by surveying the incidence of wire strikes and determining the conditions in which they occur. The second study measured pilot visual acuity during flight in two different helicopter types. It was concluded that under normal conditions the loss of visual acuity in these two helicopters was unlikely to be a major cause of wire strikes. The third investigation resulted in the detailed specification of the vibration experienced in the Scout AH Mk 1 helicopter. Particular emphasis was placed on the changes in vibration with the various flight conditions and the differences between pilots and between aircraft of the same type. The final series of experiments were designed to determine the minimum levels of vibration which would affect visual acuity. Author

N75-27700 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
MECHANISMS OF VIBRATION EFFECTS ON AIRCREW PERFORMANCE
Richard W. Shoenberger *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 9 p refs (For availability see N75-27685 18-51)

The effects of vibration on a variety of human performance tasks are reviewed. Research is categorized with respect to the predominant performance requirements of the tasks investigated, and results are evaluated in order to determine which aspects of task performance (sensory input, central processing, and motor output) are affected by vibration interference. This procedure reveals that the vast majority of vibration effects occur for tasks which require fine sensory discrimination or precise motor response, or both; only a very few studies show effects which can be attributed to interference with intellectual or cognitive functions. On the basis of logical analyses of differential vibration effects on various types of tasks it is suggested that the predominant mechanism for vibration performance effects is direct mechanical interference with functions occurring in the input and output stages of operator performance tasks. Vibration effects on tasks which are primarily intellectual in nature and have minimal sensorimotor requirements are discussed in relation to generalized stress mechanisms. Recent research is described in which analytical decomposition of reaction time measures made it possible to definitively isolate vibration effects on peripheral and central performance functions within a single task. Author

N75-27701 Dayton Univ. Research Inst., Ohio.
PERFORMANCE AND PHYSIOLOGICAL EFFECTS OF COMBINED STRESS INCLUDING VIBRATION
J. C. Guignard *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 6 p refs (For availability see N75-27685 18-51)

Whole body vibration affects human task performance by two main mechanisms: peripherally, by mechanical interference at the point of contact between the man and his task; and centrally, by burdening the brain with irrelevant sensory information. In the latter regard, the action of vibration is in some ways akin to that of noise. Any particular effect of vibration on performance depends on many factors, including the physical characteristics of the vibration, the nature of the task and the skill and motivation of the performer, time, and the presence of other stressful agents or circumstances. Unfortunately, our ignorance of the psychophysiological mechanisms by which vibration degrades particular kinds of task performance is still profound, and our knowledge for the most part qualitative in nature. That is mainly because much laboratory based research into the psychophysiological actions of vibration suffers from the lack of an appropriate standardized methodology and of complete and proper measurements of the vibratory forces affecting the man at the time when his performance is being evaluated. Author

N75-27702 Medical Research Council, Cambridge (England).
EFFECTS OF DURATION OF VERTICAL VIBRATION BEYOND THE PROPOSED ISO "FATIGUE-DECREASED PROFICIENCY" TIME, ON THE PERFORMANCE OF VARIOUS TASKS
R. T Wilkinson and R. Gray (RAE, Farnborough, England) *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 5 p refs (For availability see N75-27685 18-51)

Six subjects carried out four 3-hour sessions of performance tasks, two with continuous 5 Hz, 1.2 m/s squared rms vertical vibration and two under static conditions. There was no general support for a prediction from the proposed ISO curves of fatigue-decreased proficiency (FDP) that vibration can lower proficiency as a function of duration of exposure. However, vibration associated with a 1-hour vigilance task and knowledge of results decreased proficiency towards the end of the 3-hour work period. Author

N75-27703 Advisory Group for Aeronautical Research and Development, Paris (France).
PERIPHERAL VISION ARTIFICIAL HORIZON DISPLAY

R. Malcolm, K. E. Money, and P. Anderson *In its* Vibration and Combined Stresses in Advan. Systems Mar. 1975 3 p ref (For availability see N75-27685 18-51)

The artificial horizon instrument currently used in aircraft suffers from two shortcomings: the pilot cannot obtain continuous information from it, since he must also look at other instruments and second, during episodes of heavy vibration, turbulence or disorientation, a small instrument becomes extremely difficult to read. This paper describes a device which projects a line or bar of light from beside the pilot's head forward onto the instrument panel. The line is approximately one to four inches wide and subtends 160 - 170 deg of arc from the pilot's head, so that it extends well into his peripheral vision. The light source is driven by servomotors which are controlled from the aircraft's inertial gyros, such that the bar of light seen by the pilot duplicates the pitch and roll motions of the real horizon outside the cockpit. The advantages of this display are: visibility during turbulence and vibration, visibility while looking at other instruments, and reduction of the pilot's workload by making use of the neural programming which naturally orients us with the horizon. Author

N75-27704 Federal Inst. for Occupational Safety and Accident Research, Dortmund (West Germany).
A REVIEW OF BIOMECHANICAL MODELS FOR THE EVALUATION OF VIBRATION STRESS
Wolfgang Lange *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 8 p refs (For availability see N75-27685 18-51)

Physical resonances of the human body or of its parts under vibration correlate with subjective responses. Biodynamic models can be calculated from data of vibration investigations. Several such models are discussed. The models differ in their degrees of freedom, in their mass, elasticity and damper elements, and in the way these elements are coupled. A further important parameter is the linearity or nonlinearity of the model. For the evaluation of vibratory stress it is necessary to establish physiological and/or psychological criteria which correlate with biomechanical responses that can be simulated by models. Several methods for evaluating vibration stress are discussed and compared. Author

N75-27705* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
AN ELEMENTARY PSYCHOPHYSICAL MODEL TO PREDICT RIDE COMFORT IN THE COMBINED STRESS OF MULTIPLE DEGREES OF FREEDOM
Ralph W. Stone, Jr. *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 7 p refs (For availability see N75-27685 18-51)

The quality of airplane rides probably will become increasingly important to passengers, particularly in terminal area operations and on short haul trips. The development of models to predict ride comfort is considered. An elementary model concept is presented herein and compared with subjective ride comfort response ratings measured on actual scheduled airline flights and simulated flights. Author

N75-27706 Kentucky Univ., Lexington.
MODELS OF THE CARDIOVASCULAR SYSTEM UNDER WHOLE BODY VIBRATION STRESS
Charles F. Knapp *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 13 p refs (For availability see N75-27685 18-51)

Five major mechanisms can be listed as the main factors responsible for producing alterations in the circulatory system exposed to vibration. The mechanisms important for vibration stress of a given waveform, frequency, displacement, acceleration, transmitted force, axis, and duration are: (1) reaction of the fluid and vessel system; (2) reaction of large body organ systems and the musculoskeletal system; (3) reaction of the mechanoreceptors; (4) reaction of the hormonal metabolic and hematological systems; and (5) reaction modification through the central nervous system and the psychophysiological pathways. Analytical efforts are reviewed as they relate to the five mechanisms listed above and current efforts in modeling the hydrodynamic aspects of the cardiovascular system are discussed in order to estimate its relative contribution to the total changes in arterial pressures and flows measured in animals exposed to whole body sinusoidal vibration. Author

N75-27707 Systems Technology, Inc., Hawthorne, Calif.
EVALUATING BIODYNAMIC INTERFERENCE WITH OPERATIONAL CREWS
Henry R. Jex and R. Wade Allen *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 18 p refs (For availability see N75-27685 18-51)

A review is made of operational situations in which biodynamic interference with aircrews is a problem, and it is shown that there is a large contrast between the information needed to

evaluate these problems in operational situations versus that available from existing laboratory research. A structure and means for extrapolating the large and growing empirical data base is discussed. Some progress in work along these lines is presented, including: Systems performance models for interrelating the many variables; refined biomechanical models for analyzing vibration feedthrough to controls in closed loop manual tasks; and procedures for including habitability or ride ratings in the overall evaluations. Author

N75-27708 Advisory Group for Aeronautical Research and Development, Paris (France).
THE ISO GUIDE FOR THE EVALUATION OF HUMAN WHOLE BODY VIBRATION EXPOSURE
G. Bobbert *In its* Vibration and Combined Stresses in Advan. Systems Mar. 1975 6 p refs (For availability see N75-27685 18-51)

It exists a demand for regulations to evaluate the vibration exposure of human beings. Although the knowledge of the human reaction is not sufficient for all cases of vibration exposure, experts from ten countries discussed a standard which gives a guide for the evaluation. As this standard is agreed by the ISO-Council and it is now going to be printed, the background of this standard and the most important details are reported. Author

N75-27709 Royal Aircraft Establishment, Farnborough (England). Human Engineering Div.
PROPOSED LIMITS FOR EXPOSURE TO WHOLE BODY VERTICAL VIBRATION, 0.1 TO 1.0 Hz
Geoff Allen *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 11 p refs (For availability see N75-27685 18-51)

The need for design standards for civil and military vehicles to cover human reaction to vibration below 1 Hz is outlined. Limits are proposed against two criteria: the first, to prevent severe discomfort merges at 1 Hz with the DIS2631 exposure limit; the second, to prevent reduced comfort merges at 1 Hz with the DIS2631 reduced comfort boundary. Because of lack of information, limits have been given for 25 minute and 8 hour durations only, and it has not been possible to suggest values for the preservation of working efficiency. The information on which the proposals are based is outlined, namely some twenty laboratory and field investigations and critical reviews, yielding about fifty data points. Considering the approximate nature of some of the information it is relatively consistent, and reinforces previous assertions that the critical frequency range for motion sickness is below 0.5 Hz. Author

N75-27710 Boeing Co., Wichita, Kans.
RIDE QUALITY OF CREW MANNED MILITARY AIRCRAFT
Stanley H. Brumaghim *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 7 p refs (For availability see N75-27685 18-51)

Ride quality criteria are compared in terms of both short term and extended term crew performance decrement thresholds. Flight test data are included which illustrate the capability to modify aircraft response to gusts through ride control systems. Requirements to strengthen application of existing criteria to design of airplane ride control systems are given. Chief among these areas are the need for improved ability to handle human response to frequencies of vibration below 1.0 Hz and in validation of thresholds for extended exposure to vibration. Test data are also discussed which show the need to consider impact of ride environment on time to complete crew tasks, in addition to the more frequent concern with impact on performance errors. Author

N75-27711 Centre de Recherches de Medecine Aeronautique, Paris (France).
STUDY OF MAN'S PHYSIOLOGICAL RESPONSE TO EXPOSURE TO INFRA-SOUND LEVELS OF 130 dB [ETUDE CHEZ L'HOMME DES EFFETS PHYSIOLOGIQUES D'UNE EXPOSITION A DES NIVEAUX INFR-SONORES DE 130 DB]
P. Borredon, J. Nathie, and A. Gibert *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 13 p refs In FRENCH (For availability see N75-27685 18-51)

Infrasound effects on the physiological functions of man, after a 50 minute exposure period, were investigated. Special efforts were made to observe circulatory reactions and summarize totally the action of aerial infrasonic vibrations. Measurements were made of time response to a luminous solicitation, cardiac frequency, and maximum and minimum arterial pressure. An audiogram was made of the aerial luminary tones. Detailed results are given in tabular form. Transl. by E.H.W.

N75-27712 Centre de Recherches de Medecine Aeronautique, Paris (France).
EFFECT OF LOW FREQUENCY AERIAL VIBRATIONS ON NOCTURNAL ACTIVITY OF A RAT [EFFET D'UNE EXPOSITION A DES VIBRATIONS AERIENNES DE BASSE FREQUENCE SUR L'ACTIVITE NOCTURNE DU RAT]
P. Pasquier and J. Nathie *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 4 p refs In FRENCH (For availability see N75-27685 18-51)

Observations were made of rat nocturnal activity after exposure to general aerial vibrations. The rats were exposed for eight hours to sinusoidal vibrations at a pressure of 147 dB and at frequencies of 8, 16, and 32 Hz. Results indicate the vibrations were not loud enough to severely influence nighttime activity, however, some increases and decreases were noted depending on exposure level. Transl. by E.H.W.

N75-27713 Erlangen-Nuremberg Univ. (West Germany)
VIBRATESE LANGUAGE
Wolf D. Keidel *In* AGARD Vibration and Combined Stresses in Advan. Systems Mar. 1975 9 p refs (For availability see N75-27685 18-51)

A brief review of the work done to develop vibratese languages is given. A special type of vibratese language is described using the v. Bekesy model of the cochlea. Here the frequency range of speech is adapted to that of the vibrotactile system without changing the time domain so that the speech communication by means of a mechanical stimulation of the skin of the human forearm can be performed in real time. A highly sophisticated computer program for the LINC 8 or PDP 12 has been written for this purpose. Author

N75-29722# Advisory Group for Aerospace Research and Development, Paris (France).
CURRENT STATUS IN AEROSPACE MEDICINE
Walton L. Jones, ed. (NASA, Washington) May 1975 75 p refs Presented at the Aerospace Med. Panel Meeting, Naples, 16-20 Sep. 1974
(AGARD-CP-154) Avail: NTIS

Papers are presented which discuss the following topics: habitability factors in the design of future space systems, ejection problems, and health and career management issues in the military services. For individual titles, see N75-29723 through N75-29729.

N75-29723 United Aircraft Corp., Washington, D.C. Hamilton Standard Div.
SPACE LIFE SUPPORT TECHNOLOGY FOR A MODULAR INTEGRATED UTILITY SYSTEM
Edwin J. Wulff *In* AGARD Current Status in Aerospace Med. May 1975 8 p refs (For availability see N75-29722 20-51)

Space station environmental control systems developed to provide water purification, waste disposal, heating, cooling, contaminant control, and power generation are considered for commercial application. An earth oriented program, Modular Integrated Utility System (MIUS), designed to recycle energy through the integration of utility services in a single plant that provides solid and liquid waste treatment, water purification, domestic hot water, air conditioning and space heating, and electricity is described. The modularity of the MIUS concept is adaptable to military and disaster-relief applications and makes possible the desired technology transfer from the space program to the utility needs of the less developed nations. Author

N75-29724 European Space Technology Center, Noordwijk (Netherlands).
HABITABILITY DESIGN IN EUROPE'S SPACELAB: A STATUS REPORT
A. B. Thompson *In* AGARD Current Status in Aerospace Med. May 1975 7 p refs (For availability see N75-29722 20-51)

The habitability data obtained on previous manned space missions, particularly Skylab are reviewed in terms of the Spacelab module design, both interior environment and laboratory architecture. Unresolved habitability problems concerning the lack of up-to-date anthropometric data on males and females and potential motion sickness during the first days of weightlessness are considered. J.M.S.

N75-29725* National Aeronautics and Space Administration, Washington, D.C.
A SUMMARY OF SKYLAB FINDINGS OF INTEREST TO LIFE SCIENTISTS
Walton L Jones *In* AGARD Current Status in Aerospace Med. May 1975 16 p refs (For availability see N75-29722 20-51)

The medical findings of the Skylab mission are discussed along with the habitability, man machine factors, and the reliability of Skylab life support systems. Author

N75-29726 Italian Air Force Aerospace Medical Center, Rome.
PRELIMINARY RESEARCH ON BODY DISPLACEMENT DURING LUNAR WALKING
A Scano and A Castellani *In* AGARD Current Status in Aerospace Med May 1975 6 p refs (For availability see N75-29722 20-51)

A 16 mm film taken during Scott's and Irwin's walk on the surface of the moon is employed to analyze body displacement during lunar walking. The technique and results are described. J.M.S.

N75-29727 School of Aerospace Medicine, Brooks AFB, Tex. Biodynamics Branch.
THE PLUS Gz PROTECTIVE METHODS FOR USE IN ADVANCED FIGHTER-ATTACK AIRCRAFT
Robert W. Krutz, Jr., Sidney D. Leverett, Jr., Russell R. Burton, and John W. Burns *In* AGARD Current Status in Aerospace Med. May 1975 7 p refs (For availability see N75-29722 20-51)

Methods to enhance acceleration tolerance and protection are reviewed. Emphasis is placed on the following anti-G devices or techniques: (1) the L-1 straining maneuver, (2) positive pressure breathing, (3) preacceleration inflation, (4) uniform pressurization of the lower body, and (5) a tilt-back seat. J.M.S.

N75-29728 School of Aerospace Medicine, Brooks AFB, Tex. Clinical Sciences Div.
THE AIRCREWMAN AT INCREASED RISK OF ISCHEMIC VASCULAR DISEASE
Malcolm C. Lancaster *In* AGARD Current Status in Aerospace Med. May 1975 5 p refs (For availability see N75-29722 20-51)

A combined risk approach is proposed to delay or prevent the serious consequences of ischemic vascular disease (IVD). The approach consists of a set of risk factors that predict individual susceptibility to IVD and a set of proven interventions directed at specific risk factors. J.M.S.

N75-29729 Defense Dept., Washington, D.C. Office of the Assistant Secretary of Defense for Health and Environment.
A STUDY ON MEDICAL OFFICER CAREER MANAGEMENT AND RETENTION IN THE USA ARMED FORCES
John E. Murphy *In* AGARD Current Status in Aerospace Med. May 1975 13 p refs (For availability see N75-29722 20-51)

Factors which influence career management and retention of medical officers in the Armed Forces are identified. Various mathematical techniques were used to identify the individual goals of medical officers and the relationship of these goals to selected aspects of a military career. Results include information on the perceptions and expectations of young medical officers toward a career in the Armed Forces. Specific potential policy changes are evaluated in terms of improved career management and increased retention of medical officer. Author

N75-32716# Advisory Group for Aerospace Research and Development, Paris (France).
BIODYNAMIC RESPONSE TO WINDBLAST
D. H. Gleister, ed. (RAF Inst. of Aviation Med.) Jul. 1975 87 p refs In ENGLISH and partly in FRENCH Conf. held at Toronto, 6 May 1975
(AGARD-CP-170) Avail NTIS HC $4.75

The specific problem of windblast is considered as it affects human tolerance to high speed ejection. Topics discussed include: prevalence of ejection injury, injury mechanisms, prevention, and problems of head restraint and helmet loss. For individual titles, see N75-32717 through N75-32726.

N75-32717 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
USAF NON-COMBAT EJECTION EXPERIENCE 1968-1973 INCIDENCE, DISTRIBUTION, SIGNIFICANCE AND MECHANISM OF FLAIL INJURY
W. Steves Ring, James W. Brinkley, and Frank R. Noyes *In* AGARD Biodyn. Response to Windblast Jul. 1975 8 p refs (For availability see N75-32716 23-51)

The USAF noncombat ejection experience during the period 1968-1973 is reviewed attempting to characterize the incidence, distribution, significance, and mechanism of flail injuries. The overall incidence of flail injury is 7% in which 4% involved injuries of a major type. The distribution of injuries is characterized by (1) an absence of major head and neck flail injury, (2) a predominance of proximal over distal injury, and (3) in marked contrast to earlier data, a slight predominance of upper over lower extremity flail injury. The importance of analyzing the forces acting upon the limbs as well as having a clear understanding of the mechanisms of failure is discussed and the need for improved limb restraints is emphasized Author

N75-32718 Italian Air Force Military School of Aviation Medicine, Rome.
SURVEY ON BIODYNAMIC RESPONSE TO WINDBLAST IN EJECTIONS: PATHOGENETIC MECHANISM, ANALYSIS AND PREVENTION OF INJURIES
Gaetano Rotondo *In* AGARD Biodyn. Response to Windblast Jul. 1975 9 p refs (For availability see N75-32716 23-51)

Injuries caused by windblast during escape by ejection seat from high speed jet aircraft are analyzed along with traumatic injuries suffered by aircrews within the cockpit of aircrafts following accidental loss or sudden opening of the canopy or after its explosion in-flight. The pathogenetic mechanisms of the injuries caused by windblast are examined along with the relative limits of human tolerance and the systems which could be employed and improved to increase human resistance to aerodynamic pressure of the wind. Emphasis is placed on the prevention and reduction of the fatality of these injuries. Author

N75-32719 Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).
ACCIDENT STATISTICS RELEVANT TO WINDBLAST
R. E. Noble and S. W. Olsen *In* AGARD Biodyn. Response to Windblast Jul. 1975 4 p refs (For availability see N75-32716 23-51)

During the period 1966-1974 injuries were significant problems in ejections from Canadian Forces (CF) aircraft. There were ninety nonfatal ejections. Of these, eight crew members escaped free from injuries, sixty-three received minor injuries, and nineteen received serious injuries. An analysis of the injury patterns indicates that they occurred at both low and high speeds. Specific problems are addressed and recommendations are made to enhance aircrew safety during ejection. Author

N75-32720 Royal Naval Scientific Service, London (England).
PATHO-PHYSIOLOGICAL EFFECTS OF WIND BLAST FROM CONVENTIONAL AND NUCLEAR EXPLOSIONS
J. S. P. Rawlins *In* AGARD Biodyn. Response to Windblast Jul. 1975 5 p refs (For availability see N75-32716 23-51)

The patho-physiological effects of wind blast resulting from conventional and nuclear explosions are analyzed and related to the effects of wind blast encountered in high speed aircraft ejections and in airborne aircraft breakup, and to some instances of ground impact. It is suggested that data derived from studies of explosive blast effects may contribute to the analysis of aircraft accidents, and to the development of protective equipment for the crews of high performance aircraft. Author

N75-32721 Centre d'Essais en Vol, Bretigny-sur-Orge (France).
INJURIES OBSERVED FOLLOWING HIGH-SPEED EJECTIONS IN THE FRENCH AIR FORCE [LESIONS OBSERVEES APRES EJECTION A GRANDE VITESSE DANS L'ARMEE DE L'AIR FRANCAISE]
R. P. Delahaye (Hopital Begin), B. Vettes, and R. Auffret *In* AGARD Biodyn. Response to Windblast Jul. 1975 8 p refs In FRENCH (For availability see N75-32716 23-51)

A review is presented concerning 256 ejections from French Air Force aircraft at speeds ranging between 0 and 750 knots, that took place between 1960 and 1974. The following overall statistics are given: 47 ejections (18 %) were fatal, while 209 (82 %) were successful. A total of 130 helmets (51 %) and 30 masks (15 %) were lost. In the case of ejections performed at speeds above 400 knots (23 cases), air blast effects increase the severity of injuries to personnel and damage to equipment. The percentage of fatalities remains at 18 %, while the percentage of injured aircrews reaches 78 % (as opposed to an overall percentage of 35 %); 78% of helmets and 40% of masks are lost. Only one pilot landed unhurt. Injuries range from so-

chymoses to avulsion of limbs. The above data agrees fairly well with comparable data from other air forces. Three cases are discussed in detail. Transl. by Y.J.A.

N75-32722 Royal Aircraft Establishment, Farnborough (England). Engineering Physics Dept
WINDBLAST: PROTECTION FOR THE HEAD BY MEANS OF A FABRIC HOOD
J. M. Rayne *In* AGARD Biodyn. Response to Windblast Jul. 1975 10 p refs (For availability see N75-32716 23-51)

Wind tunnel experiments and operational experience indicate that current helmets are lost during ejection as a result of windblast. The feasibility is studied of protecting the head from exposure to blast by means of an automatically erected fabric hood. It is shown that such a hood placed over the face of a dummy test subject drapes the head effectively on exposure to blast, and prevents the loss of even simple helmet assemblies up to Mach 1. Author

N75-32723 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
AN ARM RESTRAINT SYSTEM FOR EJECTION SEATS IN HIGH PERFORMANCE AIRCRAFT
P. H. R. Gill *In* AGARD Biodyn. Response to Windblast Jul. 1975 4 p refs (For availability see N75-32716 23-51)

A restraint system designed for high performance aircraft from which ejection at high speeds is likely is described. The system evolved comprises a seat portion consisting of two fixed length tapes, and a man portion incorporated into a sleeved life preserver. Each seat tape is enclosed in a fabric tube which allows automatic disconnection of the two portions during emergency ground egress. The system functions on ejection by retracting the arms in a similar manner to leg restraint systems. The development, testing and performance of the system is described. Limited studies have demonstrated that the proposed rate of arm retraction is physiologically acceptable both with the hands on the firing handle and under simulated commanded ejection. The arm restraint tapes can be routed unobtrusively to prevent interaction upon routine cockpit movement during normal flight. The performance of the arm restraint system during ejection tests using dummies is also described. Author

N75-32724 Payne, Inc., Annapolis, Md.
ON PUSHING BACK THE FRONTIERS OF FLAIL INJURY
Peter R. Payne *In* AGARD Biodyn. Response to Windblast Jul. 1975 7 p refs (For availability see N75-32716 23-51)

Under combat conditions, limb flail injury in U.S. open ejection seats is shown to be a severe problem. Adequate passive entrapment devices demonstrated in the wind tunnel and adequate seat stabilizing devices also demonstrated in full-scale wind tunnel testing and by air drops are reviewed. An extraction escape system is described which offers hope, not only of avoiding the high speed problems of existing tractor rocket escape systems, but also of substantially reducing system volume, cost, and weight, as well as simplifying the flail injury problem. Author

N75-32725 Payne, Inc., Annapolis, Md.
EXPERIMENTAL EVALUATION OF LIMB FLAIL INITIATION AND EJECTION SEAT STABILITY
Fred W. Hawker and Anthony J. Euler *In* AGARD Biodyn. Response to Windblast Jul. 1975 17 p refs (For availability see N75-32716 23-51)
(Contract F33615-74-C-4015)

Limb dislodgement forces were determined in free flight simulation of an ejection along with the static stability of the seats/occupant combination. The forces and moments measured with anthropometric dummies and live subjects in identical ejection seats were compared. Results are presented and discussed. Author

N75-32726 Research Inst. of National Defence, Stockholm (Sweden).
HIGH SPEED EJECTIONS WITH SAAB SEATS
B. O. Andrae, E. Ek, H. Lorin, and B. Ch. R Stroemblad *In* AGARD Biodyn. Response to Windblast Jul. 1975 5 p ref (For availability see N75-32716 23-51)

The Swedish development work on devices to protect against windblast effects at high speed ejections is surveyed. Examples of past, present, and future solutions are given. The Swedish Air Force Experience with high speed ejections is summarized. Author

N76-11693# Advisory Group for Aerospace Research and Development, Paris (France).
RADIATION HAZARDS
Aug. 1975 149 p refs Presented at a Lecture Series in The Netherlands, 22-23 Sep. 1975, Germany, 25-26 Sep. 1975, and Norway, 29-30 Sep. 1975 Sponsored by the Aerospace Med. Panel and the Consultant and Exchange Programme of AGARD
(AGARD-LS-78) Avail: NTIS HC $6.00

There has been a remarkable development and increase in the number of processes and devices that utilize or emit non-ionizing radiation which includes ultra-violet, visible light, infrared, microwave, radiofrequency, ultrasound. This series provides a scientifically accurate, authoritative review and critical analysis of the available information and concepts to give a basis for informed judgements and judicious application of these energies for maximal benefit and minimum risk or hazard to man. For individual titles, see N76-11694 through N76-11704.

N76-11694 Rochester Univ., N.Y. School of Medicine and Dentistry.
PATHOPHYSIOLOGIC ASPECTS OF EXPOSURE TO MICROWAVE
Sol M. Michaelson *In* AGARD Radiation Hazards Aug. 1975 7 p refs (For availability see N76-11693 02-51)

Body temperature increase during exposure to microwaves is explored. Awareness of microwave exposure is developed by several mechanisms, including cutaneous thermal sensation or pain. Cataracts were produced in some experimental animals, primarily rabbits, when the eyes were directly exposed to rather high power density of microwaves over periods ranging from several minutes to hours. Microwave effects on the tests was studied, along with chromosome changes, hematopoiesis, and cardiovascular effects. J.A.M.

N76-11695 Bristol General Hospital (England).
PHYSICAL ASPECTS - ULTRASOUND
B. N. T. Wells *In* AGARD Radiation Hazards Aug. 1975 7 p refs (For availability see N76-11693 02-51)

Ultrasound, which is a form of energy consisting of mechanical vibrations the frequencies of which lie above the range of human hearing, travels through media in the form of waves. At frequencies of tens to hundreds of kilohertz, ultrasound may be generated and detected by magnetostriction; at higher frequencies, piezoelectric, and particularly ferroelectric, transducers are used. At megahertz frequencies, ultrasonic powers are most conveniently measured by radiation pressure detectors, or by calorimetry. In biological soft tissues, ultrasonic waves are usually in the longitudinal mode, and travel at velocities of around 1 500 m/s. The shape of ultrasonic field depends on the size of the transducer in relation to the wavelength. Focusing systems of quite small dimensions can be used to produce high intensities at megahertz frequencies. Specular reflection occurs at discontinuities in characteristic impedance which are large in relation to the wavelength; energy is scattered by smaller discontinuities within biological materials. Author

N76-11696 Washington Univ., Seattle. Bioelectromagnetics Research Lab.
BIOPHYSICS - ENERGY ABSORPTION AND DISTRIBUTION
Arthur W. Guy *In* AGARD Radiation Hazards Aug. 1975 14 p refs (For availability see N76-11693 02-51)

The interpretation of the biological effects observed in tissues exposed to EM fields requires a complete quantitative description of the fields within the tissues. These fields are complex functions of the source configuration, shape and size of the exposed subject, and the frequency. The average and maximum absorbed power density may vary over many orders of magnitude for the same applied field intensities. Depending on conditions, power absorption may be predominantly at the surface of the subject or may be effecting only superficial tissues in the interior of the subject affecting deep tissues. Author

N76-11697 Air Force Systems Command, Brooks AFB, Tex. Radiation Physics Branch.
ELECTROMAGNETIC RADIATION EFFECTS ON THE EYE

John C. Mitchell *In* AGARD Radiation Hazards Aug. 1975 6 p refs (For availability see N76-11693 02-51)

The purpose is to analyze, collectively, the EMR research studies on ocular effects and provide an overview of the practical aspects of this problem today. The principal conclusions from

this effort are (1) The acute thermal insult from high intensity EMR fields is cataractogenic if intraocular temperatures reach 45-55 C. (2) The EMR exposure threshold is about 100-150 mW/sq cm applied for about 60-100 minutes. (3) There does not appear to be a cumulative effect from EMR exposures unless each single exposure is sufficient to produce some irreparable degree of injury to the eyes. Author

N76-11698 Rochester Univ., N.Y. Dept of Radiation Biology and Biophysics

ENDOCRINE AND CENTRAL NERVOUS SYSTEM EFFECTS OF MICROWAVE EXPOSURE

Sol M. Michaelson *In* AGARD Radiation Hazards Aug. 1975 8 p refs (For availability see N76-11693 02-51)

Functional alterations in the neuroendocrine system of both animals and humans exposed to microwaves were reported. Findings include changes in the secretions of the pituitary gland, adrenal cortex, thyroid gland, and the gonads. In most cases, the endocrine changes attributed to microwave exposure were not adequately documented. Findings of a large number of studies were used to overstate the conclusions, or derive assumptions incompatible with the cybernetic model of the function of the neuroendocrine system. Author

N76-11699 Washington Univ., Seattle. Bioelectromagnetics Research Lab.

MICROWAVE INDUCED ACOUSTIC EFFECTS IN MAMMALIAN AUDITORY SYSTEMS

Arthur W. Guy and Chung-Kwang Chou *In* AGARD Radiation Hazards Aug. 1975 17 p refs (For availability see N76-11693 02-51)

Pulsed microwave fields with incident energy densities of 20 to 40 micro Joule per sq cm per pulse will produce responses in the auditory system of man and animals similar to those produced by auditory stimuli. Recent studies indicate that the responses may be originated from high frequency vibrations induced in the head of the exposed subject by a transient thermal expansion of tissue due to the rapid absorption of the pulsed microwave energy. Author

N76-11700 Royal Marsden Hospital, Sutton (England). Physics Div.

BIOLOGICAL EFFECTS OF ULTRASOUND

C. R. Hill *In* AGARD Radiation Hazards Aug. 1975 4 p refs (For availability see N76-11693 02-51)

Ultrasound comprises mechanical vibrations occurring in the frequency range above 20 kHz and extending in practice to above 10 Hz; correspondingly, there is a very wide range of practical applications, each with different possibilities for exposure of human beings to ultrasonic energy. Three main areas that are necessary to understand the possible hazards from ultrasound use are discussed: (1) the actual physical exposures encountered by humans in various activities; (2) the nature of the biophysical interactions of ultrasound with human tissues; and (3) the evidence for and against significant changes being produced in living systems by the action of ultrasound. Author

N76-11701 Washington Univ., Seattle. Bioelectromagnetics Research Lab

ENGINEERING CONSIDERATIONS AND MEASUREMENTS

Arthur W. Guy *In* AGARD Radiation Hazards Aug. 1975 36 p refs (For availability see N76-11693 02-51)

Quantitation of the biological effects in subjects exposed to electromagnetic fields requires that both the fields in the environment and within the exposed tissues be measured. Fields in the environment can be measured by means of standard off-the-shelf field survey meter sensors consisting of small dipoles with diode or thermocouple-type transducers for converting microwaves or RF energy to proportional electrical signals. Fields and associated absorbed power density in the tissues can be measured by means of thermocouples, thermistors, fiber optic liquid crystal sensors, and thermography. The quantitation of fields associated with exposure of test subjects can be significantly simplified by a judicious choice of exposure techniques. Author

N76-11702 Air Force Systems Command, Brooks AFB, Tex. School of Aerospace Medicine.

ELECTROMAGNETIC INTERFERENCE OF CARDIAC PACEMAKERS

John C. Mitchell *In* AGARD Radiation Hazards Aug. 1975 10 p refs (For availability see N76-11693 02-51)

The effect of electromagnetic radiation (EMR) on cardiac pacemakers is a unique bioeffects problem. Current test procedures, including methods to simulate pacemaker implant conditions and the use of fiber optics instrumentation techniques for cardiac simulation and pacemaker interference evaluation, are presented. Test results and their clinical significance are discussed for different types of EMR emissions including microwave ovens, electrical appliances, gasoline engine ignition, radar, and intense electromagnetic pulse generators. Threshold values for pacemaker electromagnetic interference (EMI) range from 10 V/m for the more sensitive devices to greater than 300 V/m for the less susceptible devices. Such EMI threshold values are further modified by the frequency and pulse width of the incident EMR signal. Maximum interference coupling appears to occur at frequencies between 100 and 500 MHz and the EMI threshold is inversely proportional to pulse width over the range from one microsecond to several milliseconds. The ultimate biological effect is dependent on the characteristics of the EMR source, the proximity of the pacemaker user to the source, the attenuation afforded by body shielding and orientation, and the state-of-health of the pacemaker user. The test results presented provide considerable evidence that many manufacturers have recognized EMI as a potential bioeffects problem and have taken the necessary corrective actions to build devices with good electromagnetic compatibility. Author

N76-11703 Washington Univ., Seattle. Dept. of Rehabilitation Medicine.

ON EMP SAFETY HAZARDS

Arthur W. Guy *In* AGARD Radiation Hazards Aug. 1975 7 p refs (For availability see N76-11693 02-51)

The only two quantitative criteria presently available for setting of electromagnetic pulse (EMP) safety standards are: (1) the ANSI C95.1 Safety Standard based on limiting thermal insult at microwave frequencies, and (2) the thresholds for the stimulation of excitable membranes by electric current. The first is not realistic for application to the EMP since the induced currents and energy deposition in exposed tissue is not based on an applied field amplitude and duration relationship, but is related only to the rise and fall time of the applied field pulse. The induced currents in the tissues of man exposed to impulsive electromagnetic fields do not appear to be sufficient for stimulating action potentials. Author

N76-11704 Rochester Univ., N.Y. School of Medicine and Dentistry.

PROTECTION GUIDES AND STANDARDS FOR MICROWAVE EXPOSURE

Sol M. Michaelson *In* AGARD Radiation Hazards Aug. 1975 6 p refs (For availability see N76-11693 02-51)

The development of adequate and operable standards requires comprehensive evaluation of information obtained from animal experiments and surveys of individuals exposed occupationally. The criteria to be used in evaluating experimental results of microwave exposure and the interacting variables in such assessment requires the exercise of informed judgement. Since there are variations in the criteria used in many countries, these have to be understood and evaluated. Guides and exposure levels in force today appear to be entirely safe. So far, there is no documented evidence of injury to military or industrial personnel or the general public from the operation and maintenance of radars and other RF and microwave emitting sources within the 10 mW/sq cm limit of exposure. There is no evidence of hazard to man from RF and microwaves under normal conditions of operation and exposure. Nevertheless, concern has been aroused about the safety of personnel in intense RF fields close to transmitting antennas operating in the frequency bands below 30 MHz. Such environments are in general of a near-field type which precludes the measurement of power flux. Since hazard evaluation in this frequency range is a function of measurement in the near-field, attention should be paid to the problems inherent in such measurement. Author

N77-11644# Advisory Group for Aerospace Research and Development, Paris (France).
THE PATHOPHYSIOLOGY OF HIGH SUSTAINED +G SUB z ACCELERATION, LIMITATION TO AIR COMBAT MANOEUVERING AND THE USE OF CENTRIFUGES IN PERFORMANCE TRAINING
Neville P. Clarke, ed. (Texas A and M Univ., College Station) and Sidney D. Leverett, Jr., ed. (School of Aerospace Med.) Oct. 1976 77 p. refs Papers presented at the Aerospace Med. Panel Specialists' Meeting, Copenhagen, 5-9 Apr. 1976 (AGARD-CP-189) Avail: NTIS HC A05/MF A01

The risk of significant cardiovascular change to a tactical fighter pilot from exposure to aerial combat accelerations such as those postulated for new high performance aircraft is investigated. Miniature swine were used as animal models to study the effects of high sustained acceleration. The seatback angle was assessed in relation to the psycho-physiological and physio-chemical changes in the human body. The utilization of the human centrifuge for training military pilots for air combat maneuvering +Gz stress is covered including the stress response and stress tolerance during the maneuvers. Centrifuge training improves the pilot's ability to effectively perform in the high G environment. For individual titles, see N77-11645 through N77-11653.

N77-11645# School of Aerospace Medicine, Brooks AFB, Tex.
CHANGES IN CLINICAL CARDIOLOGIC MEASUREMENTS ASSOCIATED WITH HIGH +G SUB z STRESS
Kent K. Gillingham and Phelps P. Crump *In* AGARD The Pathophysiol. of High Sustained +G sub z Acceleration, Limitation to Air Combat Manoeuvering and the Use of Centrifuges in Performance Training Oct. 1976 9 p refs (For primary document see N77-11644 02-51)
Avail: NTIS HC A05/MF A01

Because of reports of subendocardial hemorrhage and myofibrillar degeneration in animals exposed to sustained high G loads, questions have been raised regarding the safety of exposing pilots and human subjects to the similar G-stress levels likely to be encountered in the new high performance fighter aircraft. Noninvasive clinical cardiologic data, including ECGs, vectorcardiograms, systolic time intervals, and maximal treadmill stress tests, were obtained from two groups of subjects before and at several times after exposure to high-G stress. The group exposed to the greater G stress developed moderate cutaneous petechiasis and had other minor physical findings after the G stress, but showed few significant changes in cardiologic data: serum total CPK and LDH levels rose, and preejection period shortened at 48 h poststress. The group exposed to the lesser G stress had no symptoms following the G stress, but the vectorcardiograms revealed transient T-loop angle changes, and preejection period measured at one week poststress was significantly decreased. Because the serum enzyme changes were noncardiac in origin, and because the few other changes were not in a direction indicative of cardiac damage, the G stresses imposed were not significantly injurious. Author

N77-11646# School of Aerospace Medicine, Brooks AFB, Tex.
VENTRICULAR PATHOLOGY IN SWINE AT HIGH SUSTAINED +G SUB z
William F. MacKenzie and Russell R. Burton *In* AGARD The Pathophysiol. of High Sustained +G sub z Acceleration, Limitation to Air Combat Manoeuvering and the Use of Centrifuges in Performance Training Oct. 1976 3 p refs (For primary document see N77-11644 02-51)
Avail: NTIS HC A05/MF A01

Study of miniature swine has shown two distinct types of cardiac pathology as the result of exposure to HSGz. Grossly visible endocardial hemorrhage of varying degrees of severity occur consistently. In severe cases damage to Purkinje fibers is adequate to explain some of the ECG changes that have been found. A stress myocardiopathy is also found characterized by randomly distributed single or grouped, degenerate and dead muscle fibers surrounded by normal appearing fibers. Electron microscopically the lesion is characterized by profound changes in the contractile myofibrils known as myofibrillar degeneration. These changes have also been found in Purkinje fibers. It appears that the subendocardial hemorrhage is related to the combination of tachycardia, strong contractions (positive inotropism), and a hypovolemic ventricle. The stress myocardiopathy has a distinctly different and complex etiology. The ultrastructural lesions are not indicative of a primary hypoxic insult although hypoxia undoubtedly contributes. Author

N77-11647# Naval Air Development Center, Warminster, Pa. Crew Systems Dept.
PSYCHO-PHYSIOLOGICAL AND PHYSIO-CHEMICAL ASSESSMENT OF ACCELERATION INDUCED CHANGES IN HUMANS POSITIONED IN VARIOUS SEATBACK ANGLE CONFIGURATIONS
Victoria M. Voge, Harald J. VonBeckh, and Jeffry S. Bowman *In* AGARD The Pathophysiol. of High Sustained +G sub z Acceleration, Limitation to Air Combat Manoeuvering and the Use of Centrifuges in Performance Training Oct. 1976 9 p refs (For primary document see N77-11644 02-51)
Avail: NTIS HC A05/MF A01

A series of high-G tests were conducted on pilot/subjects using the multi-posture adjustable centrifuge test seat. An increase in human tolerance to sustained acceleration was demonstrated by employing several seat configurations. A significant increase in G tolerance was demonstrated with each increase in seatback angle. The position of the lower legs made no significant difference. Ten subjects between the ages of 20 and 44 with various body builds and G experience took part. All had passed the equivalent of a first class Navy flight physical, including complete spine X-rays and a determination of mental status. Some had previous G experience, either operational or in the human centrifuge, others did not. They were taking no significant medications at the time of the program, and were encouraged to eat normally, to get sufficient rest, and to avoid alcoholic beverages. The testing was carried out over a period of six weeks. The tests were carried out on the analog computer controlled, double gimbaled, dynamic flight simulator which consists of a human centrifuge having a fifty foot radius arm with the capability of attaining 40 G's in 7 seconds. S.M.

N77-11648# Royal Air Force Inst. of Aviation Medicine, Farnborough (England). Biodynamics Div.
CENTRIFUGE ASSESSMENT OF A RECLINING SEAT
David H. Glaister and Brian J. Lisher *In* AGARD The Pathophysiol. of High Sustained +G sub z Acceleration, Limitation to Air Combat Manoeuvering and the Use of Centrifuges in Performance Training Oct. 1976 8 p refs (For primary document see N77-11644 02-51)
Avail: NTIS HC A05/MF A01

A reclining seat has been built which would give a pilot a significant increase in acceleration tolerance whilst maintaining adequate forward vision. The effect of anti-G suit inflation has been investigated using three different pressure regimens, and positive pressure breathing (PPB) has been used to counter the added inspiratory effort which resulted from the considerable +G acceleration vector. The reclining seat alone gave an increase in tolerance of 1.4G when compared with a conventional seat; anti-G suit inflation afforded a further 1.0 to 1.6G; and PPB a further 1.0G. The combination led to relaxed greyout thresholds which averaged 7.4G in nine subjects. PPB produced a significant increase in vital capacity and restored the expiratory reserve volume to near normal levels. Subjectively, breathing became much easier. The closing volume of the lung was increased by acceleration, but was not significantly affected by PPB. However, the increase in expiratory reserve volume with PPB should lead to less airway closure during tidal breathing, with a consequent increase in arterial oxygen levels and a decreased susceptibility to acceleration atelectasis. A seat in which a near supine position is adopted with respect to the G vector, when used in conjunction with an anti-G suit and positive pressure breathing, will result in a G tolerance which is in more accord with the performance of modern military aircraft. Author

N77-11649# Texas Univ., Galveston. Medical Branch.
CORONARY FLOW AND MYOCARDIAL BIOCHEMICAL RESPONSES TO HIGH SUSTAINED +G SUB z ACCELERATION
H. L. Stone, L. A. Sordahl, R. T. Dowell, J. N. Lindsey, and H. H. Erickson (School of Aerospace Med.) *In* AGARD The Pathophysiol. of High Sustained +G sub z Acceleration, Limitation to Air Combat Manoeuvering and the Use of Centrifuges in Performance Training Oct. 1976 8 p refs (For primary document see N77-11644 02-51)
Avail: NTIS HC A05/MF A01

In order to determine directly the myocardial response to +Gz acceleration, miniature swine were used as the experimental subjects. Some of the animals underwent surgical implantation of flow probes around the left circumflex coronary artery and a solid-state pressure transducer in the left ventricular cavity. All of the unanesthetized instrumented subjects were exposed to multiple +Gz acceleration levels for 60 to 120 seconds on a human centrifuge. Other subjects were exposed to a single acceleration level for 120 seconds and the hearts removed for

biochemical analysis 1 to 2 hours later. Mitochondria and a lysosomal fraction were isolated from the left ventricle of all animals. Mitochondrial analysis of ADP:O ratio, respiratory control index (RCI), oxygen uptake (QO2) and calcium uptake were made. Free and bound acid phosphatase measurements were made in the lysosomal fraction. Left circumflex coronary artery flow (LCCF), heart rate (HR), left ventricular pressure (LVP), and the rate of rise of LVP (P), were measured in the instrumental animals. LVP and HR increased at all levels of acceleration studied while P increased initially but would decline later. LCCF decreased at all levels of acceleration stress. The mitochondrial ADP:O ratio and the RCI were unchanged but the QO2 and calcium uptake were increased at 9 + Gz. Free acid phosphatase increased at the same level of acceleration. Author

N77-11650# Ohio State Univ., Columbus. Coll. of Veterinary Medicine.

EFFECT OF SUSTAINED +G SUB z ACCELERATION ON CARDIAC OUTPUT AND FRACTIONATION OF CARDIAC OUTPUT IN AWAKE MINIATURE SWINE

Robert L. Hamlin and Sidney D. Leverett, Jr. (School of Aerospace Med.) *In* AGARD The Pathophysiol. of High Sustained +G sub z Acceleration, Limitation to Air Combat Manoeuvering and the Use of Centrifuges in Performance Training Oct. 1976 6 p refs (For primary document see N77-11644 02-52)

Avail: NTIS HC A05/MF A01

Effects of sustained +Gz on cardiac rhythm and output, and on fractionation of cardiac output (CO) were studied in 12 miniature swine centrifuged, while awake, to either +3Gz or +5Gz. CO and its subfractions were measured by injecting radiolabeled microspheres into the left atrium. Percentage of CO perfusing most organs fell precipitously during +5Gz, while that to the heart increased by twofold and that to the pelvic musculature remained nearly constant. At +3Gz percentage perfusing most organs fell, but that to heart and all skeletal muscle rose twofold. When regional flow decreased, it decreased most to the eye, and next to liver, cerebrum, and renal cortex. It decreased least to the midbrain, spleen, renal medulla and gut. The profound changes in CO and fractionation of CO in awake miniature swine subjected to +Gz may represent a summation of: reflex response, a waterfall effect, or deformation of nutrient arteries. Author

N77-11651# Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome (Italy).

UTILIZATION OF HUMAN CENTRIFUGE FOR TRAINING MILITARY PILOTS IN THE EXECUTION OF PROTECTIVE STRAINING MANEUVERS

C. A. Ramacci and G. Meinon *In* AGARD The Pathophysiol. of High Sustained +G sub z Acceleration, Limitation to Air Combat Manoeuvering and the Use of Centrifuges in Performance Training Oct. 1976 3 p (For primary document see N77-11644 02-51)

Avail: NTIS HC A05/MF A01

The importance of the utilization of human centrifuges in the training of pilots in a rational execution of protective straining maneuvers is investigated. A group of young military pilots were submitted to +Gz for comparatively long durations. During the first centrifuge run the subjects were instructed to refrain from performing any voluntary straining maneuvers. Later, the same subjects were submitted to the same acceleration pattern, accompanied, this time, by the execution of the aforesaid straining maneuvers. Exposures to G were repeated. Changes in performance and in tolerance to G were evaluated by recording morphological changes of EXG and heart rate. Subjective feelings of pilots were recorded. Author

N77-11652# School of Aerospace Medicine, Brooks AFB, Tex. Biodynamics Branch.

THE USE OF A FIXED BASE SIMULATOR AS A TRAINING DEVICE FOR HIGH SUSTAINED OR ACM (AIR COMBAT MANEUVERING) +G SUB z STRESS

S. D. Leverett, Jr. and R. R. Burton *In* AGARD The Pathophysiol. of High Sustained +G sub z Acceleration, Limitation to Air Combat Manoeuvering and the Use of Centrifuges in Performance Training Oct. 1976 6 p refs (For primary document see N77-11644 02-51)

Avail: NTIS HC A05/MF A01

The imposition of +Gz stress on 92 highly experienced tactical air command fighter pilots is investigated. A typical class of 22 of these pilots had an average of 1351.66 fighter hours, and were 29.04 years of age (+ or - 0.54). In this same class of 22 fighter pilots they estimated the highest G that they had ever pulled was + or - 9.0 Gz for 6.4 sec. From this data it was apparent that fighter pilots flying the F4E Phantom jet did not pull high sustained G. Therefore a centrifuge program was initiated in order to train pilots at high sustained G and at ACM G. The profile used was as follows: (1) +3 Gz/15 sec - this was an orientation run in order to familiarize the pilot with the centrifuge environment; (2) +5 Gz/45 sec - this extended run was designed to enable the pilot to learn to pace his breathing and straining maneuver properly while being exposed to G sufficient to cause the anti-G suit to inflate; (3) a final ACM type profile that exposed him initially to +5 Gz/10 sec and then proceeded to +8 Gz/30 sec, decelerated to +5 Gz/10 sec and finally the centrifuge was brought to a halt. Under these conditions the 92 pilots' heart rate and rhythm was continuously monitored. Resting heart rate for this larger group prior to initiation of the run averaged 115.93 bpm. While the maximum heart rate at +8 Gz was 167.04 bpm in all instances using a students t-test, the P value is < .001 when the heart rates at any G level are compared to the pre-run control heart rates. All of the pilots were able to complete the proposed series of runs after receiving training by the centrifuge group without a loss of vision. Author

N77-11653# EEG Research Inst., Oslo (Norway).

STRESS RESPONSE AND STRESS TOLERANCE IN FIGHTER PILOTS DURING 6 G MANOEUVERS

C. W. Sem-Jacobsen *In* AGARD The Pathophysiol. of High Sustained +G sub z Acceleration, Limitation to Air Combat Manoeuvering and the Use of Centrifuges in Performance Training Oct. 1976 6 p (For primary document see N77-11644 02-51)

Avail: NTIS HC A05/MF A01

EEG and EKG have been monitored from 250 active fighter pilots flying combat training involving repeated 6 G turns and pullups. 50 students and 9 pilots have been monitored while riding in the back seat of two seater fighters going through the same manoeuvers. More than half of those pilots who had committed pilots error were unconscious with convulsions following 6 G manoeuvers. Gross EEG changes were seen in the EEG. Studies of the EKG and heart rate illustrates the cardio-vascular response. The well suited pilots had a quick response with increase of heart rate when needed to maintain adequate blood supply to the brain. The unsuited groups demonstrate a slow, unsufficient cardiac response leading to brain-anoxia unconsciousness and convulsion. The student pilots and the 9 pilots fell in the same two different categories indicating a basic difference in the functioning of the autonomic nervous system in these two groups. Author

52 AEROSPACE MEDICINE

Includes physiological factors; biological effects of radiation; and weightlessness.

N74-21718# Advisory Group for Aerospace Research and Development, Paris (France)
MAN AT HIGH SUSTAINED +Gz ACCELERATION
R. R. Burton (School of Aerospace Med.), S. D. Leverett, Jr. (School of Aerospace Med.), and E. D. Michaelson (Mt. Sinai Hosp.) Mar. 1974 31 p refs
(AGARD-AG-190; AGARDograph-190) Avail: NTIS HC $4.75 CSCL 06P

Man has tolerated +9Gz for 45 sec and +8Gz for 60 seconds. Physiological changes and tolerance limits in a sustained high acceleration environment are expressed by: (1) high heart rate; (2) reduction in SaO2; (3) cardiac arrhythmia; and (4) subject fatigue. The effects of HSG are marked in terms of gas exchange and arterial hypoxia. Fatigue appears to be the critical factor regarding human limitations to HSG, and arterial desaturation appears to be the limiting factor in subjects using a reclining seat to prevent fatigue. Author

N74-26632# Advisory Group for Aerospace Research and Development, Paris (France). Aerospace Medical Panel.
HELICOPTER AIRCREW FATIGUE
I. C. Perry, ed. May 1974 25 p refs
(AGARD-AR-69) Avail: NTIS HC $4.25 CSCL 05E

A study was conducted to provide: (1) a definition of aviator fatigue, (2) a list of the effects of fatigue on operational effectiveness, (3) a statement of causal factors and diagnostic criteria, (4) a statement of preventive measures, and (5) a statement of methods of treatment of aviator fatigue. These specific aims were accomplished and are presented. In addition, the results are given of an aircrew opinion questionnaire and a review of 120 helicopter accidents. D.L.G.

N74-34570# Advisory Group for Aerospace Research and Development, Paris (France).
OPERATIONAL ASPECTS OF VARIATIONS IN ALERTNESS
Bryce O. Hartman (School of Aerospace Med.), William F. Storm (School of Aerospace Med.), John E. Vanderveen (School of Aerospace Med.), Ernestine Vanderveen (School of Aerospace Med.), Henry B. Hale (School of Aerospace Med.), and Ralph R. Bollinger (School of Aerospace Med.) Aug. 1974 42 p refs
(AGARD-AG-189; AGARDograph-189) Avail: NTIS HC $5.25

Variations in alertness undoubtedly affect operator performance, sometimes to a degree which significantly degrades operational effectiveness. Alertness is a biological state with behavioral, neurophysiological and biochemical elements. Related states are vigilance, attention, and arousal. This monograph summarizes the literature on these topics, as well as the influence of various environments on alertness levels, spontaneous fluctuations in alertness, and effects of such variation on operator performance. The environments under consideration include long duration flights, flights at night, monotonous tasks, solitude, mild hypoxia, and variations in thermal conditions in a flight compartment. Author

N75-17079# Advisory Group for Aerospace Research and Development, Paris (France).
SURVEY OF CURRENT CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS IN MEDICAL SELECTION AND CONTROL OF AIRCREW
A. Sceno (Scuola Militare di Sanita Aeronautica, Roma) Dec. 1974 138 p refs
(AGARD-AG-196; AGARDograph-196) Avail: NTIS HC $5.75

Procedures for conducting the physical examination of aircrew personnel to determine the condition of cardiovascular and respiratory systems are discussed. The examination methods are identified by the country in which performed. Charts are developed which summarize the procedures with respect to: (1) the method used, (2) the aim, (3) the techniques for implementation, (4) the limits of reliability, (5) the weight conferred on each test, and (6) an evaluation of the results. P.N.F.

N75-17936# Advisory Group for Aerospace Research and Development, Paris (France).
AN ANTHROPOMETRIC SURVEY OF 2000 ROYAL AIR FORCE AIRCREW, 1970/71
C. B. Bolton (RAE), M. Kenward (Loughborough Univ.), R. E. Simpson (RAE), and G. M. Turner (RAF) Dec. 1974 84 p refs
(AGARD-AG-181; AGARDograph-181) Avail: NTIS HC $4.75

An anthropometric survey of 2000 Royal Air Force aircrew personnel was conducted. Comparisons of means of certain body dimensions are shown for surveys conducted during periods from 1944 to 1971. The apparatus used on the procedures for conducting the measurements are reported. Other subjects discussed include the following: (1) sociological data, (2) the choice of measurements, (3) data recoding and processing, and (4) check measurements. Photographs of subjects being measured are provided. Results of the measurements are tabulated. Author

N75-23150# Advisory Group for Aerospace Research and Development, Paris (France).
SPINAL INJURY AFTER EJECTION
R. Auffret and R. P. Delahaye Feb. 1975 59 p refs
(AGARD-AR-72) Avail: NTIS HC $4.25

The statistical results of a survey conducted by 7 NATO Nations are analyzed, and the death rate as well as the rate and distribution of rachis fractures are given. Anatomical and physiological aspects are reviewed, and the pathogenic mechanism of fractures is discussed. In most cases, it is difficult to determine whether the rachis fractures occur when the seat is released or at landing. The pilot's position in the seat plays a fundamental role in the success of the ejection. The radiological aspects of rachis fractures are described, and the stress is laid on the difference between stable and unstable fractures. The therapy applied and the durations of unavailability from duty are indicated. An X-ray examination of the whole spine is recommended after each ejection. Author

N75-29736# Advisory Group for Aerospace Research and Development, Paris (France).
TREADMILL EXERCISE TESTING AT THE USAF SCHOOL OF AEROSPACE MEDICINE: PHYSIOLOGICAL RESPONSES IN AIRCREWMEN AND THE DETECTION OF LATENT CORONARY ARTERY DISEASE
V. F. Froelicher (School of Aerospace Med.), F. Yanowitz (School of Aerospace Med.), A. J. Thompson (School of Aerospace Med.), and M. C. Lancaster (School of Aerospace Med.) May 1975 65 p refs
(AGARD-AG-210, AGARDograph-210) Avail: NTIS HC $4.25

Despite the selective nature of the USAF flying population, coronary heart disease is the leading disease cause of death, disability and removal from flying duties. The purpose is to present the experience of the United States Air Force School of Aerospace Medicine (USAFSAM) in the use of treadmill exercise for evaluating asymptomatic aircrewmen. The monograph consists of separate studies involving aspects of treadmill testing experience at the USAFSAM including descriptions of techniques. For

N75-29737 Advisory Group for Aerospace Research and Development, Paris (France)
PHYSIOLOGICAL PARAMETERS OF EXERCISE PERFORMANCE
In its Treadmill Exercise Testing at the USAF School of Aerospace Med. May 1975 p 1-14 (For availability see N75-29736 20-52)

When technology became available to collect and analyze expired air, the measurement of maximal oxygen consumption (VO2 max) was considered advantageous in evaluating functional capacity. Tests were specifically designed to measure this physiological parameter. Maximal aerobic working capacity is defined as the work level at which oxygen consumed fails to increase linearly with further increases in workload and the oxygen consumption at this point is called VO2 max. A study was designed to compare VO2 max and other physiological parameters measured during three standard protocols and to evaluate the reproducibility of each. Author

N75-29738 Advisory Group for Aerospace Research and Development, Paris (France).
ELECTROCARDIOGRAPHIC ASPECTS OF EXERCISE TESTING
In its Treadmill Exercise Testing at the USAF School of Aerospace Med. May 1975 p 14-60 refs (For availability see N75-29736

With additional experience and reevaluation of the original criteria, emphasis was placed on the importance of ST segment depression as the primary sign of myocardial ischemia. A table summarizes the studies screening asymptomatic men using the double Master's test or a test with a comparable workload. These studies included follow-up data and it is apparent that postexercise ST segment depression identified a high risk group of men. The epidemiological terms used to describe the performance of screening tests are defined. Author

N76-14758# Advisory Group for Aerospace Research and Development, Paris (France)
AEROMEDICAL IMPLICATIONS OF RECENT EXPERIENCE WITH COMMUNICABLE DISEASE
R. E. Mammen, ed. (Naval Aerospace and Regional Med. Center, Pensacola, Fla.) Sep. 1975 88 p refs Conf. held at Toronto, Canada, 7-8 May 1975
(AGARD-CP-169) Avail: NTIS HC $5.00

Epidemiology, detection and diagnosis, treatment and prevention of infectious diseases of aeromedical interest are discussed. For individual titles, see N76-14759 through N76-14773

N76-14759 Institut fuer Wehrmedizin und Hygiene, Koblenz (West Germany).
EPIDEMIOLOGIC RISK FACTORS OF FLUSH-RECYCLE TOILETS IN AIRCRAFT
Wolfgang H. Fischer *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep. 1975 2 p (For availability see N76-14758 05-52)

In connection with emergency air transports from areas of low hygienic standards and presence of important infectious diseases, laboratory tests and field trials disclosed a number of serious hygienic deficiencies which were taking an exceedingly critical course during middle range and long distance flights and also by exposal of ground servicing personal and vehicles to infectious waste material. It is shown that toilet sanitation systems presently used in airliners do not meet the standards required for the health of air crews and passengers. Commonly used sanitary fluids for toilet operation are presented and their quality discussed. Recommendations are given to improve the aircraft toilet sanitation. Author

N76-14760 Air France, Paris. Service Medical Central.
TRANSPORTATION OF PASSENGERS WITH CONTAGIOUS DISEASES ON AIRLINERS [LE TRANSPORT DES MALADES CONTAGIEUX EN AVION DE LIGNE]
Michel Perin *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep 1975 8 p refs In FRENCH, ENGLISH summary (For availability see N76-14758 05-52)

The problems related to the transportation of passengers with contagious diseases on airliners were discussed. It was pointed out that the refusal of most airlines to transport such passengers can scarcely be justified by reference to either laws or regulations, it introduces the risk of arbitrary, mistaken, or prejudiced conduct and it can cause serious harm to certain patients. It also does not seem logical since airlines learn about only a small fraction of the contagious persons who travel, and public health is much more greatly endangered by unknown contagious persons. It was concluded that airlines should continue to refuse to transport only those passengers having diseases characterized by vomiting or serious diarrhea or transmitted through the air, if it is impossible by simple means to avoid the risk of contaminating other travellers and flight crew members who might be receptive. Author

N76-14761 Johann-Wolfgang-Goethe-Universitat, Frankfurt am Main (West Germany).
FOOD POISONING OBSERVED WITH AIRPLANE CREW AND PASSENGERS DEPENDING ON AIRPLANE OPERATIONS
R. Schubert *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep 1975 3 p refs (For availability see N76-14758 05-52)

Many food poisonings can more easily be caused during air plane operations. They can create even more serious problems than on earth. In this connection they can be caused during the flight if it is of long duration and even bring about the symptoms of the illness. More frequently, however they have been acquired before. Sometimes a gastrointestinal disturbance, the traveller's disease, can be observed appearing like a food poisoning without being such in the original sense. On flights from certain regions of the globe, especially from the Far East, one must expect cases of food poisoning in the air traffic more often than from other countries. Author

N76-14762 Bayerische Landesimpfanstalt, Munich (West Germany)
IMPORTATION, DIAGNOSIS AND TREATMENT OF SMALLPOX, CHOLERA AND LEPROSY
H. Chr. Huber, V. Hochstein-Mintzel, and H. Stickel *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep 1975 4 p refs (For availability see N76-14758 05-52)

Since 1967 a total of 11 cases of smallpox have been introduced into the FRG. The final diagnosis was usually delayed until the 10th day after the onset of clinical symptoms. The diagnosis of variola must be supported by epidemiological data and laboratory tests. Epidemiological data refer to travel in endemic areas, the probability and time of contact, and the resulting incubation period. Laboratory examination is usually restricted to three tests: serological examination for hemagglutination inhibiting antibodies electron microscopy of skin scrapings, and virus isolation on the chorioallantoic membrane of embryonated eggs. The importation of cholera and leprosy bears minor problems as to the possible spread of the diseases. Introduction of cholera cannot be avoided by public health measures. An endemic spread, however, does not need to be considered in countries of appropriate standards of public hygiene. The prognosis of the disease is quite favorable, provided that proper therapy is initiated in the early stages. Author

N76-14763 Deutsche Lufthansa Aktiengesellschaft, Frankfurt am Main (West Germany)
TRANSPORTATION BY AIR OF A LASSA FEVER PATIENT IN 1974
Horst H. Renemann *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep 1975 5 p refs (For availability see N76-14758 05-52)

Lassa fever, also known as arenavirus disease and Casals' disease, was recognized for the first time in 1969 in Lassa, Nigeria. Its fatality ratio has been high in clinically observed cases; 10 out of 22 infected physicians and medical workers died of it. The person-to-person transmission probably takes place when airborne viruses from thin sore mucous membranes in the mouth and pharynx are expelled by breathing, talking and coughing. A German patient with arenavirus, Dr. Mandrella, was transported from Nigeria to Germany in March 1974, by Condor Boeing 707-430 manned by a volunteer flight crew of Lufthansa. The special preparation of the plane to prevent transmission of airborne viruses to the flight crew and other measures taken against contamination will be described. Author

N76-14764 Air Transport Command, Trenton (Ontario).
LASSA FEVER: TO AIR EVACUATE OR NOT
A. J. Clayton *In* AGARD Aeromedical Implications of Recent Experience with Communicable Diseases Sep 1975 4 p refs (For availability see N76-14758 05-52)

The clinical features of Lassa Fever are briefly discussed and the epidemiology of the disease is outlined with respect to the five recorded outbreaks between 1969 and 1974. The Canadian Government having become involved in two potential air evacuations of patients from West Africa is concerned over the risks to medical flight teams and receiving hospital personnel in the event of cases of Lassa Fever being repatriated to Canada. A survey is being carried out on Canadian Forces long range transport aircraft to study the microbiological environment within two types of aircraft during flights by dispersing non-pathogenic organisms. The objective is to determine the optimum location for a patient with a highly infectious disease and to ensure minimal transmission of organisms. Author

N76-14765 School of Aerospace Medicine, Brooks AFB, Tex. Epidemiology Div.
INTERNATIONAL QUARANTINE FOR CONTROL OF MOSQUITO-BORNE DISEASES ON GUAM
Wesley R. Nowell *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep 1975 8 p refs (For availability see N76-14758 05-52)

The initial mosquito survey of Guam conducted in 1936 revealed the presence of five indigenous species. Subsequent surveys showed a steady climb to fifteen species in 1969, and a dramatic jump to thirty-five by 1972. Japanese B encephalitis, and filariasis, five primary mosquito-borne diseases known to

occur on Pacific islands, have been found on Guam, and trends of the diseases are emphasized. The island of Guam is centrally located in the Western Pacific and aircraft are implicated in the introductions of new mosquito species. Chronic problems associated with aircraft quarantine inspections and insect control procedures are described, and methods to curb the introduction of new mosquito species and their associated diseases are discussed. Author

N76-14766 School of Aerospace Medicine, Brooks AFB, Tex. Epidemiology Div

AN EPIDEMIC OF CHIKUNGUNYA IN THE PHILIPPINE ISLANDS: POSSIBLE ROLE OF AIRCRAFT DISSEMINATION

George D. Lathrop and Paul J. Homme *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep. 1975 6 p refs (For availability see N76-14758 05-52)

Twin outbreaks of chikungunya, a Group A arbovirus, are analyzed that occurred on the island of Negros, Republic of the Philippines during 1968-1969. Epidemiologic data derived from interviews, serologic, and virologic testing showed that young and middle aged people were immunologically susceptible, and that the disease was transmitted in three weak waves by the mosquito, Aedes albopictus. Inferential evidence suggested that acquired immunity due to an apparent 1920 chikungunya epidemic accounted for a lower attack rate in the elderly population. Chikungunya was probably introduced into Negros by aircraft or ships from Manila, where a smaller outbreak had been documented in 1967-1968. The outbreaks on Negros subsided naturally prior to increased mosquito abatement and public health control measures. Unconfirmed clinical evidence suggested that the disease was disseminated into the adjacent islands of Cebu and Mindanao. Author

N76-14767 Bayerische Landesimpfanstalt, Munich (West Germany).

THE ATTENUATED LIVE SMALLPOX VACCINE, STRAIN MVA RESULTS OF EXPERIMENTAL AND CLINICAL STUDIES

V. Hochstein-Mintzel, H. Stickel, A. Mayr, H. Chr. Huber, H. Schaefer, and A. Holzner *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep. 1975 6 p refs Prepared in cooperation with Inst. fuer Mikrobiol., Muenchen (West Germany) (For availability see N76-14758 05-52)

In an attempt to basically alter and improve smallpox vaccination, the use of an attenuated strain of vaccinia virus was proposed. Attenuation was effected through more than 500 continuous passages in chick embryo fibroblast cultures. Animal experiments showed the complete absence of neurovirulence for the attenuated strain. The favorable experimental results led to a field study of primary vaccinations in the human. The recommended procedure was to administer 0.1 ml of attenuated vaccine intradermally, followed by conventional cutaneous smallpox vaccination 7 to 28 days later. The results may be summarized as follows: the local reaction to the attenuated vaccine merely amounted to slight reddening and infiltration at the site of injection with complete absence of typical vaccinal lesions. Untoward systemic reactions were not observed. The subsequent cutaneous vaccination resulted in 84% major reactions and 9% equivocal reactions. Seven percent remained negative. 78% of the takes were of the accelerated type, giving evidence of the immunizing capacity of the attenuated strain. Author

N76-14768 Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).

COCCIDIOIDOMYCOSIS AND AVIATION

G. Apel and V. Grouls *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep 1975 3 p refs Prepared in cooperation with Inst of Pathol., Bonn-Venusberg (West Germany) (For availability see N76-14758 05-52)

In the age of transatlantic travel and mass tourism it can not be precluded that Coccidioidomycosis will be brought to areas on the globe in which this disease has hitherto been unknown. Since the incubation period will last two to three weeks and occasionally also four weeks, the disease will frequently occur only after all passengers have long returned to their home countries. Considering the striking similarity with the clinical picture of pulmonary tuberculosis, it is not surprising that in Europe the disease is diagnosed as tuberculosis, even more so since tuberculination may often be positive. The patients are then subjected to an anti-tuberculous therapy, which necessarily must remain without success in such cases. If an exact case history including travels abroad and residences in endemic areas of Coccidioidomycosis can be established, a clue pointing to the true nature of the disease may be obtained. Author

N76-14769 Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).

THE INDUCTION OF INTERFERON AND SPECIFIC SMALLPOX IMMUNITY BY ORAL IMMUNIZATION WITH LIVE ATTENUATED POX VIRUS

V. Hochstein-Mintzel, A. Mayr, and H. Stickl *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep 1975 5 p refs Prepared in cooperation with Inst. fuer Mikrobiol., Muenchen (West Germany) (For availability see N76-14758 05-52)

In the human, oral immunization with live attenuated virus was effected by the administration of virus-containing tablets. The procedure caused no untoward effect in primary vaccinees. Subsequent skin testing and conventional cutaneous vaccination resulted in accelerated takes, demonstrating successful oral pre-immunization. Attenuated heterologous pox virus was shown to have a high interferon inducing capacity. Induction was optimal when the virus was applied to the mucous membranes of the oral cavity. Clinical trials showed significant effects of interferon induction in recurrent herpetic infections. Oral application of vaccines needs neither trained staff nor medical equipment. It confers short term non-specific protection from disease, followed by specific immunity. The usual contraindications to smallpox vaccination need not be observed. Untoward effects, quite common to routine methods, are not to be expected. Author

N76-14770 Centre Principal d'Expertises Medicales du Personnel Navigant, Paris (France).

INCIDENCE OF INFECTIOUS TROPICAL DISEASES DIAGNOSED ON FLYING PERSONNEL. [IMPORTANCE DE LA PATHOLOGIE INFECTIEUSE D'ORIGINE TROPICALE DANS L'EXPERTISE MEDICALE DU PERSONNEL NAVIGANT]

R. Carre, J. Patacq-Crouzet, A. Didier, and J. Bastien *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep. 1975 6 p In FRENCH (For availability see N76-14758 05-52)

Statistical data on the incidence of infectious tropical diseases diagnosed during the period 1969 to 1972 on French military and commercial flight crews was presented. The personnel examined were those making regular trips to Africa, Madagascar, the West Indies, and Reunion Island. The two diseases most widely detected were amebiosis (106 cases, including 13 severe cases localized in the liver and 93 cases localized in the intestinal tract) and malaria (45 cases, including 8 severe cases with encephalic and comatose involvements). The following other parasitic diseases were observed: bilharziasis (6 cases), filariasis (4 cases), stomatosis (2 cases), strongyloidiasis (8 cases), and ankylostomiasis (5 cases). Most cutaneous diseases detected were of bacterial origin. Viral hepatitis was widely observed on personnel having travelled in Africa, and dengue was diagnosed on military personnel returning from the Pacific. Y.J.A.

N76-14771 Tropen Inst., Hamburg (West Germany)

DIAGNOSTIC METHODS IN TROPICAL MEDICINE

Werner Mohr *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep. 1975 3 p (For availability see N76-14758 05-52)

The doctor consulted by persons returning from overseas countries should have a certain knowledge of geographical medicine. He must know in which regions on the globe malaria occurs, and where intestinal diseases are prevalent. A precise anamnesis of the patient's itinerary is most essential. During the physical examination the examiner is likely to recognize a number of symptoms which will help him along diagnostically. (1) Rashes and dischromia; (2) edemas; (3) fever; (4) enlargement of the liver; (5) enlargement of the spleen; (6) respiratory changes; (7) changes in stool (diarrhea); and (8) changes in urine (hematuria), to name but a few. Author

N76-14772 Bayerische Landesimpfanstalt, Munich (West Germany)

THE THREAT OF TROPICAL DISEASES AND PARASITOSES (SOME EPIDEMIOLOGICAL AND CLINICAL ASPECTS)

G. T. Werner, H. Chr. Huber, H. Stickl, and V. Hochstein-Mintzel *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep 1975 6 p refs (For availability see N76-14758 05-52)

The rapid increase of travels to the warm countries has brought the threat of tropical diseases to our doors. Furthermore

a great number of people are in employment overseas. Besides, the continuous influx of laborers, students or immigrants from tropical countries can create new medical problems. There is no real danger that tropical diseases are going to cause epidemics in the highly developed countries, as the hygienic standards prevent generalized outbreaks. There is, however, a substantial danger in the individual case due to missed or delayed diagnosis and treatment. Reviewed are those tropical diseases which are imported frequently or which present problems in the single case. Cosmopolitan diseases which are more common in the tropics, like hepatitis, polio, tuberculosis, are excluded. Author

N76-14773 Tropen Inst., Hamburg (West Germany)
AIR TRAFFIC AND THE PROBLEM OF IMPORTATION OF DISEASES FROM THE TROPICS
Werner Mohr *In* AGARD Aeromedical Implications of Recent Experience with Communicable Disease Sep. 1975 3 p (For availability see N76-14758 05-52)

It is not possible to deal with all diseases which could be imported from the tropics to Europe or the temperate climate zones respectively. However, helminthic diseases should be referred to briefly. The most frequent and important ones among them are hookworm infestation, bilharziosis (schistosomiasis) in all its various forms, and filariasis. Time and again it can be observed that persons returning from the tropics may have contracted a variety of infectious diseases, especially intestinal parasites. There are a number of measures that should be taken to give protection against the diseases described above: (1) Protective inoculation against certain diseases and prophylactic medication; (2) it is of great importance to instruct physicians at home, i.e. in the temperate climate zones, in tropical diseases and their diagnosis; and (3) any person on return from the tropics should be subject to a close medical examination, in particular when such a person suffered from any disturbances of health during his stay in the tropics or is still suffering from such disturbances. Author

N76-17786# Advisory Group for Aerospace Research and Development, Paris (France).
EFFECTS OF LONG DURATION NOISE EXPOSURE ON HEARING AND HEALTH
Milton A. Whitcomb, ed (NSF) Nov. 1975 94 p refs Presented at the Aerospace Med. Panel Specialists Meeting, Toronto, 5 May 1975
(AGARD-CP-171) Avail: NTIS HC $5.00

There can be no doubt that noise exposures of durations greater than eight hours present a hazard to the hearing of air crews flying noisy aircraft and, particularly, for those more susceptible crew members. Noise reduction around NATO airports to insure public health is examined. Data are examined on the incidence of stress-induced pathologies such as ulcers or emotional disorders for those exposed to long-duration noise, as compared to nonnoise exposed individuals. Flight crews exposed to such long durations of noise were monitored both audiometrically and for abnormal incidence of cardiovascular disease, ulcers, and other psychosomatic complaints. Long-duration noise exposure to the moderate levels of noise that occur in aircraft cockpits was also studied. The fundamental mechanisms causing cochlear damage (mechanical and biological) are critically examined. For individual titles, see N76-17787 through N76-17799.

N76-17787 Ohio State Univ., Columbus. Dept. of Otolaryngology.
MODE OF COCHLEAR DAMAGE BY EXCESSIVE NOISE, AN OVERVIEW
David J. Lim and William Melnick *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 6 p refs (For availability see N76-17786 08-52)
(Contract F33615-74-C-4049)

Damage to the cochlea is examined and is believed to be caused by a physical or metabolic stress exerted on the sensory cells. Evidence to support both mechanisms is overwhelming, and is reviewed. Injury can be brought about by the chemical or metabolic alteration in the surrounding medium. Besides apparent mechanical damage inflicted on the organ of Corti by the acoustic hyperstimulation, the evidence of metabolic damage to the sensory cells is subtle. The subtle changes include: (1) proliferation and vacuolization of endoplasmic reticulum in sensory cells, (2) swelling of mitochondria in both sensory cells and afferent nerve endings, (3) morphological alteration of stereocilia and (4) swelling and degeneration of stria vascularis. These findings imply that the high-energy-yielding enzyme systems are rendered inoperative in these cells, resulting in cell degeneration. Photomicrographs are shown. Author

N76-17788 Ohio State Univ., Columbus. Dept. of Otolaryngology
TTS IN MAN FROM A 24-HOUR EXPOSURE TO AN OCTAVE BAND OF NOISE CENTERED AT 4 kHz
William Melnick *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 8 p refs (For availability see N76-17786 08-52)
(Contract F33615-71-C-4049)
(AMRL-TR-75-3)

Seven men were exposed to 24 hours of continuous noise in a sound field. The noise was an octave band centered at 4 kHz at two octave band levels, 80 and 85 db. Hearing thresholds were measured in one ear at 11 test frequencies ranging from 250 to 10,000 Hz prior to exposure and at selected intervals during and after exposure. Temporary threshold shift (TTS) reached asymptotic levels between 8 and 12 hours of exposure. Results indicate that maximum TTS occurs at 4 and 6 kHz. Asymptotic levels at the 80 db exposure level are 9.7 db for 4 kHz and 7.7 db for 6 kHz. With the 85 db noise level, these levels are 18.4 db and 16.5 db, respectively. Threshold shift for this subject group is less than would be expected from results of previous investigations, and is attributed to subject sampling bias. Author

N76-17789 Italian Air Force Medical Service of the 2d Air Region, Rome. Sanitary Group - 1st Aerobrigade.
PROTECTIVE EFFECTS IN MEN OF BRAIN CORTEX GANGLIOSIDES ON THE HEARING LOSS INDUCED BY HIGH LEVELS OF NOISE
G. Maniero and G. A. Molinari (Padua Univ., Italy) *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 5 p refs (For availability see N76-17786 08-52)

It is known that the prolonged exposure to noise of intensity greater than 70-80 decibels produces a temporary rise of the acoustic threshold (TTS). Gangliosides, (glycolipids which seem to interfere with the transmission of nervous impulse), were used in preventing TTS rise. By means of ganglioside administration, a possible interference on the traumatizing effect of noise on the cochlea was observed and studied. Following otologic and audiometric examination, 20 healthy male subjects were chosen. The TTS2 was calculated, both in basal conditions and after ganglioside administration. Results indicate that the gangliosides, administered in opportune doses and modalities, are capable of preventing in all subjects the physiological rise in the hearing threshold after exposure to noise. In contrast, the nontreated subjects in the same experimental conditions have either the same TTS2 or show a large shift. Therefore, the positive failure in shift, occuring in the treated patients, is most probably due to ganglioside effect. Author

N76-17790 Minnesota Univ., Minneapolis. Hearing Research Lab.
STUDIES OF ASYMPTOTIC TTS
W. Dixon Ward *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 7 p refs Sponsored by Natl. Inst. for Occupational Safety and Health (For availability see N76-17786 08-52)

Ten young normal-hearing listeners were subjected to a series of exposures to 4000-Hz noise for periods ranging from 2 to 24 hours. The asymptotic TTS (temporary threshold shift) was always reached in 8-12 hours with no suggestion of a sharp increase between 8 and 24 hours. Little difference could be seen in the rate of recovery from the TTS produced by 8- and 24-hour exposures. Results indicate that exposures longer than 8 hours are not unusually hazardous. If there is an increased risk of eventual permanent hearing damage from repeated daily exposures longer than 8 hours, it probably comes from the fact that as the daily exposure becomes longer than 8 hours, the quiet interval before the next exposure is shortened, so that the next day's exposure is begun with the auditory system still in a fatigued state. Author

N76-17791 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
ASYMPTOTIC BEHAVIOR OF TEMPORARY THRESHOLD SHIFT DURING EXPOSURE TO LONG DURATION NOISES
D. L. Johnson, C. W. Nixon, and M. R. Stephenson *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 6 p refs (For availability see N76-17786 08-52)

Exposure to a constant noise level (pink noise, i.e., jet aircraft noise) for more than 16 hrs has been shown by many investigators to cause a Temporary Threshold Shift (TTS) in hearing that remains

constant. This behavior, which is independent of exposure duration, is called Asymptotic TTS. Data are given which show that although TTS may remain constant, the recovery of hearing back to normalcy does depend on the duration of the exposure. Significant differences in recovery between a 24 hr exposure and a 48 hr exposure were observed. It is believed that for hearing conservation purposes, the time Air Force personnel should be allowed to recover from long duration noise exposures in quiet depends on the exposure duration. Suggested guidelines for assuring recovery of Asymptotic TTS are given and the research program aimed at improving these guidelines is discussed. Author

N76-17792 Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario). Behavioral Sciences Div.

THE INCIDENCE OF TEMPORARY AND PERMANENT HEARING LOSS AMONG AIRCREWS EXPOSED TO LONG-DURATION NOISE IN MARITIME PATROL AIRCRAFT

S. E. Forshaw *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 7 p refs (For availability see N76-17786 08-52)
(DCIEM-75-RP-1073)

The CP-107 Argus has been in operation with the Canadian Forces since 1957 as a long-range maritime patrol aircraft. The endurance capability of the aircraft is at least 24 hours at reconnaissance altitudes and speeds. Flight durations from 12 to 20 hours occur routinely, during which ambient noise levels at various crew and rest stations range from 90 to 99 dBA. An assessment of crew and operational problems arising from long-duration flights in the Argus shows that about half of the crew sustain temporary threshold shifts in excess of levels considered to be acceptable for long-term exposure. The hearing levels of 223 pilots, navigators and flight engineers were studied with career flying times in the Argus ranging from 2500 to 10,000 hours. Results of the study suggest that repeated long-duration noise exposure, as experienced in the aircraft, are not any more deleterious to hearing thresholds than is repeated exposure, at approximately equivalent intensity levels, in short- and medium-range aircraft. Author

N76-17793 Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome (Italy).

PSYCHO-PHYSICAL PERFORMANCE OF AIR FORCE TECHNICIANS AFTER LONG DURATION NOISE EXPOSURE

Cesare A. Ramacci and Paolo Rota *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 3 p refs (For availability see N76-17786 08-52)

Psychological and psycho-physiological tests were carried out (Toulouse Pieron test, flicker fusion test, reaction time) on 20 Air Force technicians, on duty at an aircraft maintenance and flight line, exposed to high level noise. Work conditions considered were: (1) continuous exposition to noise of about 120 db, for one hour and half; and (2) continuous exposure for five hours to 60-80 db noise, with transient increases up to 90-115 db. The technicians used, when necessary, individual or collective ear protection. The technicians were divided into 3 groups and given specific tasks to perform. The tests, carried out before and after noise exposure, do not show significant changes of task performance. Author

N76-17794 Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).

THE EFFECTS OF EAR PROTECTORS ON SOME AUTOMATIC RESPONSES TO AIRCRAFT AND IMPULSIVE NOISE

G. R. Froehlich *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 5 p (For availability see N76-17786 08-52)

Three different types of ear protectors were evaluated for protection against jet aircraft noise and other noise. Autonomic nervous system responses were measured for 25 subjects who participated in the study. Peripheral blood flow and electrodermal responses were also measured. Jet aircraft noise levels of 95 db, and other noises (a pistol shot) of 130 db were provided. Subjects were asked to select the ear protector giving the greatest protection. Results are presented and discussed. J.R.T.

N76-17795 Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome (Italy)

INFLUENCE OF THE NOISE ON CATECHOLAMINE EXCRETION

G. Paolucci *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 2 p (For availability see N76-17786 08-52)

Aviation specialists were exposed daily to high noises and fully protected against hearing damage by ear plugs. The exposed people were divided in two groups of ten subjects, each one exposed to different noisy conditions. One group was exposed to continuous and steady noise of 120 db for 1 hour and 1/2 hour, and the other was exposed to intermittent noise of 80-100 db for 5 hours, with intervals between impulsive bursts of 20 feet, lasting each only a few seconds. The subjective tolerance was good and no disturbance or fatigue reactions appeared at the end of the exposure. Urinary catecholamine excretion was assayed the day before the test (in noiseless place) and the next one at the end of the exposure. Results indicate that no change in catecholamine release occurs upon trained people with hearing fully protected. Author

N76-17796 Naval Regional Medical Center, San Diego, Calif. Dept. of Otolaryngology.

EFFECTS OF NOISE EXPOSURE

Robert W. Cantrell *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 13 p refs (For availability see N76-17786 08-52)

It is known that noise can damage the inner ear, result in hearing loss, be a source of annoyance, disturb sleep, and interfere with speech. There is some evidence that it may adversely affect mental health, the cardiovascular system, basic biochemistry, and decrease work performance. Current knowledge is reviewed of how intensity, duration and frequency composition of noise affects the auditory, annoyance, sleep and speech interference, psychological and sociological responses in man. Author

N76-17797 Naval Regional Medical Center, San Diego, Calif. Dept. of Otolaryngology.

PHYSIOLOGICAL EFFECTS OF NOISE

Robert W. Cantrell *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 11 p refs (For availability see N76-17786 08-52)

The effect of noise on the biochemistry of the body, the cardiovascular system, and the organ systems controlled by the autonomic nervous system are examined. Noise serves as a stressful stimulus which provokes the General Adaption Syndrome, and is one of the several stressful stimuli which activate this syndrome via the hypothalmus to the pituitary which produces ACTH resulting in increased adrenocortical activity. There is considerable evidence to support this concept, and this theory along with recently carefully controlled studies, are reviewed. Author

N76-17798 Army Aeromedical Research Lab., Fort Rucker, Ala.

AN INVESTIGATION OF AIRCRAFT VOICE COMMUNICATION SYSTEMS AS SOURCES OF INSIDIOUS LONG-TERM ACOUSTIC HAZARDS

Robert T. Camp, Jr., Ben T. Mozo, and James H. Patterson *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 6 p (For availability see N76-17786 08-52)

The acoustic output of voice communication systems was measured helicopter during training flights. The results of analyses of samples of aircraft voice communication systems noise are examined. Specifically discussed are ear protecting devices (helmets) used to reduce cockpit noise and passenger compartment noise. It is found that the microphones in the helmets emit sound levels which are harmful over a long period of time. Author

N76-17799 Universitaetsklinikum Essen (West Germany).

PHYSIOLOGICAL RESPONSES DUE TO NOISE IN INHABITANTS AROUND MUNICH AIRPORT

Gerd Jansen *In* AGARD Effects of Long Duration Noise Exposure on Hearing and Health Nov. 1975 5 p (For availability see N76-17786 08-52)

Results are examined of an interdisciplinary research study on aircraft noise effects on inhabitants around German airports. A pilot study (around Hamburg airport) and a main study (around Munich airport) were conducted by acoustical, demographic, social scientific, psychological, physiological and medical sections of scientists. It was found out that, in general, there is no adaptation to aircraft noise. A linear relation exists between increasing noise stimuli (combined noise, exposure, measure of noise levels, and number of flyovers) and human reactions. A discussion of physiological results leads to the opinion that physiological reactions are more related to sound levels whereas the 'whole reaction' (annoyance, blood pressure etc.) is more related to combined noise exposure measures. Author

N76-19789# Advisory Group for Aerospace Research and Development, Paris (France)
THE USE OF IN-FLIGHT EVALUATION FOR THE ASSESSMENT OF AIRCREW FITNESS
Chester L. Ward, ed. (Army Med. Res. and Develop. Command, Washington, D. C.) Feb. 1976 70 p. refs. Presented at Aerospace Med. Panel Specialists Meeting, Ankara, 24 Oct. 1975
(AGARD-CP-182; ISBN-92-835-1208-1) Avail: NTIS

Various aspects of in-flight determinations of physical, psychological, physiological and bioaeronautical suitability and fitness of aircrew are presented. These include some in-flight and simulation techniques, examination methods, bioinstrumentation and procedures for fitness studies as well as results of assessment of the ability to fly safely with orthopedic injuries, amputations, and visual deficiencies, plus a few other physiological and psychological situations. Also included are assessments of paratroopers and nonpilot aircrew in their performance of duty. For individual titles, see N76-19790 through N76-19796.

N76-19790 Army Medical Research and Development Command, Washington, D.C.
US ARMY MEDICAL IN-FLIGHT EVALUATIONS, 1965-1975
Chester L. Ward, Nicholas F. Barreca (Brooke Army Med. Center, Ft. Sam Houston, Tex.), Robert J. Kreutzmann (Madigan Army Med. Center, Washington), David D. Glick (Army Aeromed. Res. Lab., Fort Rucker, Ala.), and Morris A. Shamah *In* AGARD The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness Feb. 1976 10 p. refs (For availability see N76-19789 10-52)

The U.S. Army has recognized that the services of many experienced but medically disqualified aviators can be lost unless a method is established to comprehensively investigate an individual's adaptation and complete capability. Therefore one hundred thirty-two in-flight evaluations for a 10 year period (1965-1974) were reviewed. Information from the records and reports reposited at the U.S. Army Aeromedical Center, Fort Rucker, Alabama, was read, extracted and synthesized. Evaluation methods used, plus the results of compiling case classifications and the subsequent medical recommendations for duties involving flying are presented and discussed. Specific categories of individuals presented in detail are lower extremity amputees, 'one-eyed' aviators, and color vision defective aviators. Author

N76-19791 Civil Aeromedical Inst., Oklahoma City, Okla.
ACCIDENT EXPERIENCE OF CIVILIAN PILOTS WITH STATIC PHYSICAL DEFECTS
J. Robert Dille and Charles F. Booze *In* AGARD The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness Feb. 1976 5 p. refs (For availability see N76-19789 10-52)

The U.S. Federal Aviation Administration (FAA) is committed to establishment of airman physical standards and certification policies that are as liberal as possible compromising aviation safety. Throught the years, medical flight results, research, and consultant opinions have resulted in relaxation of medical standards and policies and current FAA certification of 4,704 pilots with blindness or absence of one eye, 14,421 who wear contact lenses, 15,779 with deficient color vision, 15,543 with deficient distant vision and smaller, but significant, numbers with paraplegia, deafness, and amputations. Limitations are placed on flying activities when appropriate. Routine aircraft accident investigations seek to determine the presence of physical problems in the involved airmen and any probable association of the defect with the accident cause. The FAA experience with these civilian pilots who have static physical defects is examined and accident rates were calculated for several categories of pathology for comparison with the overall accident rates in general aviation activities. Three categories show significant increases in accidents: (1) blindness or absence of one eye, (2) deficient color vision with a waiver, and (3) deficient distant vision. However, these groups reported much higher median flight times than a nonaccident airman population and accident airmen without any of the pathology selected for this study. Analyses of available data prove inconclusive but increased exposure may account for most or all of the increased accidents observed for airmen with these three pathologies. None of the accidents was related to the pilots' physical condition in the reports. Statistical biomedical data are given. Author

N76-19792 Italian Air Force Medical Appeal Board, Rome.
STRESS AND PSYCHIC FUNCTIONS: OPERATIONS OF FLIGHT CREWS AND PARATROOPS DURING PARACHUTE OPERATIONS
Luigi Longo *In* AGARD The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness Feb. 1976 6 p. refs (For availability see N76-19789 10-52)

Observations are presented which were made of the behavior of a considerable number of parachutists and flight crews during parachute operations. Such operations are marked by a series of phases or pre-arranged maneuvers which involve both the higher processes and simple motor mechanisms. A trained parachute officer and psychiatrist of the Italian Air Force studied the stresses which occur in the various phases and especially the involvement of the higher psychic processes. It appears that the emotive-affective complex is especially exposed to operational stress in this situation. Hypotheses are advanced on such issues as these with special reference to the psychological content and to the effect of drill and discipline on stress. Author

N76-19793 Army Aeromedical Research Lab., Fort Rucker, Ala.
COMPARISON OF VISUAL PERFORMANCE OF MONOCULAR AND BINOCULAR AVIATORS DURING VFR HELICOPTER FLIGHT
Thomas L. Frezell and Mark A. Hofmann *In* AGARD The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness Feb. 1976 9 p. refs (For availability see N76-19789 10-52)

The inflight visual performance of six binocular Army aviators and one monocular Army aviator was assessed during various maneuvers in a JUH-1H helicopter. A corneal reflection technique using both video tape and 16mm film as a recording medium was employed. Information on the use of 13 visual sectors was provided for a number of maneuvers to include normal takeoffs and landings and hovering maneuvers. The aircraft windscreen was divided into eight sectors while the side windows and chin bubbles comprise an additional four sectors. The thirteenth visual sector represents the inside cockpit area. Data presented include percentage of total time spent in each sector, average dwell time per sector transition (permutation) values. Comparison data are provided between the six binocular pilots and the monocular pilot. These data reveal that in many cases there was little difference between binocular and monocular visual activity. In addition to the objectively recorded data, information concerning monocular visual cues is presented. Author

N76-19794 Army Aeromedical Research Lab., Fort Rucker, Ala.
HELICOPTER FLIGHT PERFORMANCE WITH THE AN/PVS-5, NIGHT VISION GOGGLES
Michael G. Sanders, Kent A. Kimball, Thomas L. Frezell, and Mark A. Hofmann *In* AGARD The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness Feb. 1976 15 p. refs (For availability see N76-19789 10-52)

Rotary wing flight at night in an instrumented UH-1H with aviators utilizing night vision goggles was studied. These devices restrict field of view, provide monochromatic imagery, and weight, and with the exception of bifocals require manual refocus to gain inside visual capability. These second generation image intensification systems were used during low level and nap-of-the-earth flight profiles in addition to various maneuver sets. Three intensification systems were compared to the unaided eye over these conditions. These systems included 40 deg field of view (FOV), 60 deg FOV and 40 deg FOV with a 30 percent bifocal cut. Over twenty aircraft state variables and aviator control inputs were measured and submitted to analysis. In addition to descriptive and univariate techniques, the data were subjected to a multiple discriminant analysis. The subjects (instructor pilots) also responded to questionnaires regarding the preference, training and estimated capabilities of each type of intensification system. The major findings of both the subjective and objective measures are summmarized. Author

N76-19795 Mainz Univ. (West Germany). Dept. of Physiology.
IN-FLIGHT LINEAR ACCELERATION AS A MEAN OF VESTIBULAR CREW EVALUATION AND HABITUATION
Rudolf J. VonBaumgarten *In* AGARD The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness Feb. 1976 4 p. refs (For availability see N76-19789 10-52)

Individual differences in susceptibility to motion sickness and in man's ability to habituate to vestibular stimuli was studied. It is proposed that individually oriented programs of vestibular testing (ground based) be supplemented by specific in-flight tests and in-flight habituation training for the following reasons: (1) the stimuli which cause vestibular airsickness in high performance aircraft at the shortest latency are rectilinear accelerations (otolithic-stimuli) of amplitudes, jerkloads and frequencies which cannot be simulated on the ground without enormous technical

difficulties, and (2) the conventional ways of testing for motion sickness on the ground, involving coriolis-effects on rotating chairs, swings, caloric stimulation of the ears and centrifugation, do not simulate closely enough conditions of aircraft flight. It is suggested that special vestibular in-flight test and training regimens be used, based on individual traits. The test and habituation flights should include z-Axis acceleration between -1 and +2 g's, changes of rhythm of such stimulation, and alternation between threshold and sub-threshold maneuvers of opposite direction. Preliminary data obtained in a Lear-Jet and in aerobatic light planes are examined and indicate that certain otolithic stimuli are very effective in producing motion sickness, and that habituation can be obtained against such stimuli.
Author

N76-19796 Ataturk Sanatorium, Ankara (Turkey).
EFFECT OF INCREASED ATMOSPHERIC ELECTRICITY ON THE BLOOD ELECTROLITES OF AIRPLANE CREW
Gultekin Caymaz *In* AGARD The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness Feb 1976 5 p refs (For availability see N76-19789 10-52)

Airplane pilots during flights sometimes develop disorientation and fly in wrong directions with accidents resulting. It is proposed that the cause of disorientation or collapse in some of these cases may be the sudden changes in blood electrolites and acidity of the blood produced by increased atmospheric electricity. Experiments are described that were made on airplanes and their crews which show that the atmospheric electricity is higher inside the airplane than outside. Blood samples taken before and after flight show definite changes of acidity, electrolites and cholesterol. Atmospheric electricity was measured on a daily basis, and following high voltages, there were always increased amounts of traffic and airplane accidents. The study was conducted by the Turkish Air Force.
Author

N76-19799# Advisory Group for Aerospace Research and Development, Paris (France)
SPINAL INJURY AFTER EJECTION [LESIONS VERTEBRALES APRES EJECTION]
R. Auffret (Lab. de Med. Aerospatiale du Centre d'Essais en Vol de Bretigny sur Orge, France) and R. P. Delahaye (Hopital Militaire Begin, Saint Mande, France) 1975 59 p refs In FRENCH (AGARD-AR-72(FR)) Avail NTIS HC $4.50

Statistical data from seven NATO countries dealing with the frequency of fatalities, spinal fractures, and their distribution following ejection from aircraft was presented and analyzed. The relevant anatomical and physiological aspects were reviewed, followed by a discussion on the pathological mechanism of fractures. In most cases, it is difficult to determine whether the spinal fractures take place during the initial ejection or during the subsequent landing. Proper positioning of the pilot on the ejector seat is an essential requirement for a successful ejection. The radiological aspects of spinal fractures were described by distinguishing between stable and unstable fractures. The subsequent treatment and disability period were described. It is recommended that, following any ejection, a radiological examination of the entire spinal column should be completed. The strict aptitude requirements set by most air forces for combat aircraft pilots were discussed. See also N76-23150.
Transl. by Y.J.A

N76-27819# Advisory Group for Aerospace Research and Development, Paris (France).
THE ROLE OF THE CLINICAL LABORATORY IN AEROSPACE MEDICINE
Raymond G. Troxler, ed. (School of Aerospace Med.) May 1976 127 p refs Presented at the Aerospace Med. Panel Specialists Meeting, Ankara, Turkey, 23 Oct. 1975
(AGARD-CP-180; ISBN-92-835-0165-9) Copyright. Avail NTIS HC $6.00

Papers are presented which consider laboratory screening of aircraft pilots and crews. Specific topics discussed include early detection of disease; assessment of stress in air traffic controllers and pilots; and selection of pilots based on results of physical examinations. For individual titles, see N76-27820 through N76-27836.

N76-27820 New York State Univ., Syracuse Dept. of Pathology.
THE LABORATORY ROLE IN EARLY DETECTION OF DISEASE
John Bernard Henry *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 5 p refs (For availability see N76-27819 18-52)
Copyright.

Utilization of laboratory measurements and examinations in the early detection of disease is discussed. The complex interrelations of sensitivity, specificity, and incidence and the predictive value of positive results are emphasized.
J.M.S

N76-27821 Viale Univ., Rome (Italy)
LABORATORY EMPLOYMENT IN AEROSPACE MEDICINE
G. Paolucci *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 2 p refs (For availability see N76-27819 18-52)
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Laboratory applications in aerospace medicine are summarized. These include (1) determination of the emo-biochemical state in normal or pathological conditions; (2) detection of emotional changes in flight; (3) evaluation of tissue damage in traumatized persons; and (4) applications to aviation casualties. Urinary catecholamine determination and measurement of activity of some serum enzymes are among the techniques discussed.
J.M.S

N76-27822 School of Aerospace Medicine, Brooks AFB, Tex. Aerospace Medical Div.
COMMON PROBLEMS ENCOUNTERED IN LABORATORY SCREENING OF USAF FLIGHT CREWS FOR LATENT CORONARY ARTERY DISEASE
R. G. Troxler *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 11 p refs (For availability see N76-27819 18-52)
Copyright.

Laboratory screening to identify men at increased risk for coronary artery disease is discussed. Annual determination of cholesterol and triglyceride levels, monitoring of accuracy and precision by in-house and external quality control, and effects of biological variability are among the factors included. Data are presented showing that separation of diseased from nondiseased population improves with increased laboratory precision. A normal range based on percentiles for 925 USAF male flyers without detectable coronary artery disease is also presented. The limitations of this method of normal ranges are discussed.
Author

N76-27823 Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).
EPIDEMIOLOGICAL STUDIES OF SUBCLINICAL DIABETES MELLITUS
K. Reichenbach-Klinke *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 4 p refs (For availability see N76-27819 18-52)

The incidence of asymptomatic, subclinical, or chemical diabetes in pilots and pilot applicants is studied. A coincidence of other biochemical data: of liver and risk factors of coronary disease with regard to hypertension, obesity, and ECG is also examined. Methods used and results are briefly discussed.J.M.S.

N76-27824 Marburg Univ. (West Germany).
RADIOIMMUNOASSAYS: NEW LABORATORY METHODS IN CLINIC AND RESEARCH
E. H. Graul and H. Mueller *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 9 p refs (For availability see N76-27819 18-52)
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Radioimmunoassays (RIA's) which permit quantitative determination for serum components, especially hormones and immunoglobulins, such as IgE, in very slight concentrations as well as pharmaceuticals, such as digitalis are considered. The RIA's are based on the antigen-antibody reaction, in which the substance to be measured and the corresponding radioactively labelled substance compete for binding sites on the specific antibody. Interpretation of the measurement results and further development are discussed.
Author

N76-27825 School of Aerospace Medicine, Brooks AFB, Tex. Epidemiology Div.
THE ROLE AND LIMITATIONS OF RADIOIMMUNOASSAY AS A LABORATORY DIAGNOSTIC PROCEDURE
Robert L. Buchenauer *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 5 p refs (For availability see N76-27819 18-52)
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The basic concepts of radioimmunoassay (RIA) and competitive protein binding (CPB) are reviewed. The characteristic features

of sensitivity and specificity are discussed as they relate to the problems and limitations of test variability and biological interference in the performance of radioassays in the clinical laboratory. Potential problems due to improper patient preparation and specimen collection and handling are mentioned. A survey is presented of selected biological compounds that can currently be measured by radioimmunoassay and related techniques.
Author

N76-27825 Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France)
APPLICATION OF FLIGHT STRESS SIMULATION TECHNIQUES FOR THE MEDICAL EVALUATION OF AIRCREW PERSONNEL [POSSIBILITE DE L'UTILISATION DES MOYENS DE SIMULATION DES AGRESSIONS AERONAUTIQUES POUR L'EXPERTISE MEDICALE DU PERSONNEL NAVIGANT]
J. Demange, R. Auffret, B. Vettes, and J. L. Poirier *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 7 p refs In FRENCH (For availability see N76-27819 18-52)

The role that may be played by an aerospace medicine laboratory, well equipped with simulation tools such as centrifuges, vibration generators, etc. and measuring tests such as physiologic and psychophysiologic examinations, in the more difficult medical evaluation of aircrew personnel, was described. This is based on the logic that, in borderline cases, a final decision on the medical fitness of pilots for flight status should only be reached after completion of tests that simulate, as realistically as possible, the stresses actually encountered in flight. In addition, such a laboratory is able, by repeating such tests, to objectively obtain longitudinal data on a pilot, to study transient favorable or unfavorable changes, and to observe the long-term effects of aging.
Transl. by Y.J.A.

N76-27827 Army Aeromedical Research Lab., Fort Rucker, Ala.
AVIATOR PERFORMANCE: BIOMEDICAL, PHYSIOLOGICAL, AND PSYCHOLOGICAL ASSESSMENT OF PILOTS DURING EXTENDED HELICOPTER FLIGHT
Kent A. Kimball and David B. Anderson *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 15 p refs (For availability see N76-27819 18-52)
Copyright

The physiological, psychological and performance effects of extended helicopter flight are investigated. Measurements of biochemical, physiological, and psychological parameters were obtained and compared with inflight performance measures obtained by the USAARL Helicopter Inflight Monitoring System. Six rotary wing aviators performed extended daily flight missions for a period of five days. In addition, when not flying, various psychological tests were administered. Physiological and biochemical monitoring were conducted throughout the five day period. The aviators were on a controlled diet and slept approximately three hours each night. Preliminary findings are presented in relation to performance, biochemical, physiological, and psychological parameters.
Author

N76-27828 Civil Aeromedical Inst., Oklahoma City, Okla. Aviation Physiology Lab.
STUDIES ON STRESS IN AVIATION PERSONNEL, ANALYSIS AND PRESENTATION OF DATA DERIVED FROM A BATTERY OF MEASUREMENTS
C. E. Melton, J. M. McKenzie, J. T. Saldivar, and Marlene Hoffmann *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 6 p refs (For availability see N76-27819 18-52)
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Determination of stress in aircraft pilots and air traffic controllers is considered. The complexity of the data derived from batteries of measurements of stress is discussed. A method is described in which data related to stress indicators are weighted so that their importance is equivalent. The weighted value are integrated to yield an index, C sub s, which allows a comparative overview of stress in air traffic control facilities. Data so normalized can be presented in graphic form without oversimplification. The method increases the usefulness of stress studies to managers.
Author

N76-27829 Army Research Inst. of Environmental Medicine, Natick, Mass.
THE FIELD ARTILLERY FIRE DIRECTION CENTER AS A LABORATORY AND FIELD STRESS-PERFORMANCE. MODEL 1: POSITION PAPER. 2: PROGRESS TOWARDS AN EXPERIMENTAL MODEL
J. W. Stokes, L. E. Banderet, R. P. Francescom, A. Cymerman, and J. B. Sampson *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 10 p refs (For availability see N76-27819 18-52)
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The 5-man fire direction center (FDC), common to all Field Artillery batteries, was chosen for study in the laboratory and field to evaluate the impact of environmental and situational stress on the complex performance of highly trained and motivated individuals working together as a team. The working environment of a field FDC was simulated within a hypobaric chamber and a volunteer FDC team from an elite U.S. Army unit was tested using realistic matched combat scenarios. To minimize practice effects, the team was initially given 26 hours of intensified training (ITS). The team was then tested blinded as to the altitude condition for 48 hours at both a control altitude and high altitude; the team rested 22 hours between ITS and control and 48 hours between control and the high altitude conditions. Mission performance during ITS and control was sensitive to disrupted sleep-rest cycles, with errors clustering at times of low arousal. At high altitude, performance was less efficient during the first 10 hours; most serious errors involved processing of digits. Over learned FDC skills showed little deterioration even when the men were ill with acute moutain sickness. Compensatory behaviors were evident and technical performance for the last 36 hours at high altitude equalled or exceeded control. Thus communications, psychomotor, and judgement aspects of FDC performance, as well as measures of symptoms, mood, and neuroendocrine response, appear differentially sensitive to psychological stress, hypoxia, and fatigue.
Author

N76-27830 Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).
EXPERIENCE WITH ELECTROENCEPHALOGRAPHY IN APPLICANTS FOR FLYING TRAINING 1971 AND 1972
H. Oberhole *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 6 p refs (For availability see N76-27819 18-52)
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Standard criteria for defining abnormal tracings in electroencephalography are summarized. These criteria are evaluated in relation to flying fitness examinations.
J.M.S.

N76-27831 Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome (Italy).
BEHAVIOR OF SOME RESPIRATORY PARAMETERS IN CANDIDATE PILOTS, A COMPARATIVE STUDY BETWEEN TWO DIFFERENT GROUPS EXAMINED AT TEN YEARS INTERVAL
C. A. Ramacci and G. Meineri *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 7 p refs (For availability see N76-27819 18-52)
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The hypothesis that static respiratory values could undergo a change in the course of time, in the same age groups was studied. A comparison was carried out between two groups of candidate military pilots. The respiratory parameters taken into consideration were: vital capacity and time vital capacity. The results show that no significant change took place. It is still deemed advisable to perform periodic checks. The existence of other elements that could exert a certain influence on the parameters studied was established.
Author

N76-27832 Italian Air Force Medical Service H. Q., Rome.
SURVEY ON MEDICAL REQUIREMENTS AND EXAMINATION PROCEDURES FOR THE PREVENTION OF TRAUMATIC AND NON-TRAUMATIC OSTEOARTHROPATHIES DUE TO FLYING ACTIVITIES
Gaetano Rotondo *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 6 p refs (For availability see N76-27819 18-52)
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The criteria, the medical requirements, and the examination procedures employed during the selection of pilots are examined in terms of the osteoarticular system and the spine. The conditions facilitating the occurance of osteo-arthropathies during high speed flight are emphasized.
Author

N76-27833 Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome (Italy).
CONTROL OF HEMOSTATIC DISORDERS IN AIR FORCE PERSONNEL
G. Biundo and G. Paolucci *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 2 p refs (For availability see N76-27819 18-52)
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A general examination was carried out to establish the risk from possible hemostatic disorders, due to diseases, drugs or toxic industrial products, of subjects occupationally exposed to traumatisms. The hemostatic process was examined by studying partial thromboplastin time, prothrombin time, thromboelastographic record, platelet count, and individual anamnesis. The data obtained are discussed with respect to frequencies of hemostatic disorders found, and the utility of laboratory control in medical examination. Author

N76-27834 Service de Sante pour l'Armee de l'Air, Paris (France)
INVESTIGATIONS OF THE BLOOD VESSELS ELASTIC EXPANSION, HEART OUTPUT, AND HEART RHYTHM, BASED ON THE MEASUREMENT OF VARIATIONS IN THE THORACIC ELECTRIC IMPEDANCE [EVALUATION DE LA DISTENSIBILITE VASCULAIRE DU DEBIT CARDIAQUE, ET DE LA CHRONOLOGIE CARDIAQUE, PAR LA MEASURE DES VARIATIONS D'IMPEDANCE ELECTRIQUE THORACIQUE]
J. Colin, J. Damange, and J. Langlois *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 12 p refs In FRENCH (For availability see N76-27819 18-52)
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Changes in the electric impedance measured with electrodes on the anterior portion of the thorax, near the descending aorta, were found to be proportional to the volumetric changes of the thoracic vessels in that region. Investigations of the effect of age on the data obtained with 91 healthy subjects disclosed that the change in the electric impedance are partly caused by changes in the elasticity of the blood vessels. The experimental data was also used to study the systolic volume and heart output. Calibration was obtained using 120 simultaneous measurements with the dilution method and electric impedance data on cardiac subjects. The results obtained with healthy subjects are in good agreement with those previously obtained using Fick's method, especially in regards to the effects of age and position. On the other hand, the mediocre correlation between the dilution and electric impedance methods with cardiac subjects makes this approach presently impractical clinically. Transl. by Y.J.A.

N76-27835 Amsterdam Univ. (Netherlands)
THE INFLUENCE OF ALCOHOL ON SOME VESTIBULAR TESTS
A. J. Greven, W. J. Oosterveld, and Wilhelmina Gasthuis *In* AGARD The Role of the Clin. Lab. in Aerospace Med. May 1976 6 p (For availability see N76-27819 18-52)
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In human subjects the influence of an alcoholic beverage on some vestibular tests was examined. 48 experiments were conducted in 27 normal humans, 15 men and 12 women. The effect of alcohol was observed upon fixation nystagmus, gaze nystagmus, the visual tracking pendulum test, and the optokinetic induced nystagmus. Alcohol was given in four different quantities: 0.1, 0.2, 0.4 and 0.8 g/kg body weight, as whiskey (34%). With each dosage 12 experiments were performed in 12 subjects (6 men and 6 women). Author

N76-27836 Advisory Group for Aerospace Research and Development, Paris (France)
THE CONTRIBUTION OF SKIN BIOPSY TO THE DETECTION OF VASCULAR SENESCENCE, RELATIONSHIP WITH CAROTIGRAM
C. F. Nogues, R. Carre, F. Lizeray, and E. Cava *In its* The Role of the Clin. Lab. in Aerospace Med. May 1975 9 p refs In FRENCH (For availability see N76-27819 18-52)
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The significance of the I/A ratio in the carotidogram was demonstrated, where I is the amplitude of the catacrotic inclsure and A is the total amplitude of the curve. Studies performed with hydraulic models have shown that this ratio increases with the peripheral resistance and a decrease in the elasticity. This ratio was compared to changes in the skin microscopic structure observed following biopsies performed in the region of the posterior iliac spine, using data obtained from 93 aircrew members, a very close correlation was observed between the skin structure and the I/A ratio. It follows from this that the carotidogram may be used in studies of the arterial pulse and gives an indication of the biologic age. Transl. by Y.J.A.

N76-27846# Advisory Group for Aerospace Research and Development, Paris (France).
FOURTH ADVANCED OPERATIONAL AVIATION MEDICINE COURSE
A. N. Nicholson May 1976 105 p refs Course held at Farnborough, England, 17-26 Jun. 1975
(AGARD-R-642) Copyright. Avail: NTIS HC $5.50

Various aspects of aviation medicine was studied in detail. Topics included the training of aircrew in aviation medicine, medical aspects of naval helicopter operations on the northern flank, developments in personal equipment with special reference to helmet developments, high speed escape and thermal problems, and the use of hypnotics in air operations. For individual titles, see N76-27847 through N76-27870.

N76-27847 Institute of Naval Medicine, Alverstoke (England).
MEDICAL ASPECTS OF OPERATING ON THE NORTHERN FLANK OF NATO
W. J. Blake *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 4 p refs (For availability see N76-27846 18-52)

Pre-Arctic and survival training to achieve a higher standard of physical fitness required for Arctic service is described. Emphasis is placed on protection and the problems of operating in cold environments. Among the main topics discussed are: (1) environmental effects; (2) use of protective clothing; (3) use of shelter; (4) life style; (5) cold injuries and (6) survival techniques. B.B.

N76-27848 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE OPERATION OF HELICOPTERS FROM SMALL SHIPS
J. W. Davies *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 5 p (For availability see N76-27846 18-52)

The operation of the Wasp helicopter from the decks of Tribal class and Leader class frigates of the Royal Navy is described and some of the difficulties involved in such operations, including ship movement and turbulence, are discussed. Author

N76-27849 Royal Naval Air Medical School, Seafield Park (England)
THE IMMERSION VICTIM
F. St. C. Golden *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 6 p refs (For availability see N76-27846 18-52)

The mechanisms involved in the training of rescue crews and the clinical management of the immersion victim are discussed. B.B.

N76-27850 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
MECHANICS OF HEAD PROTECTION
D. H. Glaister *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 6 p refs (For availability see N76-27846 18-52)

Various standards are discussed which cover three main aspects of helmet design, namely, (1) impact protection. The helmet is struck under controlled conditions against a first or hemispherical anvil and the transmitted force is measured, (2) penetration resistance. The helmet is struck against a conical anvil having a 0.5 mm radius tip, and (3) helmet retention. After a moderate preloading period, the strap is loaded progressively. It is further stated that the standards cover requirements for factors such as flammability, extreme cold, heat and humidity, and individual impact testing of padding materials. B.B.

N76-27851 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
AUDITORY COMMUNICATION
R. G. Green *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 3 p (For availability see N76-27846 18-52)

The problem of ambient noise in aircraft is discussed with direct relation to auditory communication and aircraft crew members. Predominant sources and nature of noise in high performance single and two seat aircraft, and propeller driven aircraft are listed. Possible solutions to reduce noise and enhance communication are reported. B.B.

N76-27852 Royal Air Force Inst. of Aviation Medicine, Farnborough (England). Applied Vision Section
EYE PROTECTION AND PROTECTIVE DEVICES
D. H. Brennan *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 8 p ref (For availability see N76-27846 18-52)

Major ocular hazards encountered in military aviation and some protective measures which may be adopted are discussed.

The hazards considered are solar glare, bird strike, wind blast, miniature detonating cord, lasers and nuclear flash. Author

N76-27853 Royal Air Force Inst. of Aviation Medicine, Farnborough (England). Flight Systems Section.
HELMET MOUNTED SIGHTS AND DISPLAYS
John Laycock. *In* AGARD 4th Advanced Operational Aviation Med Course May 1976 6 p refs (For availability see N76-27846 18-52)

The possible applications of helmet mounted sights and displays are considered. Brief details of the software and hardware problems which may be experienced with such systems are given before outlining in more detail the psychological problems encountered. The manner in which the rate of visual information processing by the pilot may be increased by varying physical parameters is discussed. Author

N76-27854 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
WARNING SYSTEMS IN AIRCRAFT CONSIDERATIONS FOR MILITARY OPERATIONS
D. C. Reader. *In* AGARD 4th Advanced Operational Aviation Med Course May 1976 3 p refs (For availability see N76-27846 18-52)

The principles employed in the design of warning systems in aircraft are presented. Visual, auditory, and tactile signals are discussed in detail. It is concluded that the concept of visual display combined in a sensory warning system is probably the most efficient method of presenting essential emergency information to the crew. It is further stated that apart from a few specific cases, audio warnings do not have distinct advantages over visual displays. B.B.

N76-27855 Royal Air Force Inst. of Aviation Medicine, Farnborough (England). Flight Skills Research Section.
ADVANCES IN MILITARY COCKPIT DISPLAYS
J. M. Rolfe. *In* AGARD 4th Advanced Operational Aviation Med Course May 1976 4 p refs (For availability see N76-27846 18-52)

Recent advances in display technology which have taken place in relation to the military cockpit were examined. Emphasis was placed upon providing adequate assessment of information needed by the aircrew in order to perform their task, and from this evolves a display system capable of presenting information in a flexible manner. It is further stated that the most widely used form of display is the cathode ray tube which has the required flexibility. B.B.

N76-27856 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
MAP DISPLAYS
R. M. Taylor. *In* AGARD 4th Advanced Operational Aviation Med Course May 1976 4 p refs (For availability see N76-27846 18-52)

The major types of map displays are distinguished and their functions are described. The principal design parameters are reviewed with particular reference to user requirements and human factors, and an outline is given of current problems of map annotation, display legibility and brightness, radar-map matching and display complexity. Author

N76-27857 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
PHYSIOLOGICAL LIMITATIONS TO HIGH SPEED ESCAPE

David H. Glaister. *In* AGARD 4th Advanced Operational Aviation Med Course May 1976 5 p refs (For availability see N76-27846 18-52)

The forces which must be imposed for satisfactory high-speed ejection approach, or even surpass, the limits of human tolerance at several stages in the ejection sequence are: (1) the +Gz acceleration of the ejection seat; (2) the -Gx acceleration due to wind drag; (3) direct (pressure) and indirect (flail) effects of wind blast; (4) other inertial forces (centrifugal, tangential) due to seat instability; (5) opening shock of drogue parachute and main canopy; and, (6) ground impact. Of these forces the first must be increased to achieve tail fin clearance at high speed, the second and third increase with the square of indicated air speed, the fourth increases with airspeed, and the fifth must be increased if escape is to be successful in the high-speed low-level case. Only the last force is uninfluenced by aircraft speed at ejection and the message is clear - high speed has a major effect on forces imposed during assisted escape from aircraft. These forces are considered in relation to the mechanism of injury, incidence of injury, tolerance to injury and in particular, to the influence of air speed at ejection. Author

N76-27858 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
PRINCIPLES AND PROBLEMS OF HIGH SPEED EJECTION
A. J. Barwood. *In* AGARD 4th Advanced Operational Aviation Med Course May 1976 4 p (For availability see N76-27846 18-52)

The principles of ejection are described to recover aircrew uninjured, which is best achieved by the use of as simple an escape system as technically possible. Once the system has been initiated all sequences automatically follow and there is no further action required by the ejectee until he is descending on a fully deployed parachute. The hazards of ejection and the development of the open ejection seat system up to the maximal capability are briefly described. The sequences of ejection on a typical Martin Baker Aircraft escape system are outlined to stress the simplicity, and therefore technical reliability, of this system as used in the majority of service aircraft in the UK Services. Author

N76-27859 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
CURRENT AND FUTURE ESCAPE SYSTEMS
D. C. Reader. *In* AGARD 4th Advanced Operational Aviation Med Course May 1976 2 p (For availability see N76-27846 18-52)

The role of escape systems in fixed wing military aircraft is now well established. Almost all combat fixed wing aircraft in NATO countries are equipped with ejection seats and considerable effort is spent on improving the performance of these seats for future aircraft. Some of these areas where current escape systems are deficient and some ways in which future systems seek to overcome those deficiencies are described. Author

N76-27860 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
HELICOPTER ESCAPE AND SURVIVABILITY
D. C. Reader. *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 2 p (For availability see N76-27846 18-52)

Military helicopters are not equipped with ejection seats as are fixed wing aircraft. Escape systems are presented to fill the need for helicopter aircrew protection. A.S.K.

N76-27861 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE PHYSIOLOGY OF HIGH G PROTECTION
B. J. Lisher. *In* AGARD 4th Advanced Operational Aviation Med Course May 1976 2 p refs (For availability see N76-27846 18-52)

The introduction of several new combat aircraft which have the structural integrity and the engine power to execute manoeuvers at high levels of acceleration for considerable periods of time reintroduces the concept that certain operations, particularly air to air combat, may be physiologically limited rather than limited by aircraft design parameters. An acceleration level of 8G sustained for 60 seconds has been suggested as a point to which acceleration protection should be aimed, although higher G levels for shorter periods of time can be expected. Two methods of high G protection are presented, one using a reclining seat and the other using immersion of the body in water. Author

N76-27862 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
A COMPARISON OF RECENT ADVANCES IN BRITISH ANTI-G SUIT DESIGN
J. W. Davies. *In* AGARD 4th Advanced Operational Aviation Med Course May 1976 3 p refs (For availability see N76-27846 18-52)

Comparisons in the field of a knee length anti-G suit and an external anti-G suit, with the standard British anti-G suit worn close to the skin, are described and the results discussed. Author

N76-27863 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
THERMAL PROBLEMS IN MILITARY AIR OPERATIONS

J. R. Allan *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 2 p (For availability see N76-27846 18-52)

The thermal problems of an aircrew functioning in air operations over the full range of natural environments are discussed A.S.K

N76-27864 Royal Air Force Inst. of Aviation Medicine, Farnborough (England). Cold Environment Research Section
OPERATIONS IN COLD ENVIRONMENTS
P. Marcus *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 3 p (For availability see N76-27846 18-52)

The incidence of cold stress in military aviation is discussed together with methods for overcoming the problems it poses, by cabin conditioning or by the use of insulating or heated garments. Protective clothing is also required by aircrew to aid survival in emergencies and the principles of its design are considered. Lastly, an account is given of the RAF's permanent cold climate detachments and of cold weather operational and survival training Author

N76-27865 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
THERMAL PROBLEMS IN HIGH PERFORMANCE AIRCRAFT
J. R. Allan *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 5 p ref (For availability see N76-27846 18-52)

A general review of current thermal problems in high performance aircraft, their origins and current design trends in their solution is given. Author

N76-27866 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
PERSONAL THERMAL CONDITIONING
Craig Saxton *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 6 p (For availability see N76-27846 18-52)

The inadequacy of cabin conditioning systems in high performance aircraft has resulted in aircrew being exposed to severe heat stress situations within the cockpit environment during certain flight profiles. To alleviate the physiological strain imposed upon the man, methods of thermally conditioning the micro-environment within flying clothing assemblies have been investigated and applied to operational situations. The cooling agents used in the personal thermal conditoning role have been air or water. The former has been utilized either as an evaporative agent or convective cooling agent. The relative merits of the different personal conditioning systems are discussed and a case made for the development of a practical liquid-cooled suit system for use in present and future high-performance aircraft. Author

N76-27867 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
CABIN PRESSURISATION AND OXYGEN SYSTEMS-REQUIREMENTS
J. Ernsting *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 5 p refs (For availability see N76-27846 18-52)

The considerable interactions between the physiological requirements for cabin pressurization and the relationship between concentration of oxygen and cabin altitude required of oxygen delivery systems for aircrew in flight are explored. Although work performed until 1960 suggested that hypoxia induced by breathing air at altitudes of up to 8,000 feet was acceptable, investigations performed more recently at RAF IAM and elsewhere suggest that the maximum acceptable degree of hypoxia for aircrew in flight is that associated with breathing air at 5,000 feet. The incidence of hypoxia due to malfunction of oxygen delivery equipment and of decompression sickness at altitudes above 20,000 feet is such that the maximum cabin altitude in combat aircraft should not exceed 20,000 to 22,000 feet. The concentration of oxygen which must be breathed to avoid transient hypoxia on sudden failure of a pressure cabin even when 100% oxygen is delivered to the respiratory tract immediately the decompression occurs is generally greater in high differential pressure aircraft than that required to prevent significant hypoxia with the pressure cabin intact. Even in modern combat aircraft this consideration requires a higher than 5,000 feet equivalent breathing mixture at aircraft altitudes greater than 35,000 feet. Author

N76-27868 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
SEAT MOUNTED OXYGEN REGULATOR SYSTEMS IN UNITED KINGDOM AIRCRAFT
A. J. F. MacMillan *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 2 p (For availability see N76-27846 18-52)

The rationale for mounting a demand oxygen regulator assembly on the ejection seat of combat aircraft is described. The special facilities which have been incorporated in systems used in the Royal Air Force by utilizing the advantages of seat mounting are discussed and it is considered that the system provides true duplication of essential components, allows very simple crew drills and reduces aircraft servicing penalties in the event of malfunction of the regulator package. Author

N76-27869 London Hospital Medical Coll. (England). Pharmacology Section
ABSORPTION, METABOLISM AND EXCRETION OF HYPNOTIC DRUGS
Stephen H. Curry *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 7 p refs (For availability see N76-27846 18-52)

Absorption, metabolism and excretion are the processes which govern the growth and decay of plasma concentrations of all drugs, including hypnotics. Variations in plasma concentrations lead to corresponding variations in effect, although the exact detail of the relation between level and effect is more complex than is implied by this statement. Existing data on absorption, metabolism and excretion for the various hypnotic drugs are of variable detail. Total absorption of oral doses is generally believed to occur, although when systematically examined, absorption has sometimes been found to be incomplete. Metabolism occurs by a variety of reactions, but only occasionally to pharmacologically-active compounds. Excretion is of both unchanged drug and metabolites in bile and urine. These events and processes as they relate to hypnotic drug actions are considered in detail. Author

N76-27870 Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
RESIDUAL EFFECTS OF HYPNOTICS
A. N. Nicholson *In* AGARD 4th Advanced Operational Aviation Med. Course May 1976 8 p refs (For availability see N76-27846 18-52)

The residual effects of hypnotic drugs after their therapeutic purpose is fulfilled was considered. Test subject motor skills were examined for residual effects using a method of adaptive tracking A.S.K

N77-16728# Advisory Group for Aerospace Research and Development, Paris (France)
BIOPHYSICAL PROBLEMS IN AEROSPACE MEDICINE
Dec. 1976 167 p In ENGLISH and FRENCH
(AGARD-AR-84, ISBN-92-835-0168-3) Avail: NTIS HC A08/MF A01

Present knowledge in the field of extraterrestrial radiation is reviewed and the exposure of flying personnel to cosmic radiation is examined. The use of lasers and radars in military aviation is discussed. Emphasis is placed on the flight safety and protection of flying and ground personnel and on the primary concern of medical officers in the various armed forces. Information is given on the positive aspects of some of the research undertaken. For individual titles, see N77-16729 through N77-16733.

N77-16729# Atomic Weapons Research Establishment, Aldermaston (England).
COSMIC RADIATION DOSES AT AIRCRAFT ALTITUDES
E. W. Fuller *In* AGARD Biophysical Probl. in Aerospace Dec. 1976 p 3-26 refs (For primary document see N77-16728 07-52)
Avail: NTIS HC A08/MF A01

The radiological doses associated with cosmic radiation in the altitude bands used by military aircraft are examined. Three altitude bands were studied: 35,000 to 40,000 ft (200g/sq cm) used by subsonic jets, 50,000-55,000 ft (100g/sq cm) for supersonic aircraft operating at about Mach 2 and 38,000 ft (20g/sq cm) for aircraft operating at Mach 3. It was seen that the greater part of the dose arises from lightly ionizing radiation and from neutrons of energy up to a few MeV. For these radiations the procedures for converting the data from flux measurements to dose estimates are well established in principle. Author

N77-16730# Hopital Begin, St Mande (France)
BIOLOGICAL STUDIES OF COSMIC RADIATION
R. P. Delahaye and A. Pfister *In* AGARD Biophysical Probl. in Aerospace Dec. 1976 p 27-36 refs (For primary document see N77-16728 07-52)
Avail: NTIS HC A08/MF A01

Various types of experiments pertinent to the biological effects of cosmic radiation are discussed. It is concluded that cosmic rays may be hazardous to personnel of space flight of long duration. L.S.

N77-16731# Hopital Begin, St. Mande (France)
RADIOBIOLOGICAL PROBLEMS OF HIGH ALTITUDE FLIGHTS (BELOW 25 km)
R. P. Delahaye and D. Sturrock *In* AGARD Biophysical Probl. in Aerospace Dec. 1976 p 37-44 refs (For primary document see N77-16728 07-52)
Avail: NTIS HC A08/MF A01

Various forms of irradiation are studied; small doses of galactic cosmic radiation, large doses from solar flares, and exposure to heavy ions. Risk due to radiocarcinogenesis and the deduction of life span due to ionizing radiation are examined. L.S.

N77-16732# Navy Dept., Washington, D.C.
NON IONISING ELECTROMAGNETIC FIELDS: ENVIRONMENTAL FACTORS IN RELATION TO MILITARY PERSONNEL
B. Servantie and P. E. Tyler *In* AGARD Biophysical Probl. in Aerospace Dec. 1976 p 45-74 refs (For primary document see N77-16728 07-52)
Avail: NTIS HC A08/MF A01

The electromagnetic radiation of radar is discussed with emphasis on its potential hazards to living systems. L.S.

N77-16733# Sanitaetsamt der Bundeswehr, Platanenweg (West Germany).
MEDICAL ASPECTS OF LASERS AND LASER SAFETY PROBLEMS
W. Schwarzer *In* AGARD Biophysical Probl. in Aerospace Dec. 1976 p 75-89 refs (For primary document see N77-16728 07-52)
Avail: NTIS HC A08/MF A01

Laser technology is explained. The benefits and hazards from a biological perspective are discussed. L.S.

N77-17710# Advisory Group for Aerospace Research and Development, Paris (France).
RECENT EXPERIMENT/ADVANCES IN AVIATION PATHOLOGY
Dec. 1976 148 p refs Presented at the Aerospace Med. Panel Specialists' Meeting, Copenhagen, 5-9 Apr. 1976
(AGARD-CP-190; ISBN-92-835-0184-5) Avail: NTIS HC A07/MF A01

Application of the methods and techniques of pathology to the investigation of aircraft accidents and aeromedical problems are discussed. Problems concerning local, national, and international law in determining jurisdiction and other (medicolegal) questions are cited along with special methods that aviation pathologist employ to aid in evaluation of the postmortem findings. These methods include developments in toxicologic examination of tissues, roentgenographic evaluation analysis of specific injuries, and injury patterns and psychological factors were studied. For individual titles, see N77-17711 through N77-17729.

N77-17711# Armed Forces Inst. of Pathology, Washington, D.C.
DEVELOPMENT OF AIRCRAFT ACCIDENT INVESTIGATION PROGRAM AT THE ARMED FORCES INSTITUTE OF PATHOLOGY
William R. Cowen *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 3 p (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

The evolution of aircraft accident investigations in civilian and military aviation is presented. Three main principles governing medical support of fatal accidents: (1) environmental factors, (2) traumatic factors, (3) pre-existing disease processes are cited. Application of the tools of the forensic pathologist to the problem was initiated. Environmental factors such as carbon monoxide, and fuels were given top priority along with development of a procedure for lactic acid to detect hypoxia. Screening procedures for alcohol and drugs were also developed, along with procedures conducted on each specimen for carbon monoxide, ethyl alcohol, lactic acid and acid basic neutral drugs which may have altered the flight performance of an individual. B.B.

N77-17712# Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).
DEVELOPMENT OF AVIATION ACCIDENT PATHOLOGY IN THE FEDERAL REPUBLIC OF GERMANY
S. Krafft *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 5 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

Responsibilities and problems of aviation accident pathology are mentioned and the importance of aviation accident pathology for the prevention of aircraft accidents and flying safety is discussed. Historical development of aviation accident pathology in Germany is presented in detail. B.B.

N77-17713# Centre de Recherches de Medecine Aeronautique, Paris (France).
THE PLACE AND ROLE OF MEDICAL SERVICES IN FLIGHT SAFETY STUDY OF THE ORGANIZATION AND MEANS USED IN THE FRENCH AIR FORCES [PLACE ET ROLE DES SERVICES MEDICAUX DANS LA SECURITE DES VOLS ETUDE SUR L'ORGANISATION ET LES MOYENS MIS EN OEUVRE DANS LES FORCES AERIENNES FRANCAISES]
P. M. Pingannaud *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 6 p In FRENCH (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

The importance of the human factor in the causes of accidents or air incidents is discussed along with the necessity for doctors to actively participate in flight safety. Organizational structure and regulatory disposition effective since 1975 are studied, and the functions of the medical profession in the investigation of the causes of accidents or air incidents are defined.
Transl. by B.B.

N77-17714# Royal Air Force, Halton (England). Div. of Aerospace Pathology.
AIRCRAFT ACCIDENT AUTOPSIES: THE MEDICOLEGAL BACKGROUND
John L. Christie *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 13 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

Problems encountered by the aviation pathologist seeking to perform autopsies on the victims of aircraft accidents are evaluated. Authorities having jurisdiction in special cases to conduct investigations are mentioned along with the various interests of each group for conducting their investigation. B.B.

N77-17715# Italian Air Force Medical Service H. Q., Rome.
MEDICO-LEGAL PROBLEMS OF FLIGHT ACCIDENTS INVESTIGATION
Gaetano Rotondo *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 14 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

Necessity is premised of close collaboration between the specialist in forensic medicine and the flight surgeon, in flying accidents investigation. These accidents are surveyed in their different types, various traumatic mechanisms and possible correlations existing between physio-psychical conditions of flying personnel and genesis of single accidents. Different body lesions, sustained by victims of flight accidents, are deeply examined. They are divided into lesions pertaining to skeleton, internal organs and external teguments; and pathogenetic interpretation of each injuries is discussed. As conclusion, reconstruction of causes and ways of flight accident production is discussed. This can be possibly carried out through the examination of differential characteristics of various traumatic findings of the different types of accidents, considering kinedynamics of the single accident as well as the phase in which the injuries were sustained (precipitation, or explosive decompression with subsequent precipitation, or impact on the ground followed by an explosion or not, or explosion in flight followed by impact, or finally the terminal fire on board with or without inhalation of smoke or toxic gases). From this reconstruction useful elements can be obtained, for the prevention of flight accidents and dependent injuries. Author

N77-17716# Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome (Italy).
LEGAL ASPECTS OF FLYING ACCIDENTS INVESTIGATION DISASTER VICTIMS IDENTIFICATION

G. Paolucci *In* AGARD Recent Experience/Advan. in Aviation Pathol Dec. 1976 4 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

Biological and non-biological systems for identification of victims in aviation disasters are discussed and described in detail. Some of the methods mentioned are the following non-biological method: (1) direct identification, (2) identification by exclusion, (3) identification by examination of clothing and personal effects, biological methods: (1) definition of race, (2) determination of sex (3) estimation of age (4) determination of individual characteristics B.B.

N77-17717# Armed Forces Inst of Pathology, Washington, D.C.
PROCEDURES FOR IDENTIFICATION OF MASS DISASTER VICTIMS
Robert R. McMeekin *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 8 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

The problems of identification of mass disaster victims is discussed. Various techniques and identification methods are cited. B.B.

N77-17718# Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).
HISTOLOGY IN AIRCRAFT ACCIDENT RECONSTRUCTION
G. Apel *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 3 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

Histological methods of examining organs of fatally crashed pilots are discussed as a means of revealing diseases which may have limited the flying fitness of a pilot. Various cardiac complications, rare nervous diseases, and communicable diseases endemic only in certain parts of the globe are cited as some of the causes revealed through histological examination of pilot fatalities. B.B.

N77-17719# Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).
THE ASYMPTOMATIC SILENT MYOCARDIAL INFARCTION AND ITS SIGNIFICANCE AS POSSIBLE AIRCRAFT ACCIDENT CAUSE
G. Beckmann and W. Eisenmenger *In* AGARD Recent Experience/Advan. in Aviation Pathol Dec. 1976 3 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A05/MF A01

Myocardial infarction in pilots is discussed as one of the numerous possible causes of aircraft disasters. Two cases are cited in which pilots 33 and 43 years old complained about retrosternal pains of short duration (1 minute) respectively nausea as encountered in hypoxia incidents. Since there was no subsequent pain, there was no cause for and examination by a physican so that the pilots continued their flying duty. After an interval of 10 months respectively 1 month the ECG taken during the periodic flying fitness examination revealed the symptoms of a myocardial infarction suffered by the respective pilots.
Author

N77-17720# Armed Forces Inst of Pathology, Washington, D.C.
CORRELATION OF OCCURRENCE OF AIRCRAFT ACCIDENTS WITH BIORHYTHMIC CRITICALITY AND CYCLE PHASE
John H. Wolcott, Robert R. McMeekin, Robert E. Burgin (Natl. Transportation Safety Board), and Robert E. Yanowitch (FAA, Washington, D.C.) *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 14 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

The occurrence of aircraft accidents on various biorhythmic phases of cycles was studied. Aircraft accident data were obtained from the National Transportation Safety Board for general civil aviation and from the U. S. Army Agency for Aviation Safety for military accidents. The accidents were divided into two groups, pilot and nonpilot involved cases, using the causal factors given by the respective accident boards. No correlation was found between the occurrence of aircraft accidents and either the critical period, the negative phase, or the peak days of the negative phase of the biorhythmic cycles. Data were evaluated by chi-square analysis when considering all three cycles or the physical and emotional cycles alone, and all were studied with a critical period of 24 or 48 hours' duration. Author

N77-17721# Armed Forces Inst. of Pathology, Washington, D.C.
THE INTERPERTATION OF PRECENTAGE SATURATION OF CARBON MONOXIDE IN AIRCRAFT-ACCIDENT FATALITIES WITH THERMAL INJURY
Joseph M. Ballo and Abel M. Dominguez *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 8 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

Victims of aircraft-accident fatalities suffering severe thermal trauma (as defined by second- or third-degree burns and/or percent saturation of carboxyhemoglobin values of 10 or greater) were evaluated. Of 518 cases accessioned from 1968 through 1974, 83 had either sublethal or no physical trauma. The mechanism of death in such cases is (1) glottal spasm, bronchospasm, or acute edema of the upper respiratory passage, (2) cardiovascular collapse secondary to vagal inhibition, (3) acute thermal hyperkalemia potentiated by high levels of circulating catecholamines, (4) complete combustion of flammable material by on-board oxygen supplies, producing an intense fire without the production of CO, or (5) poisoning by other toxic products of combustion Author

N77-17722# Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).
TOXICOLOGICAL ASPECTS IN THE INVESTIGATION OF FLIGHT ACCIDENTS
G. Powitz *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 4 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

The working methods of the German flight toxicology working group were examined. Positive alcohol results required a determination of the water content and a test of possible putrefactive processes. The various procedures for blood alcohol determination were compared and it was found that the enzyme method furnished high values differing from others. Gas-chromatography identified some endogenous substances and putrefactive components respectively, some cases of joint occurrence are mentioned. The disadvantage of the photometric determination of carbon monoxide in burned corpses was illustrated. Extraction methods required for chromatographic separations of biological material were discussed and some disadvantages compared. Author

N77-17723# Royal Air Force Inst. of Pathology and Tropical Medicine, Aylesbury (England).
RECENT AGRICULTURAL AIRCRAFT ACCIDENTS IN THE UNITED KINGDOM
D. G. Wooten *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 7 p (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

Agricultural aviation accidents were analyzed for cause, geographical distribution, and frequency. The probability of an accident occurring increased indirectly with age of the pilot and directly with his experience. Pilot error was the direct cause of the majority of accidents. Improved education and legislation would help to reduce the exposure to toxic chemicals. Author

N77-17724# Armed Forces Inst. of Pathology, Washington, D.C. Div. of Aerospace Pathology.
ACCIDENT RECONSTRUCTION FROM ANALYSIS OF INJURIES
Joseph M. Ballo and Robert R. McMeekin *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 11 p refs (For primary document see N77-17710 08-52)
Avail: NTIS HC A07/MF A01

From an ongoing study of over 500 fatally injured crewmembers of U.S military aircraft every year and an analytically oriented research program in which injury patterns were verified by computerized simulation techniques, estimates were prepared of injury correlated with both the magnitude and the direction of the applied decelerative forces. When an accurate tabulation of postmortem injuries was correlated with measurements of the path of the aircraft after it struck the ground, the dynamics of impact were deduced. This process was invaluable for accidents that occurred without witnesses or survivors and in which crash damage to flight instruments or the absence of flight-data recorders made calculation of impact kinematics difficult. Skeletal injuries,

particularly vertebral compression fractures, lacerations and contusions of viscera, aortic tears and lacerations, and cutaneous contusions caused by compression of harnesses and seat belts, were important factors in determining the direction and magnitude of the deceleration vector. Author

N77-17725# Army Aeromedical Research Lab., Fort Rucker, Ala. Bioengineering and Life Support Equipment Div.

HEAD INJURY PATHOLOGY AND ITS CLINICAL, SAFETY AND ADMINISTRATIVE SIGNIFICANCE

Stanley C. Knapp and Thomas M. Erhardt *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 9 p refs (For primary document see N77-17710 08-52)

Avail: NTIS HC A07/MF A01

A review of head trauma in war, vehicular accidents, sports, and aviation demonstrated that while the head constitutes roughly 9 percent of the body's weight, surface area and volume, it is implicated in 7 out of 10 body injuries. Head trauma causes an unacceptable 1 in 4 deaths and for motorcycling it causes a staggering 1 out of every 2 deaths. It was proposed that examination of head trauma, its costs and the effectiveness of provided protection must apply the analytic tools of epidemiology not only to the injury but to the equipment as well. Prevention requires anticipatory action, based on the knowledge of protective performance history, in order to make the onset or further occurrence of injury unlikely. Author

N77-17726# Naval Aerospace Medical Research Lab., New Orleans, La.

NEUROPATHOLOGY AND CAUSE OF DEATH IN U.S. NAVAL AIRCRAFT ACCIDENTS

Channing L. Ewing and Friedrich Unterharnscheidt *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 6 p refs (For primary document see N77-17710 08-52)

Avail: NTIS HC A07/MF A01

A frequent cause of death in naval aviation was hypothesized as drowning, associated with acceleration concussion perhaps due to neck stretch. Aircraft accident fatality data for the U. S. Navy were presented as a measure of the population at risk and recent data from the literature which might explain the causative mechanism of acceleration concussion are presented. Recommendations for improved standard autopsy protocols for aircraft fatalities were presented. Author

N77-17727# Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).

CLARIFICATION OF A FATAL HELICOPTER GROUND ACCIDENT THROUGH FORENSIC MEDICAL METHODS

G. Apel *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 3 p refs (For primary document see N77-17710 08-52)

Avail: NTIS HC A07/MF A01

Based on the investigation of a fatal helicopter ground accident, which was clarified through forensic medical methods, problems of accident prevention were pointed out, especially the conspicuity of rotating propellers, tail rotors and safety markings. The dangers encountered as a result of vigilance and concentration disturbances in personnel caused by stress of noise, workload, and distraction were discussed. Safety measures required were also presented. Author

N77-17728# Royal Air Force Inst. of Pathology and Tropical Medicine, Aylesbury (England). Dept. of Aviation Pathology and Forensic Medicine.

FATAL HELICOPTER ACCIDENTS IN THE UNITED KINGDOM

A. J. C. Balfour *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 8 p (For primary document see N77-17710 08-52)

Avail: NTIS HC A07/MF A01

There were 27 fatal helicopter crashes investigated in the United Kingdom in the years 1956 to 1975; there were 52 deaths and 15 survivors. Of the crashes 25 percent were survivable and produced 15 percent of the casualties and 73 percent of the survivors. There were 44 men killed in the non-survivable accidents and 4 escaped. In the 6 survivable crashes 8 men died; 5 drowned, one died from fire, one died from traumatic asphyxia, and one submarined out of his safety harness. The casualties emphasized the need for further improvements in training and in helicopter crash worthiness, and for the best early rescue facilities that can be provided. Author

N77-17729# Brooke Army Medical Center, Fort Sam Houston, Tex.

ROENTGENOGRAPHIC EVALUATION IN FATAL AIRCRAFT ACCIDENTS

Richard A. Mosby and Robert R. McMeekin *In* AGARD Recent Experience/Advan. in Aviation Pathol. Dec. 1976 7 p refs (For primary document see N77-17710 08-52)

Avail: NTIS HC A07/MF A01

The roentgenogram was evaluated as having great value in the investigation of fatal aircraft accidents. The entire spectrum of the accident was evaluated with this modality magnifying and enhancing the information available. Calibration of the roentgenogram for use in the investigation of a fatal aircraft accident provided even more useful and factual data. Author

X77-72034 Advisory Group for Aerospace Research and Development, Paris (France).

FOURTH ADVANCED OPERATIONAL AVIATION MEDICINE COURSE

J. Ernsting, ed. and A. N. Nicholson, ed. Jun. 1976 72 p (AGARD-R-642-Suppl) Avail: Advisory Group for Aerospace Research and Development, Paris, France NATO-Classified report

NOTICE: Available to U.S. Government Agencies

Aspects of aviation medicine of current concern to the effectiveness of NATO air forces are covered. The topics include the training of aircrews in aviation medicine, medical aspects of naval helicopter operations on the northern flank of NATO, developments in personal equipment with special reference to helmet developments, high speed escape and thermal problems, and the use of hypnotics in air operations. Air operations and chemical warfare are discussed, in which the operational, chemical, medical, and personal equipment aspects of chemical agents are presented, as well as the problems of personal protection. Author

53 BEHAVIORAL SCIENCES

Includes psychological factors; individual and group behavior; crew training and evaluation; and psychiatric research.

N74-18807# Advisory Group for Aerospace Research and Development, Paris (France).
MATHEMATICAL MODELS OF HUMAN PILOT BEHAVIOR
Duane T. McRuer (Systems Technol, Inc., (Hawthorne, Calif.) and E. S. Krendel (Pa. Univ.) Jan. 1974 83 p refs
(AGARD-AG-188; AGARDograph-188) Avail: NTIS HC $7.25

Mathematical models of the human pilot are used for analyses of the pilot/vehicle system. Elementary concepts and specific physical examples are used for a step-by-step development of what is known about the human pilot as a dynamic control component. In the process, quasi-linear models for single-loop systems with visual stimuli and multiloop systems with visual stimuli are presented and then extended to cover multiloop, multi-modality situations. Empirical connections between the pilot dynamics and pilot ratings are also considered. Nonlinear features of human pilot buhavior in adapting to changes in the character of the stimuli are described and tied to the quasi-linear models via the successive organization of perception (SOP) theory, which is reviewed and elaborated. Dual-mode control models needed to describe the pilot's behavior in response to sudden transients are presented, along with pursuit and compensatory elements of the SOP continuum. The current status of mathematical pilot models is shown to cover random, random-appearing, and transient inputs for single- and multi-loop system configurations. A bibliography of applications and a summary of analysis problems is included. Author

N74-19758# Advisory Group for Aerospace Research and Development, Paris (France)
BIBLIOGRAPHY OF PAPERS AND REPORTS RELATED TO THE GUST UPSET/PILOT DISORIENTATION PROBLEMS
Clifford F. Newberry, comp. (Boeing Co., Wichita, Kans.) Feb. 1974 20 p refs
(AGARD-R-616) Avail: NTIS HC $4.00

A compilation of papers and reports relating to the problem of an airplane being upset for atmospheric disturbances and the pilot being disorientated as a result of the upset is presented. Papers are listed by title and report number and, a summary is also provided where available. Author

N74-20720# Advisory Group for Aerospace Research and Development, Paris (France).
AIRSICKNESS IN AIRCREW
T. G. Dobie (Leeds Univ.) Feb. 1974 75 p refs
(AGARD-AG-177; AGARDograph-177) Avail: NTIS HC $6.75

The problem of airsickness is examined in terms of loss of useful training time. Figures are presented which are likely to be typical of those which occur in any modern Air Force. Various methods of reducing this incidence are discussed, as well as an approach to the management of flying personnel with airsickness. The signs and symptoms of airsickness are described. The aircraft maneuvers which are most likely to induce airsickness are analyzed. Author

N74-31850# Advisory Group for Aerospace Research and Development, Paris (France).
THE OPERATIONAL CONSEQUENCES OF SLEEP DEPRIVATION AND SLEEP DEFICIT
Averne C. Johnson (Navy Med. Neuropsychiatric Res. Unit) and Paul Naitoh (Navy Med. Neuropsychiatric Res. Unit) Jun. 1974 80 p refs
(AGARD-AG-193; AGARDograph-193) Avail: NTIS HC $6.50

The effects of total sleep loss, partial sleep loss, and sleep stage deprivation are reviewed, with particular attention to performance decrement and operational consequences. No consistent or uniform performance decrement was found in operation studies within the 36 to 48 hour range of total sleep loss most likely to be experienced by aircrew personnel, even though laboratory studies identified decrement on certain types of tasks. Physiological changes are minimal during moderate sleep loss, but mood changes are clearly noticeable. The most likely sleep problems for aircrew members are those associated with disruption of sleep-wakefulness cycles and partial sleep loss. Consistent performance decrement is difficult to find, but marked increase in fatigue is a common influence on performance, and it interacts with other stressors to enhance the stress-induced physiological responses. Deprivation of sleep stage rapid eye movement (REM) or sleep stage four produces no behavioral changes supportive of earlier beliefs that these two stages, especially stage REM, are necessary for effective waking behavior. Author

N75-10706# Advisory Group for Aerospace Research and Development, Paris (France).
COLD: PHYSIOLOGY, PROTECTION AND SURVIVAL
Fridtjov Vogt Lorentzen (Roy. Norwegian Air Force, Oslo) Aug. 1974 44 p refs
(AGARD-AG-194; AGARDograph-194) Avail: NTIS HC $3.75

The possibility of survival in a cold environment alone or in combination with other physical stresses, lies more in the field of technology and engineering, than in modifying human physiology. Practical points concerning survival techniques and equipment are discussed. The more serious problem encountered by a single man with simple equipment which has the highest possible efficiency/weight ratio is considered. Author

N75-12587# Advisory Group for Aerospace Research and Development, Paris (France).
SIMULATION AND STUDY OF HIGH WORKLOAD OPERATIONS
A. N. Nicholson, ed. (RAF Inst. of Aviation Med.) Oct. 1974 126 p refs Presented at the Aerospace Med. Panel Specialist Meeting, Oslo, 24-25 Apr. 1974
(AGARD-CP-146) Avail: NTIS HC $5.75

The use of simulation for the evaluation of aircrew performance in high operational work load situations is considered. For individual titles, see N75-12588 through N75-12603.

N75-12588 School of Aerospace Medicine, Brooks AFB, Tex.
SYSTEMS SIMULATION: A GLOBAL APPROACH TO AIRCREW WORKLOAD
Harry M. Hughes, Bryce O. Hartman, Raul Garcia, and Paul Lozano *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 14 p (For availability see N75-12587 03-53)

Aircrew workload can be studied at many different levels of detail. In the most general sense, it is a function of the total workload imposed upon a unit in relation to the number of crews in that unit. An airlift system simulation program has been designed using this global approach and a number of simulation studies have been performed. Outcomes in terms of systems effectiveness measures, crew workload, and crew welfare measures will be presented. Author

N75-12589 National Aerospace Lab., Amsterdam (Netherlands).
A SIMULATOR STUDY TO INVESTIGATE HUMAN OPERATOR WORKLOAD
P. H. Wewerinke and J. Smit *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 6 p refs (For availability see N75-12587 03-53)

Human response characteristics in control situations of widely varying difficulty were studied. The experiment was aimed at a better understanding of the human operator limitations in terms of control effort as included in the optimal control model. Based on the experimental results a control effort index is presented. The predicted control effort correlates excellently with subjective ratings and seems to have a useful generality. Author

N75-12590 Royal Aircraft Establishment, Farnborough (England). Human Factors Group.
LABORATORY RESEARCH INTO HUMAN INFORMATION PROCESSING
Jo H. F. Huddleston *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 3 p (For availability see N75-12587 03-53)

Pilot workload can be expressed as the coping with two main clusters of problem. One cluster is equipment based and theoretically amenable to physical modelling, even replacement. The other cluster is emphatically to do with humanity; to do with those elusive personal gambles on which life is felt to depend. Pilot workload might be the maintenance of a mental model encompassing these two kinds of time varying input; the continued provision of a mental solution for two sources of uncertain problem. Respectable transfer function work considers varied inputs, monitor outputs, and debate black box contents with a rare freedom. Author

N75-12591 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).

EVALUATING MEASURES OF WORKLOAD USING A FLIGHT SIMULATOR

J. M. Rolfe, J. W. Chappelow, R. L. Evans, S. J. E. Lindsay, and A. C. Browning (RAE) *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 13 p refs (For availability see N75-12587 03-53)

A flight instrument trainer, resembling a twin jet communications aircraft, was used to evaluate questionnaire, performance and activity analysis measures of pilot workload. Attempts were made to distinguish between the physical, perceptual and mental components of workload. For this purpose three flight plans were devised, of approximately equal duration, differing markedly with respect to the three above components. Six professional pilots flew each flight plan and after landing completed questionnaires to assess the workload levels and the task content. During the flights video recordings were made of the pilot's manual and communication activity. From the measures it was possible to obtain significantly different results relating to the different flight plans. These results were capable of distinguishing between the three components of workload represented in the flight s. Author

N75-12592 Royal Air Force Inst. of Aviation Medicine, Farnborough (England).

A FLIGHT SIMULATOR STUDY OF MISSILE CONTROL PERFORMANCE AS A FUNCTION OF CONCURRENT WORKLOAD

K. G. G. Corkindale *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 6 p refs (For availability see N75-12587 03-53)

Eight pilots took part in a part task simulation of the delivery of a stand-off air-to-surface guided weapon. The attack phase of a sortie was simulated. This phase lasted some 3 minutes and included a low level run to the weapon release area, weapon release, target detection on the TV monitor display and the aiming of the missile at the target. Four levels of workload were studied. The results showed that: (1) performance at the missile control was degraded by increases in concurrent workload; and (2) manual flight control and auto-pilot monitoring were adversely affected by concurrent missile control tasks. Author

N75-12593 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.

SIMULATION OF HIGH WORKLOAD OPERATIONS IN AIR TO AIR COMBAT

F. M. Holden, D. B. Rogers, and C. R. Replogle *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 4 p refs (For availability see N75-12587 03-53)

Workload measurements for the study and analysis of human performance are analyzed to provide effectiveness versus design data with specific examples from air to air combat man-in-the-loop simulations. The report concludes with a discussion of man-in-the-loop simulation as a technique for system specific human performance data and as a source for the data required to develop general methods and techniques for predicting the performance of manned weapon systems. Author

N75-12594 Dunlap and Associates, Inc., La Jolla, Calif.

PILOT LANDING PERFORMANCE UNDER HIGH WORKLOAD CONDITIONS

C. A. Brictson *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 10 p refs (For availability see N75-12587 03-53)

A longitudinal study of pilot carrier landing performance was conducted to describe the influence of prolonged operations on pilot performance. A landing performance criterion previously validated in a fleet environment was used to measure and compare pilot and squadron performance variations over time. Three levels of cumulative workload were defined to evaluate concomitant changes in performance associated with each workload. Pilot landing performance improved over time with more improvement found in night performance than day. The influence of practice on carrier landings is discussed in relation to high cumulative workload. The performance criterion was used to identify potential night pilots on the basis of landing proficiency. High and low proficiency pilots also were identified and diagnostic training information provided. Author

N75-12595 Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).

AIRCREW WORKLOAD AND HUMAN PERFORMANCE: THE PROBLEM FACING THE OPERATIONAL COMMANDER

W. D. Macnamara *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 5 p refs (For availability see N75-12587 03-53)

The information available to an operational commander on the reliability and serviceability of the human component in the air weapons system is limited when compared to that available for the aircraft and other systems components. The common use of total flying hours does not provide the commander with information consistent with that now available from aircrew workload and performance studies. A basis for and the background in the development of a trail approach to providing commanders with better information on the human component is described. Author

N75-12596 School of Aerospace Medicine, Brooks AFB, Tex. Environmental Physiology Branch.

ENDOCRINE-METABOLIC INDICES OF AIRCREW WORKLOAD: AN ANALYSIS ACROSS STUDIES

Henry B. Hale, Richard C. McNee, James P. Ellis, Jr., Ralph R. Bollinger, and Bryce O. Hartman *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 6 p refs (For availability see N75-12587 03-53)

Endocrine metabolic measures have been subjected to a cross-sectional analysis in an effort to ascertain the basic relation of endocrine metabolic activity to the workload in either actual or simulated flights. For the present purpose, load represents degree of flight difficulty multiplied by duration. Difficulty was based upon USAF expert rankings, and duration was based upon fractions of a day. Multiple linear regression analysis was performed on data for urinary epinephrine, norepinephrine, 17-OHCS, urea, Na, K, and the Na/K ratio. This report presents the findings in the first phase of the cross-sectional study. Author

N75-12597 Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany).

TIME DEPENDENCE OF THE FLIGHT INDUCED INCREASE OF FREE URINARY CORTISOL SECRETION IN JET PILOTS

G. Ulbrecht, E. Meier, R. Rothenfusser, and K. V. Werder *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 6 p refs (For availability see N75-12587 03-53)

A modified competitive protein binding assay of free urinary cortisol using a single solvent extraction and a cortisol binding globulin from a dexamethasone suppressed male subject was developed. The separation of bound and free cortisol was performed by adsorption of the free cortisol to dextran coated charcoal. The sensitivity of the method allows to measure as low as 0.2 ng per tube. In seven F-104 pilots flying two missions a day the 24 hr free urinary cortisol secretion was significantly higher compared to 12 pilots on day of rest. When 26 F-104 pilots, 12 RF 4E pilots and 14 weapon system operators (WSO) were evaluated by measuring free urinary cortisol excretion in short intervals it could be demonstrated, that only the pilots flying early in the morning showed an enhancement of adrenocortical activity compared to normal controls, suggesting a change of excitability of the hypothalamo-pituitary-adrenal system during the day. Author

N75-12598 Navy Medical Neuropsychiatric Research Unit, San Diego, Calif.

EMOTIONAL AND BIOCHEMICAL EFFECTS OF HIGH WORK-LOAD

William B. McHugh, Paul Naitoh, and C. A. Brictson (Dunlap and Associates, Inc., La Jolla, Calif.) *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 9 p refs (For availability see N75-12587 03-53)

A preliminary longitudinal multifactorial study of the interrelationships of biochemical, mood, biographical factors and landing performance under high work load conditions has been carried out with U. S. Naval Aviators. Levels of serum cholesterol, serum uric acid, blood lactate, pyruvate, and mood assessments were made during periods of non-flying activity and during periods of increased cumulative work load. Uric acid values fell during moderate cumulative work load, and cholesterol values fell during high cumulative work load. Increased variability of pyruvate and lactate were noted with increased cumulative work load. Increased cumulative work load did not affect emotions or performance but altered mood association patterns and altered the relationships of mood and performance. Experience was correlated with performance under zero cumulative work load conditions. Emotion correlated with performance under high cumulative work load conditions. Author

N76-12599 Dunlap and Associates, Inc., la Jolla, Calif.
PREDICTION OF PILOT PERFORMANCE: BIOCHEMICAL AND SLEEP-MOOD CORRELATES UNDER HIGH WORKLOAD CONDITIONS
C. A. Bricteon, W. B. McHugh (Navy Med. Neuropsychiatric Res. Unit), and P. Naitoh (Navy Med. Neuropsychiatric Res. Unit) *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 10 p refs (For availability see N76-12597 03-53)

A preliminary longitudinal study of the factors affecting the carrier landing performance of naval aviators under high workload conditions has been carried out. Using stepwise multiple regression techniques, a substantial portion of the variability in landing performance could be accounted for by six factors under zero cumulative workload conditions and by seven factors under moderate cumulative workload conditions. High cumulative workload conditions sharply reduced predictive ability. Although specific aircraft experience and total flight experience were important predictors of average landing performance, blood biochemical levels and emotional states had significant predictive ability. Sleep patterns relate strongly to performance. The factors that determine landing performance change as cumulative as workload increases. Author

N76-12600 Royal Air Force Strike Command, High Wycombe (England).
LONG RANGE AIR-TO-AIR REFUELLING: A STUDY OF DUTY AND SLEEP PATTERNS
N. H. Mills and A. N. Nicholson (RAF Inst. of Aviation Med.) *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 9 p refs (For availability see N76-12597 03-53)

The sleep patterns of ground crew, pilots and tanker crews involved in a long range air-to-air refuelling mission have been related to their duty hours. During such complex operations workload may vary considerably and the demands placed on some aircrew may be very high. It is suggested that the duty hours demanded of individual aircrew should be related to their overall workload. In this way it may be possible to maintain an acceptable sleep pattern in all aircrew and ensure that no individual pilot or crew member is subjected to excessive duty hours. Author

N76-12601 Supreme Headquarters Allied Powers Europe (Shape), Casteau (Belgium).
HIGH WORKLOAD TASKS OF AIRCREW IN THE TACTICAL STRIKE, ATTACK AND RECONNAISSANCE ROLES
F. TerBraak *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 3 p (For availability see N76-12597 03-53)

High workload tasks are outlined for aircrew performing three distinct tactical roles, namely the strike, the attack and the reconnaissance roles. The total mission is covered, which is from the time the pilot receives his orders until the debriefing following the flight has been completed. At the same differences between each role, as related to workload, are printed out so that a fairly realistic comparison can be made as to the workload of each category. Author

N76-12602 Royal Air Force, Binbrook (England).
THE AIR DEFENCE ROLE
J. Hutchinson *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 5 p (For availability see N76-12597 03-53)

In considering the workload involved in the air defense role, it is important to be clear as to the dimensions of the subject. On the one hand, any air defense situation will pose a problem which can be defined in absolute mathematical terms, and whose solution implies a certain degree of effort. The essence of air defense is that the intruder will set about making the defender's task as difficult as possible; the tactics he adopts, in addition to making the problem less tractable, may also reduce, through stress, fatigue, fear or several more factors the ability of the air defense crew to solve the problem. The perceived workload facing the crews whose ability is thus impaired may prove to be beyond their capability. Pilots need training against all possible threats from supersonic air launched missiles at high level, through high subsonic bomber penetrations at low level, to air combat manoeuvring against fighter-type aircraft. This range of possibilities includes head-on, beam and rear attacks with missiles, guns or both, pressed home either semi-automatically using electronically computed steering information, or visual information. Author

N76-12603 School of Aerospace Medicine, Brooks AFB, Tex.
PHYSIOLOGICAL COSTS OF EXTENDED AIRBORNE COMMAND AND CONTROL OPERATIONS
Ralph R. Bollinger, Robert D. ODonnell, and Bryce O. Hartman *In* AGARD Simulation and Study of High Workload Operations Oct. 1974 9 p ref (For availability see N76-12597 03-53)

During Exercise Night Star the personnel of the National Emergency Airborne Command Post successfully documented their ability to maintain a continuous airborne alert for an extended period. Biomedical evaluation showed that performance was maintained by the mission teams, flight crews, and ground support personnel. When significant fatigue did occur, whether in flight or on the ground, it developed near the beginning of the exercise. The only cases of marked or persistent fatigue were seen in those groups whose day/night, work/rest cycles were shifted and can be attributed in major part to the resulting sleep loss. However, all groups appeared to adapt to their new work schedules as the exercise progressed. Author

N76-15306# Advisory Group for Aerospace Research and Development, Paris (France).
ORIENTATION/DISORIENTATION TRAINING OF FLYING PERSONNEL: A WORKING GROUP REPORT
A. J. Benson, ed. Nov. 1974 82 p refs
(AGARD-R-625) Avail: NTIS HC $4.25

Orientation/disorientation training is reviewed of military and civilian aircrew in NATO countries. Deficiencies in current programs are discussed and 24 recommendations made for improvement of ground and in-flight training. Sections of the report review ground based training techniques, the use of familiarization devices, more complex trainers, and aspects of in-flight training. Descriptions of the conduct of ground and in-flight demonstrations, a specimen lecture syllabus, and a specification for a familiarization device, are given. Topics requiring further research or development are identified. Author

N76-25782# Advisory Group for Aerospace Research and Development, Paris (France).
HIGHER MENTAL FUNCTIONING IN OPERATIONAL ENVIRONMENTS
Bryce O. Hartman, ed. (School of Aerospace Med., Brooks AFB, Tex.) Apr. 1976 82 p refs Presented at Aerospace Med. Panel Specialists Meeting, Ankara, 21 Oct. 1975
(AGARD-CP-181; ISBN-92-835-1216-2) Copyright. Avail: NTIS HC $5.00

Psychophysiology of flight stress and human factors engineering for military aviation systems is elaborated. For individual titles, see N76-25783 through N76-25793.

N76-25783 Federal Aviation Administration, Washington, D.C. Office of Aviation Medicine.
DEFINITION AND MEASUREMENT OF PERCEPTUAL AND MENTAL WORKLOAD IN AIRCREWS AND OPERATORS OF AIR FORCE WEAPON SYSTEMS, A STATUS REPORT
Siegfried J. Gerathewohl *In* AGARD Higher Mental Functioning in Operational Environments Apr. 1976 7 p refs (For availability see N76-25782 16-53)

The determination of pilot and aircrew workload using psychological, physiological, and operational criteria has yielded valuable results. Methods used in civil aviation can be applied with appropriate modifications to military problems. However, workload measurements associated with highly complex and demanding conditions are still difficult. Data are not available from actual combat missions. The results obtained by simulation are promising and may be improved by the standardization of methods and the application of statistical approaches and mathematical models. Author

N76-25784 School of Aerospace Medicine, Brooks AFB, Tex.
THE CORRELATIONAL STRUCTURE OF TRADITIONAL TASK MEASURES AND ENGINEERING ANALOGUES OF PERFORMANCE IN THE COGNITIVE DOMAIN
Richard C. McNee, Richard A. Albanese, William G. Jackson, William F. Storm, and Bryce O. Hartman *In* AGARD Higher Mental Functioning in Operational Environments Apr. 1976 6 p refs (For availability see N76-25782 16-53)

Standard performance measures from a traditional battery of tasks (the Neptune battery) were compared with simulated

antiaircraft gunnery activities under several configurations. These measures were found to correlate only to a moderate degree, with the highest canonical correlation between the two sets being .72. Preliminary modeling of the subject reactions on the simulation, a compensatory tracking task, has been accomplished using control theory methods. A tentative conclusion from this work is that the transfer functions associated with random inputs are reasonable to use for this compensatory tracking task, which involves both deterministic and random inputs. Author

N76-25785 Milan Univ. (Italy).
A STUDY OF BEHAVIOUR DURING A TRIAL OF VIGILANCE IN NON-PILOTING PERSONNEL
Ferdinando Monesi and Francesco Ravaccia. *In* AGARD Higher Mental Functioning in Operational Environments. Apr. 1976 6 p refs (For availability see N76-25782 16-53)

Subjects highly experienced in air traffic assessment and decision making tasks underwent a performance trial involving visual vigilance in a simulated operative environment. Data were collected by administering self rating scales and recording both reaction times and brain potentials. Statistical analysis of data was performed with parametric and non parametric tests. All types of approach proved to be of value in the assessment of performance, although the greater utility of computerized neurophysiological evaluation must be emphasized for an advance in methodology. Author

N76-25786 Pacific Missile Test Center, Point Mugu, Calif.
SOME PRACTICAL CONSIDERATIONS FOR PERFORMANCE TESTING IN EXOTIC ENVIRONMENTS
Robert S. Kennedy and Ronald A. Bruns. *In* AGARD Higher Mental Functioning in Operational Environments. Apr. 1976 6 p refs (For availability see N76-25782 16-53)

Correlations and normative data for six different versions of an auditory vigilance task are presented for approximately 100 males. In addition, other findings about effects on performances of: practice, distractions, threat stress, and aircraft turbulence are discussed. Instructions for apparatus construction, scoring, and administration are reported. Author

N76-25787 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Bad Godesberg (West Germany).
AIR OPERATIONS AND CIRCADIAN PERFORMANCE RHYTHMS
K. E. Klein, H. M. Wegmann, G. Athanassenas, H. Hohlweck, and P. Kuklinski. *In* AGARD Higher Mental Functioning in Operational Environments. Apr. 1976 12 p refs (For availability see N76-25782 16-53)
(Contract F33615-70-C-1598)

Experimental results and pertinent data from literature on circadian behavioral rhythms and their modifications through various factors are reviewed. Considered are operations of aircrews round the clock and on transmeridian routes; some possibilities of appropriate scheduling are discussed. Author

N76-25788 School of Aerospace Medicine, Brooks AFB, Tex.
THE HUMAN AS AN ADAPTIVE CONTROLLER
Richard A. Albanese, Richard C. McNee, Edward J. Engelken, Peter H. Henry, and Bryce O. Hartman. *In* AGARD Higher Mental Functioning in Operational Environments. Apr. 1976 8 p refs (For availability see N76-25782 16-53)

During flight, aircrew members often function as subsystems in feedback control loops. In particular, visual tracking tasks have been studied for many years. For these tasks, it has been observed that the human alters his control actions when the device to be controlled, or when the bandwidth of the signal to be tracked, is changed. Thus, the human operator appears to be an adaptive controller. This article reviews the adaptive nature of man's control function using previously published data, and introduces information theory metrics which show a regularity in these data. Also, new data obtained from twelve subjects flying simulator while under the influence of orally administered 190 proof ethyl alcohol (0.0, 0.3, 0.6, and 0.9 gms/kg body weight) are presented. These results are related to previous studies, using both control and information theory metrics. Author

N76-25789 Civil Aeromedical Inst., Oklahoma City, Okla. Aeronautical Center
ASSESSMENT OF PERCEPTUAL AND MENTAL PERFORMANCE IN CIVIL AVIATION PERSONNEL
Siegfried J. Gerathewohl (FAA, Washington, D. C.), W. Dean Chiles, and Richard I. Thackray. *In* AGARD Higher Mental Functioning in Operational Environments. Apr. 1976 4 p refs (For availability see N76-25782 16-53)

A series of experiments were conducted in order to study functions of relevance to aircrew, pilot, and ATC performance. They concerned the assessment of mental functions and complex performance on single operators and five man crews while monitoring static and dynamic processes, of perceptual motor tracking ability, as well as group problem solving. Operator proficiency was measured at various levels of demand induced by the simultaneous performance of different combinations of tasks, requiring the exercise of psychological and mental processes. It was found that multiple task performance varied significantly as a function of information input and group interaction. Substantial correlations were obtained between perceptual motor type problem solving and mental ability tests. Moreover, the results obtained from two tracking tasks suggest that a central process exerts a regulatory influence on a variety of physiological variables during increased attention demand and, furthermore, a correlation exists between the ability to sustain attention and personality characteristics of the operator. Author

N76-25790 Surrey Univ., Guildford (England).
EMOTIONAL STRESS AND FLYING EFFICIENCY
L. R. C. Haward. *In* AGARD Higher Mental Functioning in Operational Environments. Apr. 1976 5 p refs (For availability see N76-25782 16-53)

A comparative study of the effects of emotional and intellectual stress upon flying performance is described. Ten pilots with self confessed emotional problems, but certified medically fit to fly were matched approximately for age and flying experience with ten pilots confessing to no emotional problems. Emotional stress was induced by a clinical abreactive technique and measured in terms of psychophysiological concomitants. Intellectual stress was induced by the PASAT technique which is an automated numerical task designed to produce mental overload. Flying skill was measured in the presence and absence of both types of stress separately by means of a crossover design. The results show significant differences in flying performance between the two groups and between the two types of stress. It is demonstrated that intellectual stress produces impaired flying skill which is predictable both in degree and duration, whereas emotional stress produces substantially more severe but fluctuating degrees of impairment of unpredictable duration. The use of a psychometric technique using personal keywords and physiological monitoring clearly differentiates the two groups of pilots and indicates the origins of emotional stress. Its possible use for screening aircraft captains before important missions is examined. Author

N76-25791 Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).
A CONCEPTUAL MODEL FOR OPERATIONAL STRESS
William A. LePage, Robert F. Thatcher, and Peter J. Dean. *In* AGARD Higher Mental Functioning in Operational Environments. Apr. 1976 5 p refs (For availability see N76-25782 16-53)

In the Canadian Forces, as in the NATO Air Forces, there are a variety of stressful operations. In discussing these complex stress situations with operational commanders, it was found beneficial to utilize a conceptual model to describe the circumstances. This model is described and discussed. Author

N76-25792 Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
SECONDARY TASK ASSESSMENT OF COGNITIVE WORKLOAD IN ALTERNATIVE COCKPIT CONFIGURATIONS
Robert D. ODonnell. *In* AGARD Higher Mental Functioning in Operational Environments. Apr. 1976 4 p refs (For availability see N76-25782 16-53)
(AMRL-TR-75-49)

New developments in cockpit design introduce significantly greater cognitive demand on the crew member. In a series of pilot studies, traditional secondary task reserve capacity concepts were modified to be used at sub-maximal levels of workload. A primary flight simulation was performed simultaneously with the item recognition task. This task was chosen because the intercept and slope functions of the memory load/reaction time function appear to independently assess cognitive and sensory motor workload. The secondary task shows reliable and consistent changes with variations in workload, and appears promising as

an objective measure of higher mental functions. Auditory and visual versions have been constructed, and further validation studies are being carried out. Author

N76-25793 School of Aerospace Medicine, Brooks AFB, Tex.
THE EFFECTS OF TWO STRESSORS ON TRADITIONAL AND ENGINEERING ANALOGUES OF COGNITIVE FUNCTIONING
William F. Storm, Richard C. McNee, Richard A. Albanese, and Bryce O. Hartman *In* AGARD Higher Mental Functioning in Operational Environments Apr 1976 12 p refs (For availability see N76-25782 16-53)

The sensitivities to stress of traditional psychometric measures and human operator technology engineering parameters were compared in two experiments. In the first study, the effects of mild (8,000 ft) and moderate (15,000 ft) hypoxia were assessed. In the second study, standby alert duty was simulated. Systematic comparison was made between performance following sudden awakening and performance following enforced wakefulness. A battery of tasks emphasizing cognitive processes generated traditional performance measures. Psychomotor functions involving vigilance, problem solving, short term memory, and compensatory tracking were exercised. In addition, a two dimensional tracking task provided traditional task measures and human operator engineering parameters. The properties of the task were systematically varied and models developed for each condition. Both the traditional task measures and the HOT model parameters were analyzed for changes suggestive of alterations in cognitive functioning. The data suggest significant influences of both stressors on cognitive functioning. Conventional performance measures from the HOT task were more sensitive to the stress effects than the traditional task battery. Author

54 MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT

Includes human engineering, biotechnology, and space suits and protective clothing.

N76-23166# Advisory Group for Aerospace Research and Development, Paris (France).
STANDARDISATION OF IMPACT TESTING OF PROTECTIVE HELMETS A Working Group Report
D. H. Gleister, ed. Feb. 1974 14 p refs
(AGARD-R-629) Avail: NTIS HC $3.25

Standardization of biodynamic impact testing on aircrew helmets is considered. A classification of currently used test procedures is attempted and a compromise approach is proposed which could form the basis for agreement within the NATO membership. In addition to impact protection, penetration resistance and helmet retention, it specifies requirements for blast protection, maximum all-up weight and location of helmet's center of gravity. Author

N77-12708# Advisory Group for Aerospace Research and Development, Paris (France).
VISUAL AIDS AND EYE PROTECTION FOR THE AVIATOR
Thomas J. Tredici (School of Aerospace Medicine, Brooks AFB, Tex.) Oct. 1976 89 p Presented at the Aerospace Med. Panel Specialist Meeting, Copenhagen, 5-9 Apr. 1976
(AGARD-CP-191; ISBN-92-835-0177-2) Avail: NTIS HC A05/MF A01

Information concerning visual aids and eye protective devices used by the aviator is discussed. Among the topics considered were: protection from retinal burns and flash blindness due to atomic flash; vision with the AN/PVS-5 night vision goggle; in-flight evaluation of optically stabilized target acquisition devices; and the correction of presbyopia. For individual titles, see N77-12709 through N77-12717.

N77-12709# Royal Aircraft Establishment, Farnborough (England). Neurosciences Div.
EYE PROTECTION, PROTECTIVE DEVICES AND VISUAL AIDS
D. H. Brennan *In* AGARD Visual Aids and Eye Protection for the Aviator Oct. 1976 p 12 (For primary document see
Avail: NTIS HC A05/MF A01

The major ocular hazards encountered in military aviation are discussed and some protective measures which may be adopted are described. The hazards considered are solar glare, bird strike, wind blast, miniature detonating cord, lasers and nuclear flash. The role of image intensifiers in aviation is also discussed. Author

N77-12710# Naval Air Development Center, Warminster, Pa. Crew Systems Dept.
INTEGRATION OF AVIATORS EYE PROTECTION AND VISUAL AIDS
Gloria T. Chisum and Phyllis E. Morway *In* AGARD Visual Aids and Eye Protection for the Aviator Oct. 1976 p 7 (For primary document see N77-12708 03-54)
Avail: NTIS HC A05/MF A01

Recent technological developments have resulted in additional functions being assigned to the helmet and visor. The additional functions range from static aids for distant vision to dynamic displays of information for use in weapon control and guidance, and aircraft management and situational information. Basic requirements for the protective equipment were established. The expanded functions for the protective equipment require that modifications be made in the equipment configuration. The modifications must be accomplished without sacrificing the basic functions of protection. Accomplishment of these two goals requires cooperation between the display designers and crew equipment specialists. Author

N77-12711# Sandia Labs., Kirtland AFB, N. Mex.
PROTECTION FROM RETINAL BURNS AND FLASHBLINDNESS DUE TO ATOMIC FLASH
Billy J. Pfofp (ASD/SMLS Life Support SPO, Wright-Patterson, AFB, Ohio), J. Thomas Cutchen, and J. O. Harris *In* AGARD Visual Aids and Eye Protection for the Aviator Oct. 1976 p 6 refs (For primary document see N77-12708 03-54)
Avail: NTIS HC A05/MF A01

Transparent ferroelectric ceramic material, lead lanthanum zirconate titanate (PLZT), has enabled the development of large aperture electrooptic shutters in goggle or window type formats which provide sufficiently rapid decrease in transmitted light intensity to prevent flashblindness and permanent retinal burn from ultraviolet, visible and infrared radiation encountered in nuclear explosions. Author

N77-12712# Air Force Systems Command, Brooks AFB, Tex.
USAF AVIATOR GLASSES. HGU-4/P: HISTORY AND PRESENT STATE OF DEVELOPMENT
Thomas J. Tredici *In* AGARD Visual Aids and Eye Protection for the Aviator Oct. 1976 p 6 refs (For primary document see N77-12708 03-54)
Avail: NTIS HC A05/MF A01

The aviator goggle HGU-4P has the important fundamental role of enhancing and protecting the vision of U.S. Air Force aviators. The spectrum of presently available lenses is reviewed. Studies to improve the product are detailed, in particular, the impact tests, both drop ball and ballistic, of glass (heat treated and chemical ion exchange) and plastic (CR-39 and polycarbonate). The practical tests of plastic versus glass lenses used in the field is reviewed. The culmination of this research has resulted in the presently available product, one that is felt to be the best that the state-of-the-art can presently produce. Author

N77-12713# Centre Principal d'Expertises Medicales du Personnel Navigant, Paris (France).
CONCERNING FLIGHT AND THE CORRECTION OF PRESBYOPIA [A PROPOS DU VOL ET DE LA CORRECTION DES PRESBYTES]
J. F. Chevaleraud and Ch. Corbe *In* AGARD Visual Aids and Eye Protection for the Aviator Oct. 1976 p 4 refs In FRENCH (For primary document see N77-12708 03-54)
Avail: NTIS HC A05/MF A01

The use of eyeglasses by civil and military pilots over the age of 40 is investigated. The need for special lenses for flight use is discussed. A method is presented for determining the corrective measures needed for subjects with diminished power of accommodation for near objects. A.H.

N77-12714# Service de Sante pour l'Armee de l'Air, Paris (France).
FLIGHT FITNESS AND PLIANT CONTACT LENSES [APTITUDE AU VOL ET LENTILLES DE CONTACT SOUPLES]
J. P. Chevaleraud and G. Perdriel *In* AGARD Visual Aids and Eye Protection for the Aviator Oct. 1976 p 4 refs In FRENCH (For primary document see N77-12708 03-54)
Avail: NTIS HC A05/MF A01

Four subjects were tested in a pressurized tank to determine the physiological effects of flexible contact lenses having 40% absorbency. Corneal sensitivity, ocular tone and the permeability of lachrymal ducts were observed. Lachrymal secretion and binocular vision were measured. The advantages of soft contact lenses over hard lenses is discussed. A.H.

N77-12715# Army Aeromedical Research Lab., Fort Rucker, Ala.
VISION WITH THE AN/PVS-5 NIGHT VISION GOGGLE
Roger W. Wiley and Frank F. Holly *In* AGARD Visual Aids and Eye Protection for the Aviator Oct. 1976 p 12 refs (For primary document see N77-12708 03-54)
Avail: NTIS HC A05/MF A01

Results are presented from a series of experiments in which visual performance using the AN/PVS-5 night vision goggle was measured. Visual modulation transfer functions of the man-goggle system were determined and compared to results obtained with unaided viewing. The man-goggle system performance was superior to unaided visual performance at average target luminances equivalent to 5% and 25% moon illuminances. At a target luminance equivalent to a full moon illuminance, unaided visual performance was superior at higher spatial frequencies, while remaining poorer at the lower spatial frequencies. Using a modified Howard-Dolman apparatus, it was determined that the stereoscopic threshold was degraded with the man-goggle system. Field measurements of relative depth discrimination using all available visual cues showed that performance of the man goggle system was statistically equivalent to unaided phototopic visual performance at intermediate viewing distances, but was inferior to unaided viewing at distances of 500 feet or greater. Author

N77-12716# Centre de Recherches du Service de Sante des Armees, Clamart (France).

EXPERIMENTAL STUDY OF VISION DIMMING IN AN ANIMAL [ETUDE EXPERIMENTALE DE L'EBLOUISSEMENT CHEZ L'ANIMAL]

L. Court, J. P. Chevaleraud, G. Perdriel, and M. Basin *In* AGARD Visual Aids and Eye Protection for the Aviator Oct. 1976 p 11 refs In FRENCH (For primary document see N77-12708 03-54)
Avail: NTIS HC A05/MF A01

Vision dimming is a temporary deficit in visual perception in a subject submitted to intense luminous energy, at a level higher than that of his level of adaptation. Electrodes were implanted in a monkey and [illegible] to study the electrophysiological rectification and behavior [illegible] by glare. The time of recuperation is measured. Transl. by A.H.

N77-12717# Army Aeromedical Research Lab., Fort Rucker, Ala.

IN-FLIGHT EVALUATION OF HAND-HELD OPTICALLY STABILIZED TARGET ACQUISITION DEVICES

David D. Glick *In* AGARD Visual Aids and Eye Protection for the Aviator Oct. 1976 p 13 (For primary document see N77-12708 03-54)
Avail: NTIS HC A05/MF A01

Several target acquisition devices are compared in-flight. Considering size, weight, complexity, and performance in an in-flight visual acuity task, one of the devices looked promising. A group of twenty-nine subjects used a single device in a scout helicopter flight scenario. The device produced motion sickness and the experimental plan was designed to assess this as well as visual acuity in flight. The subjects flew the scenario first with the unaided eye and then with the device in both a stabilized and unstabilized (caged) mode. The latter two flights were counterbalanced across subjects. Following the flight phase, the subjects were given a series of tests to evaluate individual susceptibility to motion sickness. Performance in the visual acuity task was significantly correlated with the airsickness rating of an on-board experimenter; however, there was no significant difference between the magnitude of the symptoms observed when the device was stabilized and the magnitude when caged. Author

59 MATHEMATICAL AND COMPUTER SCIENCES (GENERAL)

N75-10713# Advisory Group for Aerospace Research and Development, Paris (France)
GLOSSARY OF DOCUMENTATION TERMS. PART 2: COMPUTER-USER TERMS
D. C. C. Gibbs (Royal Naval Coll.) Sep 1974 41 p refs (AGARD-AG-182-Pt-2; AGARDograph-182-Pt-2) Avail: NTIS HC $3.75

A compendium of definitions and, where appropriate, descriptions are provided which will assist the computer user, particularly in the field of information science and documentation, to understand the terminology which proliferates in the field of computing. Although designed primarily for the user, it is hoped that computer personnel also will find the entries of some value when, for example, dealing with aspects of computing outside their own specialization. Author

N75-16236# Advisory Group for Aerospace Research and Development, Paris (France).
PRINCIPLES OF AVIONICS COMPUTER SYSTEMS
J. N. Bloom, ed. (Commun. Res. Centre) Dec. 1974 187 p refs
(AGARD-AG-183; AGARDograph-183) Avail: NTIS HC $7.00

An introduction to fundamentals of digital computers, data acquisition and communication, logical partitioning and optimization of subsystems is given. A methodology of design is developed by philosophical discussion, detailed description of processes, and by practical examples of the application of basic principles to the problems of system and component design. The technique of specifying a requirement is discussed in detail as are the various steps required to satisfy it. For individual titles, see N75-16237 through N75-16246.

N75-16237 Politecnico di Torino (Italy). Inst. di Elletrotecnica Generale.
BASIC DIGITAL COMPUTER CONCEPTS
A. R. Mac *In* AGARD Principles of Avionics Computer Systems Dec. 1974 p 3-29 refs (For availability see N75-16236 07-59)

Discussed are the five functional units of a digital computer: (1) arithmetic unit; (2) memory; (3) input devices; (4) output devices; and (5) control unit. In addition to these basic units and their construction and operation, information is given on flip-flops and registers, numeric information coding in a computer, boolean algebra, building blocks, and computer software. A.L.

N75-16238 Norwegian Defence Research Establishment, Kjeller.
DATA ACQUISITION AND COMMUNICATION FUNCTION
Yngvar Lundh *In* AGARD Principles of Avionics Computer Systems Dec. 1974 p 30-41 refs (For availability see N75-16236 07-59)

An avionics computer, as part of a real time system either in the air or on the ground, has to communicate with the rest of the system. To communicate requires the exchange of data in one form or another. Various aspects of such data exchange are discussed along with a brief review of some typical devices which may be part of an avionics system. Some example cases are given to show how these would communicate with the computer. A.L.

N75-16239 Norwegian Defence Research Establishment, Kjeller.
OPTIMIZATION
Yngvar Lundh *In* AGARD Principles of Avionics Computer Systems Dec. 1974 p 42-46 (For availability see N75-16236 07-59)

An avionics computer system, as well as all other engineering jobs, requires optimization. This optimization process may be different depending on whether the systems designer or the computer designer does the job. For this discussion it was assumed that the solution was not constrained by limited choices of standard sizes, shapes and forms, or by choices made by someone else, past history or bad fortune. Some management considerations are briefly discussed. Important technical parameters such as: logic speed, computing speed, memory capacity, communication capacity, survivability, modularity, physical parameters, and programming complexity are briefly described. Some important tradeoffs which are useful to know when seeking a way out of the multitude of possible configurations which a computer based system may be given are also identified. A.L.

N75-16240 Royal Radar Establishment, Malvern (England).
SYSTEMS AND SYSTEM DESIGN: SOFTWARE DESIGN IN COMPUTER BASED SYSTEMS
C. S. E. Phillips *In* AGARD Principles of Avionics Computer Systems Dec. 1974 p 47-63 refs (For availability see N75-16236 07-59)

This discussion is concerned with the production of software by professional teams for computer controlled systems dedicated to some special purpose. Such systems are essentially software based, usually real time, and much more complex than they appear to the outsider. Discussed are: (1) system design methodology; (2) programs as systems; (3) functional system approach; (4) purpose of programming network diagrams; (5) data rectangles; (6) process circles; (7) simple hierarchic program network; (8) hierarchy of diagrams; (9) simulation and testing; and (10) real time computer systems. As computer systems become less of a novelty, standardization at lower levels, though restricting possibilities, offers the avionics system engineer fewer problems if use is made of existing technologies. A.L.

N75-16241 Ferranti, Ltd., Bracknell (England).
AVIONICS SYSTEM ARCHITECTURE
R. E. Wright *In* AGARD Principles of Avionics Computer Systems Dec. 1974 p 64-87 refs (For availability see N75-16236 07-59)

The system architect's task is to define and combine a set of hardware components to form a system whose aggregate behavior will meet the operational requirement for the system. Most avionic systems start with an operational requirement specified by a user or airframe manufacturer. During the short history of aviation there has been a growth of such operational needs which have presented problems requiring technical solutions. The avionic system derives much from the general development in system engineering, but is subject to particular operational requirements, physical environments, and physical constraints which together justify a somewhat specialized approach. Some of the problems and techniques involved are briefly described and discussed. A.L.

N75-16242 Selenia S.p.A., Rome (Italy).
DEFINING THE PROBLEM AND SPECIFYING THE REQUIREMENT
Silvio Bosso and Rodolfo Gamberale *In* AGARD Principles of Avionics Computer Systems Dec. 1974 p 88-118 (For availability see N75-16236 07-59)

This discussion deals with the functional requirements of computer system and aims at the definition of a methodology for deriving them from the knowledge of the tasks to be performed. The considerations presented may be applied both to determine the suitability of a certain computer architecture and to compare different computers against a given application. The treatment starts with a brief survey of typical tasks of an avionic system, from which a sample is taken to be further analyzed as an example. Computer tasks are analyzed, also with the aid of examples, in order to show how the computer requirements can be arrived at. Author

N75-16243 Smiths Industries Ltd., London (England). Aviation Div.
MONITORING AND CONTROL OF AEROSPACE VEHICLE PROPULSION
E. S. Eccles *In* AGARD Principles of Avionics Computer Systems Dec. 1974 p 119-142 refs (For availability see N75-16236 07-59)
Avail: NTIS

The application of digital computer systems to the design of systems for monitoring and control of the propulsion of aerospace vehicles is discussed. The general context is related to commercial operation of vehicles using airbreathing engines. This limitation permits concentration of attention on the systems problem and removes the need for any extensive discussion of powerplant characteristics. The restriction is not serious in terms of broad powerplant characteristics. The basic features of control requirements are common to all plants using chemical energy sources and combustion for energy conversion. There are strong conceptual similarities, for instance, between throttleable rocket motors and augmented (reheated) gas turbine powerplants. Time

constants and thrust levels differ but the basic problems of mixture control via independent fuel and oxidant flow control and their pumping (in the general sense) remain the same. The plant control details will be less relevant to systems using hypergolic fuels and nuclear or electric propulsion. In the same way, the operational criteria will be similar for vehicles which, in themselves, are as different as the space shuttle and STOL feeder liner systems. Commercial and military operational criteria also have many analogous, if not entirely homologous, features. Similar design trade-offs are involved for both types of organizational structure and mission objectives. The discussion identifies the basic principles involved and enables read-across to other types of operation and to other avionics systems disciplines. Author

N75-16244 Advisory Group for Aerospace Research and Development, Paris (France).
MAN-MACHINE INTERFACE
E. Keonjian *In its* Principles of Avionics Computer Systems Dec. 1974 p 143-149 (For availability see N75-16236 07-59)

As the complexity of aerospace systems grows, the requirement for augmenting, expanding and simplifying crew control capabilities becomes more demanding. The man-machine interface, which essentially is a problem of exchanging data between the system and the human has become more crucial for the operation of modern aerospace systems. To cope with this problem a new class of information processing systems (aerospace computers, multiprocessors, multiplexers), control systems and displays have been developed, and the trend toward greater integration is realized. As a consequence, the degree of pilot/operator involvement with the machine has increased in scope and complexity. Some basic elements of the man-machine interface optimization process and its relations to the total avionics system design are briefly reviewed. Author

N75-16245 Advisory Group for Aerospace Research and Development, Paris (France).
NOVEL DEVICES AND TECHNIQUES
E. Keonjian *In its* Principles of Avionics Computer Systems Dec. 1974 p 150-162 refs (For availability see N75-16236 07-59)

Considerable advances have been made over the whole range of avionic devices and techniques which have been finding their way into avionics systems, making them more effective in terms of reliability and operational capability. These are coupled with simplicity and lower cost for maintenance and ownership. This process has been accelerated particularly by the rapid progress in microelectronics, with its far reaching consequences especially for future avionic computer systems. Some advanced devices and technologies still in development are reviewed, which, when matured, could further improve the effectiveness of avionic computer systems. Author

N75-16246 Plessey Co. Ltd., Ilford (England).
SPECIFYING THE REQUIREMENTS
A. L. Freedman *In* AGARD Principles of Avionics Computer Systems Dec. 1974 p 163-178 (For availability see N75-16236 07-59)

A four step procedure is described for deriving the specification of an avionics computer system as a whole. Such a specification makes it possible to decide first of all whether to go ahead with the system, and secondly if the decision is taken to go ahead, to eliminate the main sources of the troubles which have plagued these projects in the past. The procedure stems directly from the definition of a real time system as a tool to assist in performing a given activity. The activity may be the control of interceptor aircraft or the control of the systems on board an aircraft. Techniques used to design an optimum system to meet the specification are briefly covered. A.L.

62 COMPUTER SYSTEMS

Includes computer networks.

N75-16257# Advisory Group for Aerospace Research and Development, Paris (France).
REAL TIME COMPUTER BASED SYSTEMS
Dec. 1974 410 p refs In ENGLISH partly in FRENCH Presented at Avionics Panel Symp., Athens, 27-31 May 1974
(AGARD-CP-149) Avail: NTIS HC $10.50

Computer design and software generation for real time avionics systems are considered. For individual titles, see N75-16258 through N75-16294.

N75-16258 Space and Missile Systems Organization, Los Angeles Air Force Station, Calif.
COMPUTER SOFTWARE TESTING AND CERTIFICATION

Kenneth E. Nidiffer *In* AGARD Real Time Computer Based Systems Dec. 1974 5 p refs (For availability see N75-16257 07-62)

The major problems yet to be solved in the test and certification of computer software are to insure in a cost effective manner that: (1) the software has no bugs which could cause the overall system to malfunction at critical times; and (2) the software meets the functional requirements of the user. Fertile areas of further investigation include: (1) guidance on how to test and certify software for large computer systems; (2) a reevaluation of the cost and performance trade-offs associated with third party software developers, integrators and maintainers, and (3) a realignment of the R and D support to meet current test and certification needs. Author

N75-16259 Royal Radar Establishment, Malvern (England).
SYNTACTIC METHODS FOR THE PRESCRIPTION OF PROCESSES
J. T. Webb *In* AGARD Real Time Computer Based Systems Dec. 1974 11 p refs (For availability see N75-16257 07-62)

It is proposed that an extended version of Foster's syntax improving device be used to generate the computer useable form of a process. The reasons for the extensions and their effect on the resulting syntax analyzers are discussed and conclusions drawn as to the flexibility and use of the technique. Author

N75-16260 Advisory Group for Aerospace Research and Development, Paris (France).
REDUCED SIZE OPTIMAL CONTROL LAWS
P. Bernhard (IRIA, Rocquencourt) *In its* Real Time Computer Based Systems Dec. 1974 6 p refs (For availability see N75-16257 07-62)

The problem considered is that of reducing the number of state variables fed back in the optimal control of a linear plant with quadratic performance index. A classical approach is discussed, where the state variables, or their combinations, to be fed back are chosen a priori. A new approach is proposed where we look for those state variables (or combinations of) that can be ignored. The two are compared and turn out to have very different properties. It is argued that the new method is more significative, less hazardous, and far simpler to carry out. Author

N75-16261 Texas Instruments, Inc., Huntsville, Ala.
A PROCESS DESIGN SYSTEM FOR LARGE REAL TIME SYSTEMS
Roger R. Bate *In* AGARD Real Time Computer Based Systems Dec. 1974 8 p refs (For availability see N75-16257 07-62)
(Contract DAHC60-72-C-0156)

A process is designed from the top down in a structured programming known as the Process Design Language (PDL). Each level of design consists of references to modules which are defined later at the next lower level of design. Undefined modules at any stage are simulated by simple models to permit execution of the system on a computer. In this way the high level logical structure is verified before expensive detailed coding at lower levels is accomplished, and modules can be tested within a realistic environment. The Process Design System (PDS) provides translator, library management, and simulator construction facilities which relieve the process designer of most of the housekeeping chores associated with configuration control of a large system under evolutionary design. Author

62 COMPUTER SYSTEMS

N75-16262 Royal Military Coll. of Science, Shrivenham (England).
REAL TIME OPERATING SYSTEMS
K. L. Hunt *In* AGARD Real Time Computer Based Systems Dec. 1974 11 p refs (For availability see N75-16257 07-62)

The development of standard approaches to the design of operating systems is explored. Two systems currently under development or in use illustrate at least a trend to a standard approach. The relevance of work of a more formal nature to the design of operating systems is discussed in the light of recent work on synchronizing sequences. Author

N75-16263 Marconi-Elliott Avionic Systems Ltd., Borehamwood (England).
THE CYCLIC TIME SLOT INTERFACE AND ITS INFLUENCE ON THE SOFTWARE EXECUTIVE
A. Tonkin and R. Malcolm *In* AGARD Real Time Computer Based Systems Dec. 1974 12 p (For availability see N75-16257 07-62)

The cyclic time slot interface is described which has advantages when peripherals exhibit peaky data rates. Software executives are classified and it is shown that under certain well defined conditions a scanning executive, with a cyclic time slot interface, is the optimum. A surveillance radar system is described and this is used as an illustration of an application of the interface. Author

N75-16264 Royal Radar Establishment, Malvern (England).
AN EXERCISE IN MULTI-PROCESSOR OPERATING-SYSTEM DESIGN
R. S. Newton *In* AGARD Real Time Computer Based Systems Dec. 1974 9 p refs (For availability see N75-16257 07-62)

Design concepts and structuring of a multiprocessor general purpose operating system are discussed, and those features of the operating system peculiar to multiprocessing are identified. Author

N75-16265 Royal Radar Establishment, Malvern (England).
MASCOT: A MODULAR APPROACH TO SYSTEM CONSTRUCTION OPERATION AND TEST
K. Jackson and H. R. Simpson (Royal Air Force, Leeming, Engl.) *In* AGARD Real Time Computer Based Systems Dec. 1974 18 p refs (For availability see N75-16257 07-62)

The MASCOT approach has formalized a method for dealing with the interconnection and intercommunication between loosely coupled programs i.e. programs which interact in a manner other than by direct call. To this end, some basic types of modules have been defined which are independent even after compilation. These modules may be connected together to construct subsystems which interface with each other by user defined channels. This construction facility is supported by some basic software which allows software synchronization both within subsystems and between subsystems to ensure an orderly and sustained flow of data through the system. To back up the paper study, the majority of the key features have been implemented using Coral 66 on a Marconi Myriad computer. Author

N75-16266 Siemens A.G., Munich (West Germany).
A REAL-TIME PROGRAM SYSTEM FOR CONTROLLING A PHASED ARRAY RADAR
Heinz Knetsch *In* AGARD Real Time Computer Based Systems Dec. 1974 10 p (For availability see N75-16257 07-62)

The software of an experimental radar system is described that is equipped with a planar phased array antenna and two linear phased array antennas. The planar antenna is used as a primary radar antenna while the two orthogonally arranged linear arrays serve as secondary radar antennas. To operate the experimental radar system it is necessary to have a software system for radar process control and evaluation of the air situation. This software system consists of a series of relatively independent process control programs whose execution is initiated by a superordinate control program under real time conditions. A priority and time slice control in the executive program ensures real time operation. The user programs are complemented by input/output programs each of which controls and supervises an individual device connected to the system. The executive program supervises all events occurring during the process and initiates the required activities. Author

N75-16267 Naval Electronics Lab. Center, San Diego, Calif.
THE CS-4 HIGH LEVEL LANGUAGE AND ITS USE IN REAL TIME SYSTEMS
Warren E. Loper and James S. Miller (Intermetrics, Inc.) *In*

AGARD Real Time Computer Based Systems Dec. 1974 11 p refs (For availability see N75-16257 07-62)

The All Applications Digital Computer (AADC) program is used in the development of a modular computer designed to be assembled from off-the-shelf, large scale integrated (LSI) silicon wafer and magnetic thin film building blocks. From these components can be configured a simple minicomputer, or a large multiprocessor, or anything in between. Exploitations of the architecture of machines such as the AADC require the supporting exploitations of the state-of-the-art of computer programming languages and their use in the development of reusable program modules in the construction of large systems. In an attempt to reduce the high cost of software, CS-4 is being designed to meet this requirement. Author

N75-16268 Smiths Industries Ltd., Bishops Cleeve (England).
COMPACT INTERPRETERS: THEIR IMPLICATIONS ON SOFTWARE AND HARDWARE DESIGN
K. A. Helps *In* AGARD Real Time Computer Based Systems Dec. 1974 10 p refs (For availability see N75-16257 07-62)

There is a place in avionics real time systems for programs to be stored in compact code and executed by interpretation. Compact interpretable code is here used to mean code designed to require near-minimum storage. Substantially smaller storage is required for compact code than for normal code as produced by an efficient compiler or assembler. Typically the compression ratio is .5 to .7 and an overhead of a few hundred words for the interpreter is required. The penalty for this compression of code is a rise in execution time. The use of compact interpretable code is very attractive in some avionics applications on storage considerations alone, but its use has repercussions on other areas of the digital systems design, particularly in improving legibility and maintainability of software and in promoting portability. Compact interpretation is a software analogue of microprogramming. Author

N75-16269 Royal Radar Establishment, Malvern (England).
CORAL 66: THE UK NATIONAL AND MILITARY STANDARD
N. J. F. Neve *In* AGARD Real Time Computer Based Systems Dec. 1974 7 p refs (For availability see N75-16257 07-62)

The evolution of CORAL 66 as a standard programming language for use in real time systems in the United Kingdom is reported, with emphasis on the managerial and executive organization necessary to launch and support the language. The organization necessary to maintain the language as a standard, and the methods adopted in practice to ensure that the standard is not debased are discussed. The benefits that have accrued from adopting a policy of language standardization are summarized. Author

N75-16270 Plessey Radar Ltd., Havant (England). Research Centre.
A LANGUAGE FOR THE SPECIFICATION OF REAL-TIME COMPUTER-BASED SYSTEMS
D. M. Balston and C. E. Morgan *In* AGARD Real Time Computer Based Systems Dec. 1974 13 p refs (For availability see N75-16257 07-62)

Current methods of conveying the specification of real time computer based systems rely heavily on natural language as the medium for communication and agreement between customer and contractor. Misinterpretation and ambiguities are easily introduced if statements are made in natural language however and the cost of rectification can be high both in monetary and time terms. The initial specification is presented for a formal language which has been developed to convey system specification information. The language forces the writer to emphasize the hierarchical nature of the system and thus encourages a logical and progressive flow of information. The resulting specification serves a dual purpose as the same text can provide both an overview of the system and a detailed specification of every sub-unit. Author

N75-16271 Litton Industries, Van Nuys, Calif. Data Systems Div.
FAST INTENT RECOGNITION SYSTEM (FIRST)
S. C. Schroeder and L. E. Vaughn *In* AGARD Real Time Computer Based Systems Dec. 1974 13 p (For availability see N75-16257 07-62)

The design of an APL language computer for use in command and control systems is investigated. The computer is divided into four functional units. The major innovation is the unit which determines, at execution time, the optimum execution code for array processing statements. This code is later executed by another unit specifically designed for array operand expressions. The design is currently being evaluated using an emulator written for an APL time sharing system. The evaluation shows a distinct cost/performance advantage over both a naive approach and a conventional computer system. In addition, use of this computer in an interactive command and control system or real time avionics application will greatly reduce software development and integration time and cost. Author

N75-16272 Burroughs Corp., Paoli, Pa. Federal and Special Systems Group.
BURROUGHS AUTOMATIC COMMUNICATIONS SYSTEM THE FOURTH GENERATION (BACS IV)
Charles S. Modriker *In* AGARD Real Time Computer Based Systems Dec. 1974 10 p (For availability see N75-16257 07-62)

The design and development of a computer system architecture is reported for application to real time processing. The avionics multiprocessor system uses either a semiconductor memory or an integrated circuitry as a communication switch. Through the use of microprogramming, instruction sets unique to an application are created and stored in a control memory for interpretation. G.G.

N75-16273 Service Technique des Telecommunications de l'Air, Paris (France).
ORGANIZATION OF STRIDA (SYSTEM FOR PROCESSING AIR DEFENSE INFORMATION) [ORGANISATION DU STRIDA (SYSTEME DE TRAITEMENT DES INFORMATIONS DE DEFENSE AERIENNE)]
D. Coulmy *In* AGARD Real Time Computer Based Systems Dec. 1974 8 p In FRENCH (For availability see N75-16257 07-62)

A real time data processing system, STRIDA, for processing air defense information is reported. The system utilizes a computer which processes data furnished by radars and presents the data to the controller. Data are included on the types of equipment, methods of programming, and the arrangement needed to insure satisfactory availability of the system. Transl. by E.H.W.

N75-16274 Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France).
PARALLEL COMPUTER WITH AUTOMATICALLY RECONFIGURABLE ORGANIZATION (COPRA) [CALCULATEUR A ORGANISATION PARALLELE RECONFIGURABLE AUTOMATIQUEMENT (COPRA)]
M. C. Meraud and M. F. Browaeys *In* AGARD Real Time Computer Based Systems Dec. 1974 5 p In FRENCH (For availability see N75-16257 07-62)

To meet the demand for reliability in digital computer data, a study was made to identify and solve the problems associated with such demands. The COPRA program is a structural arrangement which permits more confidence than is assessible by other technological means. Three fundamental mechanisms were utilized: a failure reconfiguration element which utilizes other equipment to share operations in case of performance degradation, an error detection element which inhibits the output of all errors in the results, and the resumption element which permits the continuation of the mission in cases after failure. Transl. by E.H.W.

N75-16275 Electronique Marcel Dassault, St. Cloud (France).
THE MECRA EXPERIMENTAL COMPUTER MODEL WITH AUTOMATIC RECONFIGURATION [LE MECRA MAQUETTE EXPERIMENTALE DE CALCULATEUR A RECONFIGURATION AUTOMATIQUE]
G. P. Germain *In* AGARD Real Time Computer Based Systems Dec. 1974 8 p refs In FRENCH (For availability see N75-16257 07-62)

A computer model supporting the study of diverse methods to increase reliability and security in computer operations was examined. Several types of redundancies were put to work and the gains in reliability were evaluated. Reconfiguration methods were implemented and improvements of their effectiveness were tested. Experimental conclusions and calculated reliability are

included. The validity of all solutions are examined, in particular, aspects of placing the work under LSI technology.
Transl. by E.H.W.

N75-16276 AEG-Telefunken, Konstanz (West Germany).
SOME MULTICOMPUTER CONFIGURATIONS FOR RELIABILITY IN ATC SYSTEMS
J. Zuern *In* AGARD Real Time Computer Based Systems Dec. 1974 16 p refs (For availability see N75-16257 07-62)

The experience in developing double computer systems with one computer operational and the other stand-by, showed that even for several systems with very different operational programs, the method for double computer monitoring and automatic switchover can be similar or the same for each. The method used in several applications is to have each computer send in fixed time intervals appropriate status and control information to an independent unit. Several multicomputer ATC systems are discussed in detail to illustrate the effect of various data input and output availabilities and data storage reliability requirements. The experience with these systems has shown that the reliability improvements of each type meet the high requirements of ATC.
Author

N75-16277 Forschungsinstitut fuer Funk und Mathematik, Werthoven (West Germany).
DISTRIBUTION OF THE TASKS IN A PHASED-ARRAY RADAR SYSTEM BETWEEN GENERAL-PURPOSE COMPUTERS AND SPECIAL PROCESSING UNITS
E. Hanle *In* AGARD Real Time Computer Based Systems Dec. 1974 7 p refs (For availability see N75-16257 07-62)

In a future radar system with an electronically steered antenna a lot of tasks must be handled simultaneously with high speed, which do not run down with fixed parameters and independently from each others like in usual radar systems. The presentation shows, that in this multi-function processing system no units of the same kind can be implemented, since at particular points in the system data volumes of very different sizes and in various time intervals occur. The steering of the different functions by data dependent parameters and the overall system control must be handled by programmable general purpose computers, since during these control functions a lot of different data must be stored for a long time. Examples for that are given in the presentation, including implementation of graceful degradation.
Author

N75-16278 Intermetrics, Inc., Cambridge, Mass.
FAULT-TOLERANCE FEATURES OF AN AEROSPACE MULTIPROCESSOR
James S. Miller *In* AGARD Real Time Computer Based Systems Dec. 1974 p 9 refs (For availability see N75-16257 07-62)

Processor errors are detected by comparing results from duplexed units executing concurrently. Local processor storage is also duplexed, and segregated from processing units. Parity checking is used to identify the invalid copy when a comparison failure is signalled. Instruction execution is split into phases such that no phase overwrites its input. A hard-core redundant unit is used to command instruction-phase retry following a fault. If retry fails, another processor is interrupted to unload the faulty processor's local storage and prepare the disrupted process for immediate resumption at the point of failure. Recovery from faults in main memory capitalizes on the descriptor-based memory multiplexing scheme used for normal operation. A novel use of interleaving allows hardware-supported duplicated safe storage of data segments in main memory, since these change too frequently to be duplicated on secondary storage.
Author

N75-16279 Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
IMPLEMENTATION OF THE MICRO PROCESSOR CONCEPT
R. C. Downs *In* AGARD Real Time Computer Based Systems Dec. 1974 11 p refs (For availability see N75-16257 07-62)

Because of their small size, low power consumption, high reliability, and environmental ruggedness the micro processor is entering new application fields, where previously mini processors were unacceptable. These applications include the sophistication of military and aerospace equipment, whose complex control functions are now equalled by the computing capabilities of the micro processor. The development and capabilities of the micro processor in terms of physical, hardware, and software characteristics in the implementation of the micro processor concept are discussed.
Author

N75-16280 Centre National de la Recherche Scientifique, Toulouse (France). Lab. d'Automatique et d'Analyse des Systemes.
A FAMILY OF MODULAR PROCESSORS: THE ASMODEE PROJECT [UNE FAMILLE DE PROCESSEURS MODULAIRES: LE PROJET ASMODEE]
J. C. Laprie and A. Costes *In* AGARD Real Time Computer Based Systems Dec. 1974 11 p refs In FRENCH (For availability see N75-16257 07-62)

A communication covering the ASMODEE project, including numerical techniques, real time operation, and computer architectural concepts is presented. Objectives of the project include a study of: structure concepts of numerical control better adopted to specific needs and security functions, and decentralized structures which provide for the development of a new system of distributed hierarchy control.
Transl. by E.H.W.

N75-16281* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
THE DEVELOPMENT AND DEMONSTRATION OF HYBRID PROGRAMMABLE ATTITUDE CONTROL ELECTRONICS
L. S. Smith and E. H. Kopf, Jr. *In* AGARD Real Time Computer Based Systems Dec. 1974 10 p refs (For availability see N75-16257 07-62)
(Contract NAS7-100)

HYPACE provides an adaptable, analog/digital design approach that permits preflight and in-flight accommodation of mission changes, component performance variations, spacecraft changes, etc., through programing. This enabled broad multimission flexibility of application in a cost-effective manner. The HYPACE design, which was demonstrated in breadboard form on a single-axis gas-bearing spacecraft simulation, uses a single control channel to perform the attitude control functions sequentially, thus significantly reducing the number of component parts over hard-wired designs. The success of this effort resulted in the concept being selected for the Mariner/Jupiter/Saturn 1977 spacecraft application.
Author

N75-16282 California Univ., Los Angeles. Dept. of Computer Science.
THE IMPACT OF RECENTLY DEVELOPED HYBRID COMPUTING DEVICES ON REAL-TIME SIGNAL PROCESSING
Walter J. Karplus *In* AGARD Real Time Computer Based Systems Dec. 1974 10 p refs (For availability see N75-16257 07-62)
(Grant NSF GK-31463)

Recent advances in the analog and hybrid computing field are reviewed, as well as implications of newly developed devices upon the design of real-time signal processing systems. The preprocessing of continuous data, using analog modules, prior to digitizing as well as the utilization of a number of parallel analog/digital converters appears to hold particular promise.
Author

N75-16283 Texas Instruments, Inc., Dallas.
THE ADVANCED SCIENTIFIC COMPUTER: AN ADVANCED COMPUTER ARCHITECTURE AND ITS REAL-TIME APPLICATION TO BALLISTIC MISSILE DEFENSE
John W. Blakemore *In* AGARD Real Time Computer Based Systems Dec. 1974 12 p (For availability see N75-16257 07-62)

The advanced scientific computer (ASC) is a computer system utilizing three processing units, one optimized for control, one optimized for high speed arithmetic/logical operations on ordered arrays (called vectors) of data, and the third used exclusively for data transfers. This high throughput potential is due principally to the design of the control processor which permits continuous control operations without interferring with vector processing operations and to the fact that the ballistic missile defense problem provides vectors of data (on targets) in a natural way. The ASC control processor (through special hardware) is provided positive control over all elements of the system (i.e. memory, data channels, and the arithmetic/logical processor). It is implemented as eight independently programmable processors, each provided access to the entire memory space. The memory space may be implemented in slow or fast memory or a mixture of the two. The memory is all solid state, interleaved and overlapped, providing data to the processing elements at a maximum nominal rate of one word every six nanoseconds. Memory management, control, and protection is facilitated by the control processor special hardware.
Author

N75-16284 Marconi-Elliott Avionic Systems Ltd., Rochester (England). Airport Works.
THE INFLUENCE OF AVIONIC SYSTEM REQUIREMENT ON AIRBORNE COMPUTER DESIGN
J. T. Shepherd *In* AGARD Real Time Computer Based Systems Dec. 1974 21 p (For availability see N75-16257 07-62)

Constraints imposed upon the airborne computer designer by system performance and aircraft operational economic environment are examined. System requirements include air data systems, autopilots and flight director systems, head up, weapon delivery systems, navigation systems, central management systems and engine control systems. Size and weight, environmental design, reliability and maintainability, integrity, and thermal and cooling requirements are considered as part of the operational constraints. The type of architectures that evolve from these requirements are discussed. Trade-off studies between instruction code/addressing structure and store utilization are also included. Author

N75-16285 Litton Industries, Van Nuys, Calif. Data Systems Div.
MACROS: AN INSTRUCTION CONCEPT CHANGE
A. J. Ess and C. C. Church *In* AGARD Real Time Computer Based Systems Dec. 1974 7 p refs (For availability see N75-16257 07-62)

Macro (in hardware) instructions make a change that improves storage efficiency and program execution time. Briefly, the computer evolution is described and includes statistics of computer instructions which led to the development of the Macro concept. The Macro instruction of 1-byte length (8 bits) provides multiple functions. Examples are given to demonstrate the advantages of Macros, storage savings, and improved computer throughput. Author

N75-16286 Computing Devices of Canada, Ltd., Ottawa (Ontario).
MICROPROGRAMMED COMPUTER COMBINED AVIONICS DISPLAY AND DATA PROCESSING
Dale R. Younge *In* AGARD Real Time Computer Based Systems Dec. 1974 12 p (For availability see N75-16257 07-62)

A small-size, high-performance, airborne-computer (IDP-974 General-Purpose Computer) was developed for application in an integrated display and processor system (IDPS) for lower-cost aircraft. The prime objective of this development was to optimize cost-effectiveness of the computer and primary displays subsystem by means of time-sharing the displays servicing, ballistics, navigation, etc., in a single central general-purpose computer. That is, the time-sharing of ballistics and navigation in the same computer is now commonplace, however, the additional task of real-time multiple displays servicing together with more sophisticated ballistics (the Hot-Line Air-to-Air mode) and navigation (multi-sensor mixing) required a sizeable increase in central computer performance. The availability of complex integrated circuits has made possible such increased performance in addition to decreased size and cost. The computer described herein averages more than 400,000 operations per second and occupies a 1/2 ATR volume. In addition to merely high-speed, performance was increased further by virtue of a more versatile architecture, such as a large quantity of operational registers and complex instructions, than is normally found in low-cost computers. Author

N75-16287 British Aircraft Corp. (Operating) Ltd., Bristol (England). Commercial Aircraft Div.
TRAFFIC MODELLING OF MILITARY COMMUNICATION SYSTEMS ON DIGITAL COMPUTERS
D. V. Turner *In* AGARD Real Time Computer Based Systems Dec. 1974 10 p (For availability see N75-16257 07-62)

A model developed by the author to simulate the flow of traffic around a network is described, and a military communication model is discussed in detail. Both the physical representation of the system as a data structure and the processing functions of the simulator are discussed. M.C.F.

N75-16288 Selenia S.p.A., Rome (Italy).
DATA ACQUISITION AND DISTRIBUTION IN REAL-TIME AEROSPACE SYSTEMS
S. Boesso and R. Gamberale *In* AGARD Real Time Computer Based Systems Dec. 1974 19 p refs (For availability see N75-16257 07-02)

The exchange of information is described between data sources, computing facilities and data users. Data routing and the control of digital, time-multiplexed data buses are discussed. A traffic model is presented to serve as a basis for developing a bus control algorithm. M.C.F.

N75-16289 Rome Air Development Center, Griffiss AFB, N.Y.
APPLICATION OF MULTI MINICOMPUTER CONFIGURATION TO INTERACTIVE GRAPHICS AND CARTOGRAPHY
William G. McLellan and B. K. Moritz (PRC Information Sci. Co.) *In* AGARD Real Time Computer Based Systems Dec. 1974 12 p (For availability see N75-16257 07-62)

This system is described to produce error free digital data cells containing topographic data in geographic coordinates that are completely identifiable. The large central minicomputer is equipped with printer, magnetic tape transports, and rotating memory. Current design allows for up to 10 work stations to be simultaneously operating with the single large minicomputer central processor. M.C.F.

N75-16290 Lear Siegler, Inc., Grand Rapids, Mich. Instrument Div.
RF SIGNAL PROCESSING VIA CONTROL OF SPECIAL PURPOSE PRE-PROCESSORS
A. Dimitriou *In* AGARD Real Time Computer Based Systems Dec. 1974 12 p (For availability see N75-16257 07-62)

Radio frequency signal processing for radar, ECM, acoustic, Loran, Nav-Sat and other applications involves rapid sampling of the received signal and quick processing of the sampled data. Two approaches are possible when a digital computer is used for signal processing. One is to dedicate the computer to signal processing functions and allow other computational tasks to be performed as time permits. The other approach is to have a pre-processor or pre-processors operating under control of a central processing element. The pre-processor, in this case, performs the time consuming tasks of data sampling and simple manipulations of the sampled data. The data is then transferred to the central processor where more sophisticated processing is performed. This paper describes the control which is necessary in order for a pre-processor to operate under control of a central data processing element. Examined specifically, is the operation of a Loran-C pre-processor. Author

N75-16291 Ministry of Defence, London (England).
DEVELOPMENT EXPERIENCES OF REAL TIME COMPUTER BASED SYSTEMS IN STRIKE AIRCRAFT
C. J. U. Roberts *In* AGARD Real Time Computer Based Systems Dec. 1974 6 p (For availability see N75-16257 07-62)

This paper will describe the nav/attack system that is fitted to the UK version of the Jaguar aircraft with particular reference to its computing sub-system. The paper will also discuss the effect that the flexibility of digital computing has had on the flight trials program together with some of the salutary experience that has been gained on the inter-relationships of hardware and software and the need for a disciplined validation process for the flight program software. Author

N75-16292 International Business Machines Corp., Owego, N.Y.
LAMPS: A CASE HISTORY OF PROBLEMS/DESIGN OBJECTIVES FOR AN AIRBORNE DATA HANDLING SUBSYSTEM
Rex Reed and Howard J. Cattle, Jr. (NADC, Warminster, Pa.) *In* AGARD Real Time Computer Based Systems Dec. 1974 11 p (For availability see N75-16257 07-62)

This paper is presented to clarify and broaden the understanding of the problems relating to computer-based realtime systems. A current U.S. Navy avionics data handling subsystem aboard a destroyer-based helicopter, will be reviewed as it progressed from the concept evaluation and flight test phases of an engineering test bed to the present engineering prototype. An analysis of the test bed's positive and negative data handling features are discussed with respect to their influence on the follow-on design. The prevailing philosophies and constraints surrounding such a development impacts the design alternatives while a balancing of hardware/software parameters assists in optimizing system performance. Finally, the importance, even in the early design efforts of hardware/software cooperation is emphasized if an optimum design is to be achieved within the surrounding realities. Such early cooperation, as seen in the example, is felt to have optimized hardware design as well as eliminated much of the software required to rectify the lack of desirable, or even essential hardware features typical of independent design efforts. Author

N75-16293 IBM Italia, Rome.
DIGITAL REAL TIME SIMULATION OF FLIGHT
Nunzio LaFerlita *In* AGARD Real Time Computer Based Systems Dec. 1974 17 p refs (For availability see N75-16257 07-62)

The simulation of flight is discussed, producing real-time

phenomenon. The problems arising from general purpose digital computers to simulate real-time flight are investigated. M.C.F.

N75-16294 Eurocontrol Agency, Maastricht (Netherlands).
THE MAASTRICHT DATA PROCESSING AND DISPLAY SYSTEM: A STEP IN AUTOMATION OF AIR TRAFFIC CONTROL (THE SOFTWARE STRUCTURE OF THE SYSTEM)
R. Ehrmanntraut *In* AGARD Real Time Computer Based Systems Dec. 1974 14 p (For availability see N75-16257 07-62)

The system performs multi radar tracking on data from up to 6 radar stations. Extensive checks of data entering the system, especially for flight plans, are carried out. The system performs correlation of plans and tracks. Information in the data bank is automatically updated by radar. Technical particularities concerning the degree of modularity are discussed, and data bank structure and some supervisory aspects are highlighted. It is shown that in the event of a hardware or software failure, a system reconfiguration will take place. In case the main computer fails, restart takes place from safe data on disk memory. Author

70 PHYSICS (GENERAL)

For geophysics see *46 Geophysics*. For astrophysics see *90 Astrophysics*. For solar physics see *92 Solar Physics*.

N75-22045# Advisory Group for Aerospace Research and Development, Paris (France).
ELECTROMAGNETIC WAVE PROPAGATION INVOLVING IRREGULAR SURFACES AND INHOMOGENEOUS MEDIA
A. N. Ince, ed. (Shape Air Defense Tech. Center) Feb 1975 501 p refs In FRENCH and ENGLISH Presented at the Electromagnetic Wave Propagation Panel Symp., The Hague, 25-29 Mar. 1974
(AGARD-CP-144) Avail: NTIS HC $12.25

The proceedings of a conference on electromagnetic wave propagation are presented. The conference was concerned with: (1) propagation of surface waves over irregular and/or inhomogeneous terrain, (2) scattering from rough surfaces and volumes, and (3) guided wave propagation in the presence of irregularities. The characteristics of communication systems which require a knowledge of electromagnetic wave propagation are discussed. Mathematical theories of radio wave propagation are included. For individual titles, see N75-22046 through N75-22086.

N75-22046 Shape Air Defense Technical Center, The Hague (Netherlands).
TECHNICAL REVIEW OF EM WAVE PROPAGATION INVOLVING IRREGULAR SURFACES AND INHOMOGENEOUS MEDIA
A. N. Ince *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 11 p refs (For availability see N75-22045 13-70)

A review of lectures on electromagnetic wave propagation is presented. The subjects of the papers are as follows: (1) development of models for electromagnetic propagation over rough surfaces, (2) electromagnetic propagation in layered guiding structures with irregular boundaries involving mode coupling and conversion, (3) remote sensing using an airborne radar scatterometer and a noncoherent pulse radar on a stationary platform, and (4) ground wave propagation over irregular and nonhomogeneous earth including land-sea boundaries, varying soil types, and mountain ridges. Author

N75-22047 Technische Hogeschool, Eindhoven (Netherlands).
MATHEMATICAL THEORIES OF RADIO-WAVE PROPAGATION: AN HISTORICAL SURVEY
H. Bremmer *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 14 p refs (For availability see N75-22045 13-70)

Mathematical models are developed to describe the characteristics of radio wave propagation. The purpose of the analysis is to determine the field strength due to a point source (the transmitter) placed in an homogeneous medium (the lower atmosphere), the field being observed on or slightly above an homogeneous sphere (the earth) and the electrical parameters of the two homogeneous media being known. The approaches considered are: (1) the Watson transformation, (2) the impedance boundary condition, (3) the effect of the horizontal atmospheric stratification, and (4) the statistical elements in wave propagation problems. Author

N75-22048 Colorado Univ., Boulder. Dept. of Electrical Engineering.
MODELING OF ROUGH SURFACES
P. Beckmann *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 10 p refs (For availability see N75-22045 13-70)

The theory of scattering electromagnetic waves by rough surfaces is analyzed in terms of the prediction problem and the probing problem. The models of central importance are identified as those generated by random processes. The models can be reduced to two broad groups: (1) models using exact boundary conditions and an approximate evaluation (the Rayleigh method) and (2) models using approximate boundary conditions and accurate evaluation (the Kirchoff method). Both methods are capable of vectorization for treating the polarization of the scattered field in addition to its amplitude and phase. Author

N75-22049 Imperial Coll. of Science and Technology, London (England).
NEW JUSTIFICATION FOR PHYSICAL OPTICS AND THE APERTURE-FIELD METHOD
R. H. T. Bates *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 7 p refs (For availability see N75-22045 13-70)

The extended boundary condition (optical extinction theorem) is used to examine the physical optics (Kirchoff) approximation to exact diffraction theory for scatterers of arbitrary shape having surfaces that can be usefully characterized by surface impedances. For inhomogeneous media with rough surfaces, without any asymptotic constraint on the shapes of the surfaces, the physical optics forms for the surface currents lead to satisfaction of the extended boundary condition deep inside the media, under fairly wide sets of conditions. The form of the incident field affects the goodness of the physical optics approximation. Flat surfaces have a special significance for physical optics. How to make use of ray-optical techniques to compute the equivalent surface currents on fictitious flat surfaces in front of the actual surfaces is discussed. Author

N75-22050 Harry Diamond Labs., Washington, D.C.
A THIRD-ORDER SPECULAR-POINT THEORY FOR RADAR BACKSCATTER
James E. Seltzer *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 16 p refs (For availability see N75-22045 13-70)

Two principal modifications to the existing theory for electromagnetic backscattering from randomly rough surfaces with Gaussian height distributions are employed to extend the theory and make it more consistent with the physical optics solutions for reflections from curved surfaces. First, the geometrical optics solution for reflection from a point of stationary phase has been modified to include the contribution from the third-derivative terms in the power series expansion of the argument of the exponential in the Helmholtz integral thereby precluding the prediction of infinite backscattered fields from specular points that are also points of zero Gaussian curvature. Second, the spatial densities of specular points have been determined as a function of the height coordinate with respect to the mean surface. In consonance with the latter development, height-dependent shadowing probabilities and means and mean-square values for the scattering amplitudes have been derived. Author

N75-22051 Texas A&M Univ., College Station.
ON VOLUME-DEPENDENT DEPOLARIZATION OF EM BACKSCATTER FROM ROUGH SURFACES
John W. Rouse, Jr. *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 6 p refs (For availability see N75-22045 13-70)

Recent investigations of the depolarization of backscatter of coherent optical energy incident upon rough surfaces indicate that subsurface volume scatter is a primary depolarization mechanism. Measurements of inhomogeneous dielectric targets indicate that a depolarization ratio of unity is possible, i.e. total depolarization, and that the depolarized component is controlled almost exclusively by the degree of volume scatter within the sample. An extension of the physical optics approach has been formulated to incorporate contributions due to scattering within the subsurface volume. The study indicates that depolarization due to volume scatter is highly dependent upon the properties of the material; that volume scatter could govern the depolarization near vertical incidence; and that multiple surface scatter is most influential at incidence angles greater than 30 deg. The basic experimental work has been performed at optical wavelengths in the laboratory, however, airborne microwave radar and radiometer measurements of sea ice have also been shown to exhibit a strong dependence on a volume scatter mechanism. This phenomena is apparently responsible for the excellent sea ice type differentiation observed in recent sensing studies. Author

N75-22052 Naval Underwater Systems Center, New London, Conn.
SCATTERING FROM A SINUSOIDAL OCEAN SURFACE EXCITED BY A LONG, HORIZONTAL, ELECTRIC LINE SOURCE
Dennis E. Fessenden *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 11 p refs (For availability see N75-22045 13-70)

The space wave electric field produced by a horizontal electric line source located above a traveling ocean surface is discussed. The ocean surface is approximated by a perfectly conducting, sinusoidal surface. Situations arise where the sinusoidal model is a good approximation of an actual ocean surface. For this case, the amplitude of the sinusoidal surface is small compared with a freespace wavelength; therefore, a Fourier integral-perturbation series approach can be used to solve the boundary value problem. The line source is oriented parallel to the crests and troughs of the sinusoidal ocean waves; thus, the problem is reduced to two dimensions and only one electric field component. The resulting space wave field is composed of the incident and specularly reflected field from a perfectly conducting, flat surface plus a scattered term for the sinusoidal roughness. The magnitude of the scattered term is directly proportional to the sinusoidal surface amplitude in wavelengths, and Bragg scattering occurs for specific wavenumber relationships. Graphs are presented of the field variation as a function of the sinusoidal wave motion. Although the scatter theory was applied to a sinusoidal surface, it can be shown that the theory can be applied to any surface that is Fourier transformable. Author

N75-22053 Technische Hogeschool, Eindhoven (Netherlands).
PROPAGATION THROUGH INHOMOGENEOUS AND STOCHASTIC MEDIA
H. Bremmer *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 10 p refs (For availability see N75-22045 13-70)

The propagation phenomena connected with the stochastic inhomogeneity of the atmosphere are discussed. The theory relates statistical properties of the inhomogeneity with those expected for the field intensity fluctuations. Two quantities prove to be of dominating importance; (1) the distance (D sub B) along which one single scattering is only to be expected and (2) the scale of turbulence, which is a measure of the inhomogeneity of the medium. The numerical values of these parameters fix the physical characteristics of the propagation in question. They can be represented by a point in a plot giving the penetration depth of the wave in the medium versus the quantity D sub B. The various domains in this plot involve different propagation properties. Results are given which concern the variance and the distribution of the possible values of the irradiance for a wave that has covered a specified distance through the medium. Author

N75-22054 Nebraska Univ., Lincoln. Dept. of Electrical Engineering.
PROPAGATION IN DUCTS AND WAVEGUIDES POSSESSING IRREGULAR FEATURES. FULL WAVE SOLUTIONS
E. Kahar *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surface and Inhomogeneous Media Feb. 1975 12 p refs (For availability see N75-22045 13-70)

The impetus to produce rigorous solutions to more realistic models of pertinent propagation problems over a wide frequency range has generated the need to derive full wave solutions to problems of radio wave propagation in nonuniform multilayered structures. The considerable growth in civil and military interest in the development of more reliable communication and detection systems, the potential for developing radio wave methods for remote sensing and the need to develop hardened communication systems have contributed much to this renewed interest. These developments have been paralleled by remarkable advances that have been made in the availability of high powered, very low frequency electromagnetic sources that are capable of radiating deeper into the earth's crust as well as the availability of transmitters operating at optical frequencies. The ready access to large, versatile digital computers has made it possible to employ the full wave approach to obtain numerical solutions to a wide class of important problems which have hitherto been either ignored or over-idealized in order to reduce them to tractable problems. Author

N75-22055 Polytechnic Inst. of New York, Farmingdale.
ASYMPTOTIC TECHNIQUES FOR PROPAGATION AND SCATTERING IN INHOMOGENEOUS WAVEGUIDES AND DUCTS
L. B. Felsen *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 5 p refs (For availability see N75-22045 13-70)

A ray-optical procedure of fairly recent origin provides new physical insight and quantitative accuracy for modal excitation and coupling due to localized sources or scatterers. The theory and several applications are reviewed. Concerning the ray-modal conversion process, attention is given to the lateral ray shift associated with total reflection; this phenomenon has been a subject of interest in the recent literature on optics and integrated optics. The ray method is then extended to the tracking of inhomogeneous waves, thereby generalizing its applicability to evanescent fields, leaky waves and Gaussian beams. This more general theory is illustrated by Gaussian beam propagation in a medium with transversely stratified refractive index, and by scattering of a Gaussian beam at a curved boundary. Some observations are made concerning the locality of propagation and scattering processes for homogeneous and inhomogeneous waves. Author

N75-22056 Laboratoire d'Optique Electromagnetique, Marseille (France).
DIFFERENTIAL FORMULAS FOR DIFFRACTION PROBLEMS IN THE RESONANCE DOMAIN [FORMALISME DIFFERENTIEL POUR LES PROBLEMES DE DIFFRACTION DANS LE DOMAINE DE RESONANCE]
R. Petit *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 11 p refs In FRENCH (For availability see N75-22045 13-70)

Differential procedures used to study diffraction grating problems of periodic surfaces are examined. In particular, partial differential equations, truncated Fourier series, Rayleigh hypothesis, and Helmholtz equations are discussed. Data cover application of conformal mapping to electromagnetic wave scattering by gratings, anomalies of diffraction gratings, scattering by dielectric cylinders with arbitrary cross section shape, and optical grating couplers. Transl. by E.H.W.

N75-22057 GEC-Marconi Electronics Ltd., Chelmsford (England).
SCATTERING OUT OF THE EVAPORATION DUCT
S. Rotheram *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 12 p refs (For availability see N75-22045 13-70)

The theory of beyond the horizon radiowave propagation in the evaporation duct with a smooth sea surface and a smooth refractive index variation is discussed. It has been shown that the theoretical predictions nearly always exceed the experimental values. It is postulated that this is a consequence of scattering out of the duct by the rough sea surface and atmospheric turbulence. A method is given for taking into account the rough sea surface in which the smooth sea reflection coefficient is replaced by a rough sea reflection coefficient of well-known form. This is then converted into a surface impedance boundary condition to be satisfied by the height-gain functions. Some numerical results are presented and a preliminary comparison made with experimental results. Author

N75-22058 Southampton Univ. (England). Dept. of Electronics.
PROPAGATION IN CURVED MULTIMODE CLADDED FIBRES
W. A. Gambling, D. N. Payne, and H. Matsumura *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 16 p (For availability see N75-22045 13-70)

An analysis is given of coupling between modes in curved, cylindrical, multimode optical fibers. The coupling coefficients are derived. The coupling characteristics of the various modes are developed. The degree of mode conversion is stated as largely restricted to a periodic exchange of energy, between the modes, along the length of the fiber with a periodicity which can be less than one millimeter. This form of quasi-single-mode operation is reflected in very low values of pulse dispersion, but is very sensitive to stress in the fiber. The significance of these results in terms of mode conversion is discussed. Author

N75-22059 Kansas Univ., Lawrence.
REMOTE SENSING OF SURFACE PROPERTIES
Albert Wayne Biggs *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 12 p refs (For availability see N75-22045 13-70)

A review of some experimental techniques used in remote sensing of the earth's surface is presented. The experimental techniques utilize remote sensing systems in airborne and

stationary platforms. The remote sensing systems are on airborne radar scatterometer and a noncoherent pulse radar on a television tower at an altitude of 75 meters above the earth's surface. The results are presented in the form of the radar backscatter coefficient as a function of elevation angle. The forms of terrain are ocean surfaces, polar sea ice and vegetation. Author

N75-22060 McDonnell Aircraft Co., St. Louis, Mo.
POLARIZATION DISCRIMINATION IN REMOTE SENSING

J. C. Leader *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 12 p refs (For availability see N75-22045 13-70)

Experimental measurements of the scattering cross section of various materials in both the microwave and optical spectrum have shown a complex behavior as a function of the experimental variables of polarization, frequency, and scattering geometry. Although it has long been recognized that the material variables of surface roughness and dielectric constant must in some fashion govern the material's scattering properties, a complete description of observed scattering behavior in terms of only these variables has not, to date, proved possible. There are numerous examples of multi-polarization radar imagery which have defied an adequate interpretation in terms of material surface scattering properties alone, particularly with regard to anomalies in the co-polarized and cross-polarizd returns. Although polarization sensitive remote sensing using active sources in the optical spectrum is in its infancy, a similar state of confusion regarding interpretation may be expected unless a better understanding is available regarding fundamental scattering characteristics. Theoretical and experimental works which provide a basis for explaining many observed scattering characteristics are reported. This explanation is made possible by including the effects of volume scattering as a re-radiation source. The experimental data provided result from optical measurements; however, corresponding agreement between theory and experiment has also been shown in the microwave spectrum. Author

N75-22061 Naval Research Lab., Washington, D.C
THE SECOND ORDER DOPPLER SPECTRUM OF RADAR SEA ECHO FOR FREQUENCIES ABOVE VHF
G. R. Valenzuela *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 11 p refs (For availability see N75-22045 13-70)

The effect of surface tension in the second order Doppler spectrum of radar sea echo is investigated. The analysis includes the angle of incidence dependence, the polarization dependence, and the lossy-dielectric properties of the sea. Surface tension is introduced in the hydrodynamic part of the transfer coefficient. The introduction of surface tension in the analysis allows for resonant interactions of the gravity-capillary wave components on the water surface. Numerical results are presented from the generalized theory for vertical and horizontal polarization as a function of radar wavelength, wind speed, and radar viewing angle in relation to the wind direction. Author

N75-22062 Kansas Univ., Lawrence.
VOLUME SCATTERING FROM ICE AND WATER IN INHOMOGENEOUS TERRAIN
Albert W. Biggs *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 13 p refs (For availability see N75-22045 13-70)

Volume scattering of electromagnetic waves from Arctic sea ice and terrain with varying amounts of water is considered. Physical properties of sea ice and dielectric properties of snow are described in terms of mixtures of ice and water and the Debye relaxation spectra of water at microwave frequencies. Scattering models include brine pockets in sea ice, ice spheroids in glacial snow, and varying amounts of water in snow and ice. Radar backscatter measurements of sea ice and SLAR images are interpreted with these models. Three models of volume scattering are described. The first model is developed from Lambert's Law, which indicates that light scattered from a radiating surface varies in intensity as the cosine of the propagation direction and the surface normal. The second is made by replacing the terrain by a single layer of spheres, which scatter equally in all directions. The third model considers many layers of spheres. The spheres of ice are treated as Eaton lenses, which yield a much higher scattering cross section than that of a perfectly conducting metal sphere of the same size. Author

N75-22063 Western Ontario Univ., London. Centre for Radio Science.
THE PROPAGATION OF RADIO WAVES THROUGH PERIODICALLY VARYING MEDIA
G. F. Lyon and A. R. Webster *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 6 p refs (For availability see N75-22045 13-70)

The propagation of radio waves through periodically varying media is discussed by treating ionospheric irregularities as perturbations in a smooth ionosphere with a normal electron density versus height profile. It is possible in this way to model any shape or size of irregularity and to predict from the model any change in the number of electrons along any ray path and any angular deviations due to the perturbation. The method is illustrated by modelling periodic irregularities associated with Travelling Ionospheric Disturbances and the findings are compared with some experimental observations. Author

N75-22064 Illinois Univ., Urbana. Electromagnetics Lab.
REMOTE PROBING TECHNIQUES FOR INHOMOGENEOUS MEDIA
R. Mittra and D. H. Schaubert *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 11 p refs (For availability see N75-22045 13-70)
(Grant DA-ARO(D)-31-124-71-G77)

A technique is presented for remote probing a stratified medium using a spectral domain approach which differs from the conventional time-domain technique. The magnitude and phase of the field at the surfaces of the inhomogeneous medium when the probing wave is from the free space region of x less than zero is determined. The value of the measured surface makes it possible to compute the spectral domain counterparts which must be processed to determine the value of x. The computer storage and processing time for this procedure are within the capability of minicomputers. Several numerical results for profile functions are included to illustrate the utility of the method. Author

N75-22065 Rome Univ. (Italy). Ist. di Elettronica.
STRUCTURE OF TROPOSPHERIC INHOMOGENEITIES AS DEDUCED FROM INTERFEROMETRIC MEASUREMENTS

Giovanni Daurio and Domenico Solimini *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 13 p refs (For availability see N75-22045 13-70)

A method for identifying the geometry of atmospheric irregularities is illustrated and its use in an experiment is described. The method consists in determining the spatial statistics of the field in a transverse plane at the receiving end of a line-of-sight propagation path. The spatial statistics are derived by measuring the degree of coherence for points aligned in vertical and horizontal directions. By the anisotropy of the coherence, the geometrical structure of irregularities of the part of atmosphere which has been passed through is inferred. By taking advantage of the observation of other quantities that the interferometric technique can provide, the diverse mechanisms of propagation are recognized, thus confirming the existence of a given structure of irregularities. The experiment has been conducted at X-band over a 37.5 Km path, and data which have been obtained from it furnish, among other things, information on the probability of occurrence of meteorological conditions related to the observed structures of irregularities. Author

N75-22066 Manitoba Univ., Winnipeg. Dept. of Electrical Engineering.
RADIOMETRIC SIGNATURES OF COMPLEX BODIES

M. A. K. Hamid *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 27 p refs (For availability see N75-22045 13-70)

The basic theory for microwave radiometric signatures of finite stationary or moving, metallic or non-metallic, bodies of simple shape which are either larger in extent than the beam coverage of the radiometer antenna or lie entirely within the beam is outlined. The theory is developed to illustrate modeling concepts by deriving a correction factor due to the finite dimensions or structural inhomogeneities of the body and is extended to few composite bodies which can be viewed as combinations of simple ones. Experimental results for the emission pattern of selected objects are also presented to show the

interaction between the physical parameters of the target and the electrical parameters of the radiometer. Author

N75-22067 Colorado Univ., Boulder. Cooperative Inst. for Research in Environmental Sciences.
REVIEW OF GROUND WAVE PROPAGATION OVER NON-UNIFORM SURFACE
James R. Wait *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 20 p refs (For availability see N75-22045 13-70)

A consolidated review of recent analytical studies of electromagnetic waves propagating over inhomogeneous surfaces is presented. Emphasis is on smooth boundaries that can be characterized by a local surface impedance. A general integral equation formulation is developed for this situation. A number of special cases are then considered and various methods of solution are described. Various concrete, practical examples are presented, particularly with regard to effects that occur at coastlines. Extensions to certain types of terrain features are also treated using the closely related mode matching method. Some controversial aspects of very recent work on the subject are described. Author

N75-22068 Army Cold Regions Research and Engineering Lab., Hanover, N.H.
SURFACE IMPEDANCE OF RADIO GROUNDWAVES OVER STRATIFIED EARTH
P. Hoekstra, A. Delaney, and P. Sellmann *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 8 p refs (For availability see N75-22045 13-70)

Ground and airborne techniques to obtain subsurface information, for geotechnical objectives, by measuring the surface impedance of radiowaves have been developed. The frequency range covered in these measurements is from 14.7 Khz (VLF) to 660 Khz (BCB). Measurements in the North America Arctic have shown that it is common to encounter changes in the effective resistivity with frequency from several thousand ohm-m at VLF to a few tenths of ohm-m at BCB. These changes are caused by a conductive organic layer over highly resistive frozen ground. Also large regional and local changes in surface impedance were observed. In the permafrost regions changes from 6000 ohm-m to 50 ohm-m at VLF were found to occur frequently over distances of about 100 m. Surveys at VLF on the ground resolve discontinuities in ground conditions over distances of a few meters. Author

N75-22069 Technical Univ. of Denmark, Lyngby. Lab. of Electromagnetic Theory.
PROPAGATION OVER PASSIVE AND ACTIVE NONUNIFORM SURFACE IMPEDANCE PLANES
R. J. King and S. H. Cho (Wisconsin Univ.) *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 16 p refs (For availability see N75-22045 13-70)
(Grant NSF GK-21218)

Electromagnetic wave propagation over and radiation from nonuniform surface impedance planes are studied by numerical methods using the integral formulation of the compensation theorem. The source is a horizontal magnetic line current and the surface impedance is assumed to only vary in the direction of propagation and have a magnitude less than the intrinsic impedance of free space. Otherwise it is unrestricted. It is shown how the Sommerfeld attenuation function for propagation over a uniform surface can be used to piecewise explain and predict the general behavior of a wave propagating over a nonuniform surface. It is used to determine impedances which support fast or slow, and growing or decaying traveling waves. This gives general guidelines for manipulating the complex surface impedance to achieve specified radiation characteristics, or alternatively, field distributions on the surface. The integral formulation is then used to study microwave surface wave antennas. By varying the profile of the surface reactance magnitude and the antenna length, the radiation characteristics such as directivity, beam width and side lobe level can be optimized. Author

N75-22070 Institute for Telecommunication Sciences, Boulder, Colo.
ANALYSIS OF GROUND WAVE PROPAGATION OVER IRREGULAR, INHOMOGENEOUS TERRAIN
R. H. Ott *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 6 p refs (For availability see N75-22045 13-70)

A numerically feasible way to calculate the field strength of a radio wave propagating over realistic, smoothly varying, inhomogeneous terrain has been developed. The terrain may be represented by a completely arbitrary profile in terms of the elevation versus distance, and the conductivity and dielectric constant may change continuously along the path. One of the features of the surface wave that has been predicted by the numerical solution is a strong focusing phenomenon on lit portions of concave hills. This focusing phenomenon can also be explained in terms of Fock currents for concave surfaces. An example is given where the Fock currents on an equivalent parabola are used to predict the focusing on the lit side of a Gaussian hill. The numerical solution is then applied to a practical engineering problem; showing the effect of terrain features on the efficiency of HF antennas for launching and receiving surface waves over the sea. It is shown that, in general, placing the antenna at the top of the hill may be less efficient than placing it at the coastline, but placing it halfway up the hill may be more efficient than at either the hilltop or the coastline. Author

N75-22071 Shape Air Defense Technical Center, The Hague (Netherlands). Communications Div.
GROUND-LOSS PROFILE ALONG A MULTI-SECTION PATH OF A SKY WAVE
J. C. Arnbak *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 10 p refs (For availability see N75-22045 13-70)

For medium- and high-frequency waves radiated by ground-based antennas at low grazing angles, the far field is highly dependent on properties of the ground along the path of propagation. Notably, the conductivity and ground irregularity inside the first Fresnel zone, which typically extends to about one hundred wavelengths in the direction of propagation, affect the strength of the field transmitted to (or received from) distant points. An engineering method to evaluate the associated path loss of a vertically polarized sky wave in the presence of a plane, sectionally homogeneous ground is discussed. The influence of randomly rough surfaces is considered. The section model allows a profitable combination of standard ground data with a fast, numerical extension of simple mixed-path theory. Author

N75-22072 Institut fuer Physikalische Weltraumforshung, Freiburg (West Germany).
ANTENNA IMPEDANCE OF A GROUND-BASED EMITTER IN THE VERY LOW FREQUENCY DOMAIN
R. Grabowski *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 17 p refs (For availability see N75-22045 13-70)

The artificial emission of signals with frequencies below 10 kHz and the application of the signals to geophysical research are discussed. The design of an antenna for the emission below 10 kHz with sufficient radiation power is investigated. The antenna impedance with respect to the interaction with the ground is analyzed. Mathematical models are developed to describe the characteristics of an optimum antenna for the low frequency emission characteristics. Author

N75-22073 Admiralty Surface Weapons Establishment, Portsmouth (England).
ANTENNA AND CONDUCTING SCREEN ON A LOSSY GROUND
J. F. Goodey *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 17 p refs (For availability see N75-22045 13-70)

The problem of a vertical monopole situated over a small, circular, highly conducting screen lying on a poorly conducting ground has been considered. The electromagnetic field of the system is obtained via a Green's function expansion in oblate spheroidal wave functions. By integrating the outward power flow over the surface of the antenna and the spherical surface at infinity the radiation and loss resistances of the antenna are obtained. Antenna resistances were obtained experimentally in the H.F. band. Radiation patterns were measured at 3 GHz (using a carbon loaded dielectric material to simulate the behavior of soil at 30 MHz) and their areas used to calculate antenna radiation resistances. The results obtained are applied to the case of an electrically small untuned receiving monopole feeding directly

into a transistor amplifier to examine the signal to noise ratio of such a system. It is concluded that although the use of an imperfect ground system can result in a marked reduction in radiation resistance for small screen sizes the effect of the corresponding loss resistance upon the signal to noise ratio is not expected to be significant in the H.F. band. Author

N75-22074 Institute for Telecommunication Sciences, Boulder, Colo.

PROPAGATION OF A LORAN PULSE OVER IRREGULAR, INHOMOGENEOUS GROUND

J. Ralph Johler and Samuel Horowitz (AFCRL, Bedford, Mass.) *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 13 p refs (For availability see N75-22045 13-70)

A numerical solution of an integral equation representation of the ground wave over irregular, inhomogeneous earth has been employed to calculate amplitude and phase of the propagated continuous wave as a function of frequency. A computer simulation again using numerical methods, transforms this result to the time domain yielding the impulse response. Then the impulse response is convolved with the Loran-C pulse function, that has been transformed from the time domain to the frequency domain. The propagation of both pulse envelope and the cycles under the envelope in the presence of irregular, inhomogeneous ground is demonstrated. Although the Loran-C pulse propagation has been studied in detail, the method is applicable to the propagation of most any shape pulse over irregular, inhomogeneous ground. In the particular case of the Loran-C pulse, the discrepancy or time difference between the pulse envelope and cycle is a unique function of the particular type of terrain over which the wave propagates, and it is, at the present state of the art, necessary to introduce such terrain into the propagation theory to give a unique prediction of the pulse propagation time. Author

N75-22075 Army Electronics Command, Fort Monmouth, N.J. Communications/Automatic Data Processing Lab.

THE BEHAVIOUR OF LORAN-C GROUND WAVES IN MOUNTAINOUS TERRAIN

Douglas C. Pearce and John W. Walker *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 9 p refs (For availability see N75-22045 13-70)

The behavior of both the horizontal H-component and the vertical E-component of a Loran-C ground wave has been measured in the vicinity of an isolated terrain anomaly, Nittany Mountain, near State College, Pennsylvania. Time difference measurements were made with Army manpack receivers at 42 sites of good geodetic control in the area. The magnetic component of the ground wave was sensed with a ferrite array antenna while the vertical component was sensed with a whip antenna. Significant local warpages of the loran grid, apparently associated with the presence of the mountain, were observed with each antenna configuration. However, the warpage patterns were not identical for each field component, implying a somewhat different perturbation of each polarization component by the terrain anomaly. These results suggest that a field calibration of a loran grid in a region of a terrain anomaly will depend somewhat on the antenna type used. Author

N75-22076 Institute for Telecommunication Sciences, Boulder, Colo.

SPATIAL AND TEMPORAL ELECTRICAL PROPERTIES DERIVED FROM LF PULSE GROUND WAVE PROPAGATION MEASUREMENTS

Robert H. Doherty *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 17 p refs (For availability see N75-22045 13-70)

Low frequency ground wave phase measurements made on two loran (100 kHz pulse transmissions) paths have been analyzed for spatial variations. One Loran-D path in Nevada and California passes over Death Valley producing a so called Death Valley Anomaly. The other 1000 km Loran-C baseline path between Carolina Beach, N. C. and Dana, Indiana was measured in detail during the spring of 1970. Four locations in addition to the transmitter locations were monitored, one near Carolina Beach (the master), one just east of the Appalachian Mountains, one just west of the Appalachian Mountains and one near Dana, Indiana (the Z slave station). Effective surface impedance values were deduced for each segment of the propagation path. In addition to these spatial evaluations of the phase, temporal variations of the phase over the eastern path were approximately one microsecond, even though synchronization accuracies were better than .1 microseconds. Changes in the surface impedance values as a function time are clearly indicated. Author

N75-22077 Imperial Coll. of Science and Technology, London (England).

SERVICE AREA PREDICTION IN THE VHF AND UHF BANDS

H. Page *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 8 p refs (For availability see N75-22045 13-70)

An analysis of the factors which affect the prediction of terrestrial transmitter performance in very high frequency and ultrahigh frequency bands is presented. The main features that determine field strength at a particular point are as follows: (1) terrain irregularities, (2) terrain features such as buildings and trees, (3) scattering of signals by local obstacles when the antenna is low, (4) temporal variations, and (5) multipath propagation. Methods for using these factors in conducting an analysis of electromagnetic propagation and scattering are proposed. Author

N75-22078 Research Inst. of National Defence, Stockholm (Sweden).

PREDICTION AND CALCULATION OF TRANSMISSION LOSS IN DIFFERENT TYPES OF TERRAIN

A. Blomquist and L. Ladell *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 17 p refs (For availability see N75-22045 13-70)

A model for the calculation of transmission loss in the VHF and UHF regions has been developed. It has been used in service area predictions in different types of irregular terrain in Sweden with much better results than the existing models. The method is very easy to handle and needs no complicated computer technique. It takes proper account of the ground dielectric constant and the terrain profile including vegetation. It is thus a deterministic model giving the long-term median of the basic transmission loss. In planning terrestrial radio systems it is also necessary to have a knowledge of the variability in time and with location. On that account measurements are presented giving the additional loss for various percentages of time and locations. The best possible use of the capacity of telecommunication systems is often limited by the depolarization produced by absorption and scattering in the terrain. The effect of depolarization is given for various percentages of locations. Author

N75-22079 Polytechnic Inst. of New York, Brooklyn. Dept. of Electrical Engineering and Electrophysics.

MIXED-PATH CONSIDERATIONS FOR RADIO-WAVE PROPAGATION IN FOREST ENVIRONMENTS

T. Tamir *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 11 p refs Sponsored in part by ECOM and Army Land Warfare Lab. (For availability see N75-22045 13-70)

The propagation of radio waves is examined for communication paths that may lie partly within a forest and partly in the air region outside the vegetation. For this purpose, the geometry of a mixed path involving a forest layer adjacent to a bare-ground area is shown to exhibit four characteristic regimes. If, for example, the transmitting antenna is inside the forest, these regimes correspond to the receiving antenna being located in one of the following regions: (1) inside the forest; (2) above the tree tops; (3) at a relatively high altitude above the bare-ground region; or (4) at a relatively low height above the bare-ground region. Depending on frequency, on distances, and on which one of the four regimes is involved, the predominant field along the mixed path may be a refracted wave or a lateral wave. By finding the conditions that determine which one of these waves is predominant, it is possible to establish path losses in practically any regions involving reasonably flat ground contours. The frequency range of application for these considerations extends well into the VHF region. Author

N75-22080 Shape Air Defense Technical Center, The Hague (Netherlands).

INFLUENCE OF TOPOGRAPHY AND ATMOSPHERIC REFRACTION IN UHF GROUND-AIR COMMUNICATIONS

A. N. Ince and H. P. Williams *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 26 p refs (For availability see N75-22045 13-70)

The results of field strength measurements in UHF ground-air communication using four different ground terminals are presented. The local conditions at the ground terminals varied considerably: in one case the site was flat and clear over a distance of 2 km, in another the site was the highest in the district, a third site had nearby buildings, while the fourth site had marked local undulations and a nearby valley. In all four cases the field strength at the optical horizon was very close to the theoretical value for a smooth earth. The field strength at this point was virtually unaffected by the local ground conditions. Using this fact, and taking into account the statistics of atmospheric refraction it is possible to predict the reliability of UHF ground-to-air communication for high-flying aircraft. Author

N75-22061 Air Force Avionics Lab., Wright-Patterson AFB, Ohio.

FLIGHT TEST RESULTS OF PROPAGATION EXPERIMENTS THROUGH INHOMOGENEOUS MEDIA

Allen L. Johnson *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 7 p (For availability see N75-22045 13-70)

Flight test evaluation of communication systems to determine the effect of the inhomogeneous propagation media on communication reliability is discussed. The approach taken has been to postulate a physical or mathematical model and then to collect data to determine the validity of the hypothesis. Two related areas which have been studied are ducting and radio holes. Both are caused by an inversion layer. Ray tracing studies were done to establish expected performance under various atmospheric conditions. Data was then gathered on an air-to-air microwave system to validate the model. The test results showed good correlation between predicted and actual results when sufficiently detailed refractive index information was available for the predictions. Two other phenomena investigated were ionospheric scintillation and multipath fading. In the case of ionospheric scintillation the model is not well defined, and the test results were used to refine the model. The test results from the multipath fading flight testing showed that for over-water communications a specular reflection model best defines the actual results while over-land the diffuse fading component is predominant. Author

N75-22062 European Space Research Organization, Noordwijk (Netherlands).

MULTIPATH IN AN AERONAUTICAL SATELLITE SYSTEM

H. J. Wuennenberg *In* AGARD Electromagnetic Wave Propagation Involving Irregular Surfaces and Inhomogeneous Media Feb. 1975 18 p refs (For availability see N75-22045 13-70)

The multipath problem as encountered in a civil aeronautical satellite system is analyzed. A model for the multipath reflection is developed and the performance of the communications channels through the satellite is evaluated. The aeronautical satellite system will be used to control air traffic over the Atlantic and Pacific oceans. Aircraft will fly at a height of 10 to 20 km. Severe impairment of the communications performance is expected due to reflection of radiowaves from the surface of the sea and inadequate protection by the aircraft antenna against multipath. A simple theoretical model for reflections from the sea is developed. Under the assumption that only very simple coding schemes can be used to improve the bit error rate for digital transmissions the application of frequency diversity, space diversity and time diversity is discussed. It is shown that frequency diversity is more suitable for the link from the satellite to the aircraft while space diversity can be used for the link from the aircraft to the satellite. The application of time diversity does not reduce the bit error rate by a great amount because of correlation between consecutive bits. It is shown that large delays between messages are necessary to make time diversity attractive. Time diversity would therefore lead to coding by blocks and to storage requirements. Author

71 ACOUSTICS

Includes sound generation, transmission, and attenuation. For noise pollution see *45 Environment Pollution*.

N74-22640# Advisory Group for Aerospace Research and Development, Paris (France).
NOISE MECHANISMS
Mar. 1974 345 p refs Mostly in ENGLISH, partly in FRENCH Presented at Fluid Dyn. Panel Specialists Meeting, Brussels, Belgium, 19-21 Sep. 1973
(AGARD-CP-131) Avail: NTIS HC $20.25

Emphasis of the conference was on the fundamental problems of noise generation and attenuation. Main aspects considered were noise generation and damping, combustion and jet noise, sonic boom theory, and noise due to boundary and shear layer effects. For individual titles, see N74-22641 through N74-22670.

N74-22641 Cambridge Univ. (England). Engineering Lab.
[THE MECHANICS OF SOUND GENERATED BY TURBULENT FLOWS]
J. E. Efowcs Williams *In* AGARD Noise Mech. Mar. 1974 15 p (For availability see N74-22640 14-02)

Emphasis of the conference was on aeronautical problems arising from the field of aircraft noise control. Presentations are grouped under six separate headings: (1) source identification; (2) influence of mean flow structure on the generation and propagation of sound; (3) distinctive large eddy structures; (4) excess noise; (5) control of jet noise, and (6) problem areas likely to become more important. The main technical points arising from the meeting are outlined and the degree to which they appear to be currently understood is assessed. Several technical areas on which there was no clear concensus are covered in some detail and some speculation is made on the way they might develop. Author

N74-22642 Cambridge Univ. (England). Dept. of Engineering.
IMPULSIVE SOURCES OF AERODYNAMIC SOUND
John E. Efowcs Williams *In* AGARD Noise Mech. Mar. 1974 6 p refs (For availability see N74-22640 14-02)

The rapid acceleration of large bodies causes the local motion to shed its kinetic energy into the radiation field. A body steadily moving in potential flow sheds all its virtual energy into sound if it is brought to rest impulsively. Such rapidly accelerated large scale motions therefore represent an extremely efficient source of aerodynamic sound. Motions of this type are discussed with a view to explaining the origin of occasional particularly violent pressure transients that are observed in the noise field of high velocity jets. Author

N74-22643 Cambridge Univ. (England). Engineering Lab.
IMPULSIVE SOURCES OF AERODYNAMIC SOUND: ORAL SCRIPT OF THE INTRODUCTORY REVIEW LECTURE
John E. Efowcs Williams *In* AGARD Noise Mech. Mar. 1974 24 p (For availability see N74-22640 14-02)

The sources of aircraft noise due to rapid acceleration of large bodies is discussed. Work by Lighthill and other investigators is reviewed and a discussion is given to explain the origin of occasional violent pressure transients observed in the noise field of high velocity jets. A.L.

N74-22644* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
EXPERIMENTAL EVALUATION OF FLUCTUATING DENSITY AND RADIATED NOISE FROM A HIGH-TEMPERATURE JET
P. F. Massier, S. P. Parthasarathy, and R. F. Cuffel *In* AGARD Noise Mech. Mar. 1974 19 p refs (For availability see N74-22640 14-02)
(Contract NAS7-100)

An experimental investigation has been conducted to characterize the fluctuating density within a high temperature (1100 K) subsonic jet and to characterize the noise radiated to the surroundings. Cross correlations obtained by introducing time delay to the signals detected from spatially separated crossed laser beams set up as a schlieren system were used to determine radial and axial distributions of the convection velocity of the moving noise sources (eddies). In addition, the autocorrelation of the fluctuating density was evaluated in the moving frame of reference of the eddies. Also, the autocorrelation of the radiated noise in the moving reference frame was evaluated from cross correlations by introducing time delay to the signals detected by spatially separated pairs of microphones. The radiated noise results are compared with Lighthill's theory and with the data of Lush. Radial distributions of the mean velocity were obtained from measurements of the stagnation temperature, and stagnation and static pressures with the use of probes. Author

N74-22645* National Aeronautics and Space Administration Marshall Space Flight Center, Huntsville, Ala.
DIRECT MEASUREMENT OF SOUND SOURCES IN AIR JETS USING THE CROSSED BEAM CORRELATION TECHNIQUE
R. J. Damkevala, F. R. Grosche (DFVLR-AVA Goettingen, W. Germany), and S. H. Guest *In* AGARD Noise Mech. Mar. 1974 16 p refs (For availability see N74-22640 14-02)
(Contract NAS8-27011)

Properties of density fluctuations were measured in the turbulent regions of a 2.54 cm air jet, at M = 0.7, 1.0 and 1.94. After calibration tests, it was found that the absorption of infrared radiation at 4.3 microns by the naturally present quantities of carbon-dioxide in air was directly proportional to the air density if a sufficiently wide bandpass (0.08 microns) was used. Moreover, regions of the band could be selected that adequately discriminated against temperature variations. The cross-correlation of two such beams intersecting in the jet gave a measure of the local properties at the intersection point. A derivation is presented relating the local density correlation function to the self and shear generated noise in the far field of the jet. The measured correlations are used to predict the axial distribution of source strengths and the spectrum of noise due to a unit volume of turbulence. Author

N74-22646 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
DISTRIBUTIONS OF SOUND SOURCE INTENSITIES IN SUBSONIC AND SUPERSONIC JETS
F. R. Grosche *In* AGARD Noise Mech. Mar. 1974 10 p refs (For availability see N74-22640 14-02)

Clues on the validity of aerodynamic noise theories can be provided by comparison of predicted distributions of sound source intensities in turbulent jets with source distributions determined directly by suitable acoustic measurements. A method of tracing the sound sources from the sound radiated into the acoustic far field was developed. The sound waves emitted by a small volume of the jet are focused upon a microphone well outside the flow by means of a large elliptical mirror. The distribution of sound source intensities is investigated by moving the mirror-microphone assembly along and normal to the jet axis. Results of measurements with subsonic and supersonic jets show interesting details of the noise generation within these jets. Author

N74-22647 Lyon Univ. (France).
CORRELATIONS BETWEEN FAR FIELD ACOUSTIC PRESSURE AND FLOW CHARACTERISTICS FOR A SINGLE AIRFOIL
M. Sunyach, H. Arbey, D. Robert, J. Bataille, and G. Comte-Bellot *In* AGARD Noise Mech. Mar. 1974 12 p refs (For availability see N74-22640 14-02)

A NACA 6512 A sub 10 airfoil, whose chord is 8 cm, was placed in a uniform flow and ducted into an anechoic chamber with a speed ranging from 20 to 40 m/s. Its acoustic far field was analyzed in relation with the normal velocity fluctuations in the wake and the pressure fluctuations on the airfoil surface. Cross-correlations measurements showed that the aerodynamic pattern close to the trailing edge, on the extrados, controls the noise emission. Author

N74-22648 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
REPRESENTATION OF HOT JET TURBULENCE BY MEANS OF ITS INFRARED EMISSION
Jean Francois DeBelleval and Mariano Perulli *In* AGARD Noise Mech. Mar. 1974 10 p refs In FRENCH, ENGLISH summary (For availability see N74-22640 14-02)

The theoretical description of a jet acoustic radiation is usually described by characteristic turbulence data, defined at the scale of the total emissive volume. These data are deduced from theoretical models or from measurements making use of correlation techniques. These data have average values in time representing the whole spectrum. After a discussion on the nature of acoustic sources which may exist in a hot jet, and after

recalling the crossed beam techniques, a representation of a hot jet turbulence by means of crossed spectral densities is presented. It is then possible to define at any point of the source volume the characteristic turbulence data by frequency bands, and thus to know their dispersion. Author

N74-22649 British Columbia Univ., Vancouver. Dept. of Mechanical Engineering
NOISE SOURCE DIAGNOSTICS USING CAUSALITY CORRELATIONS
Thomas E Siddon *In* AGARD Noise Mech. Mar. 1974 13 p refs (For availability see N74-22640 14-02)
(Grants NRC A7106, DRB-G-9611-03)

Due to the complex mix of noise mechanisms for current quieter generations of aircraft, it has become more difficult to detect the small changes in overall decibel level which may result from localized design modifications. An increasingly popular diagnostic technique establishes causative relationships between individual noise source phenomena and the overall (composite) sound radiation. The method uses real-time cross-correlations between the far field sound pressure and fluctuating physical parameters occurring in, on, and around the noise generating machine. The technique is based on established aeroacoustic theory and has been shown to yield information on acoustic source distributions, their local spectra, and scales of coherence. The basic causality formalisms are reviewed and their use illustrated by reference to a number of proven experimental applications. It is shown that by judicious choice of control surfaces the methods can be adapted in unique ways to the elucidation of a number of unresolved noise generation and suppression phenomena. Examples pertaining to jets, suppressor nozzles, rotating fan blades, and flow interaction with leading and trailing edges are included. Author

N74-22650* California Univ., Los Angeles. School of Engineering and Applied Science.
USE OF CROSS-CORRELATION MEASUREMENTS TO INVESTIGATE NOISE GENERATING REGIONS OF A REAL JET ENGINE AND A MODEL JET
W. C Meecham and P. M. Hurdle *In* AGARD Noise Mech. Mar. 1974 13 p refs Sponsored by NASA (For availability see N74-22640 14-02)
CSCL 20A

Cross-correlations are reported of the jet static pressure fluctuations (as measured with a B and K microphone fitted with a nose cone), with the far-field radiated sound pressure. These measurements were made for various probe positions and a large number of far-field positions (at various angles). In addition, the tests were run for a number of different jet exit velocities. The measured, normalized cross-correlation functions vary between 0.004 and 0.155. These values depend upon the angular position of the far-field microphone, the jet exit Mach number, and the position of the probe. In addition, the cross-correlation technique was employed to study the symmetry of the far-field radiated sound about the jet axis. Third-octave analyses of both the probe signal and the far-field radiated sound were made. This is the first time correlation measurements have been made on a jet engine. In addition, a report is given on an extensive noise survey of a model jet. The correlations are related to sound source functions and jet source regions are discussed. Author

N74-22651 Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
SOME EXPERIMENTAL OBSERVATIONS OF THE REFRACTION OF SOUND BY ROTATING FLOW
G. D. Butler, T. A. Holbeche, and P. Fethney *In* AGARD Noise Mech. Mar 1974 10 p refs (For availability see N74-22640 14-02)

Some experimental and theoretical studies of the interaction of sound with a rotating flow field in the form of an aerodynamic vortex are described. The experiments were carried out in the acoustically-treated working-section of the RAE 24-foot diameter open-jet wind tunnel. Vortices were generated by setting a sharp-edged wing at incidence in the tunnel airstream and the effect of the vortex flow downstream of the wing trailing-edge on the noise propagating from a small loudspeaker source was investigated over a range of frequencies and wind speeds. Considerable refractive redistribution of the sound energy by the vortex flow occurred, leading to far field regions of markedly decreased and increased sound intensity. Qualitatively, these effects are consistent with the predictions of ray theory, although the interaction persisted down to frequencies where ray theory might be regarded as inapplicable. Some possible reasons for the observed differences with theory are briefly discussed. Author

N74-22652 General Electric Co., Schenectady, N.Y. Mechanical Engineering Lab.
THE ISSUE OF CONVECTIVE AMPLIFICATION IN JET NOISE
Ramani Mani *In* AGARD Noise Mech. Mar. 1974 12 p refs Sponsored in part by Air Force (For availability see N74-22640 14-02)

Three problems of the sound power and power spectrum produced by moving acoustic sources shrouded by jet flows were considered. The jets were assumed (for simplicity) to be characterized by a slug flow or top hat type mean velocity profiles. The sources were simple harmonic in their own frame of reference and were assumed to convect with the same velocity as the jet. The first problem considered the case of a monopole source convecting along the axis of a round jet. The second problem considered the case of convected line sources in a plane or two-dimensional jet. This was motivated by the need to understand the effect of off-axis lines of convection. The last problem was a variation of the first wherein the jet density and temperature are allowed to differ from those of the ambient. It was motivated by the need to understand the noise from heated jets. The studies were all motivated by one notion, namely, that Lighthill's original idea of ascribing jet noise to convected sources radiating freely to the ambient needs revision to allow for mean flow shrouding effects. The studies explain several experimentally observed features of jet noise such as a failure to exhibit convective amplification (particularly at high frequencies and shallow angles to the exhaust axis) and associated failure to peak frequencies in the power spectrum to shift linearly with jet velocity. Implifications for the jet density exponent issue for heated jets were also considered. The study may be regarded as moving sources solutions to the Phillips equation for jet noise with a specific velocity profile, namely the top hat profile. The advantage of choice of a simple velocity profile is to obtain solution valid for arbitrary frequencies. Author

N74-22653 Southampton Univ. (England) Inst. of Sound and Vibration Research.
THE NOISE FROM SHOCK WAVES IN SUPERSONIC JETS
M. Harper-Bourne and M. J. Fisher *In* AGARD Noise Mech. Mar. 1974 13 p refs (For availability see N74-22640 14-02)

A theoretical model is proposed for the prediction of the characteristics of broadband shock associated noise from jets operated above the critical pressure ratio. The model regards each shock cell and as a source of acoustic radiation with relative phasing set by the time of eddy convection between them. This leads to a prediction for the peak frequency of this noise component as a function of both pressure ratio and angle of observation which is amply confirmed by experimental results. The model is also extended to the prediction of the spectrum of shock associated noise and these predictions are also compared with experimental data. It is also shown that the intensity of shock noise is a function only of pressure ratio, and is independent of jet stagnation temperature and hence jet efflux velocity. Author

N74-22654 Southampton Univ. (England). Inst. of Sound and Vibration Research.
NOISE FROM HOT JETS
P. A. Lush and M. J. Fisher *In* AGARD Noise Mech. Mar. 1974 8 p refs (For availability see N74-22640 14-02)

Measurements of the noise from several independent workers of hot subsonic jets show that the noise decreases relative to the unheated jet at high jet velocity but increases at low velocity. The decrease at high velocity has previously been explained by the reduction in the jet density for the hot jet and this explanation is confirmed by the present study. The increase in noise at low velocity is attributed to an additional source caused by entropy fluctuations which varies as U4 compared with U8 for the usual mixing noise. A simple theoretical model using Lighthill's theory of aerodynamic sound is proposed and this gives very good agreement with the experimental results, but the theoretical model cannot be justified rigorously. However it could provide a satisfactory method for prediction of the noise from hot jets and a basis for the collapse of data. Author

N74-22655 Southampton Univ. (England) Dept. of Aeronautics and Astronautics
ON THE NOISE FROM JETS
G. M. Lilley *In* AGARD Noise Mech. Mar. 1974 12 p refs (For availability see N74-22640 14-02)

A modification of Lighthill's theory is discussed in which pressure disturbances in the jet are treated as an inner flow problem which is matched to the outer flow radiation problem. In this treatment the source function involves quadratic and higher order small disturbance terms. This approach, although more complicated mathematically than the exact theory of Lighthill, has the advantage that it draws attention directly to the role played by the mean velocity and temperature distributions on the generation and propagation of the emitted sound. The model in its simplest form can be reduced to a vortex sheet model and thus draws attention to the stability characteristics of the vortex sheet. In the more general treatment the stability characteristics of the mixing region are considered and its least stable modes are regarded as dominating the large-scale eddy motion. The linear stability theory is extended to deal with non linearities and, as a result, the amplitude of the larger-scale motion is determined. This is compared with the measured large-scale structure of the jet. From this model the main characteristics of the source function are found. The paper concludes with some results from this new formulation and a comparison is made with experimental findings. Author

N74-22656 Imperial Coll. of Science and Technology, London (England). Dept. of Mathematics.
MECHANISMS OF EXCESS JET NOISE
D. G. Crighton *In* AGARD Noise Mech. Mar. 1974 7 p refs (For availability see N74-22640 14-02)

Excess noise is a term used to describe the deviations of measured noise fields from the predictions of Lighthill's theory of pure jet mixing noise. A definition is given for the current state of theoretical understanding of those excess noise fields which are not directly attributable to rotating machinery, or to shock waves in supersonic jets. It is shown that unsteady flow interaction with the jet pipe can generate intense forward arc and sideline noise levels, while abnormally high rear arc levels are suggested to arise from the propagation of genuine sound fields across the exit plane, with associated refraction and diffraction effects. A further process, not yet properly quantified, is related to the instability of a (fully turbulent) jet to certain preferred large scale disturbances, and leads to a mechanism (parametric amplification) by which internal sound fields may be greatly augmented in either the rear or forward arcs. Author

N74-22657 Gottingen Univ. (West Germany). Physikalisches Inst.
EXPERIMENTS CONCERNING THE FLOW DEPENDENT ACOUSTIC PROPERTIES OF PERFORATED PLATES
Juergen Kompenhans and Dirk Ronneberger *In* AGARD Noise Mech. Mar. 1974 6 p refs (For availability see N74-22640 14-02)

The results are presented of investigations of the influence of grazing flow on the impedance of a single orifice serving as a simplified model of a perforated plate. At small flow velocities the impedance curve plotted in the complex plane passes through a spiral. For higher flow velocities the resistive part of the impedance increases linearly with the flow velocity whereas the reactive part decreases. A relation between the impedance and the static flow resistance can be established. Possible nonlinear properties of the orifice are discussed. Author

N74-22658 National Aeronautical Establishment, Ottawa (Ontario).
A DETERMINISTIC MODEL OF SONIC BOOM PROPAGATION THROUGH A TURBULENT ATMOSPHERE
B. H. K. Lee and H. S. Ribner *In* AGARD Noise Mech. Mar. 1974 13 p refs Prepared in cooperation with Toronto Univ., Ontario (For availability see N74-22640 14-02)

The propagation of a weak normal shock wave through a turbulent atmosphere is studied in terms of an idealized model. The turbulent field is assumed to be weak and represented by the superposition of two inclined shear waves of opposite inclination to the mean flow. The resulting flow is of a cellular nature. The cells are rectangular in shape and the sense of rotation of the flow alternates from cell to cell. If the angles made by the normal of the incident shear waves with the direction of the mean flow are greater than some critical value an exponentially decaying pressure wave is generated behind the shock. Spiked or rounded waveforms are obtained by adding or subtracting this pressure wave from the steady state pressure field. An illustrative example for a mean flow Mach number of 1.0005 is considered. This gives a steady state overpressure of 2.45 lb/ft sq across the shock which is typical of the overpressure in a sonic boom. Author

N74-22659 Max-Planck-Institut fuer Stroemungsforschung, Goettingen (West Germany).
SONIC BOOM BEHAVIOR NEAR A CAUSTIC
Frank Obermeier *In* AGARD Noise Mech. Mar. 1974 14 p refs (For availability see N74-22640 14-02)

The pressure signature is analyzed of an ideal N-shaped sonic boom caused by an accelerated projectile. Its signature in the surroundings of the so-called caustic and behind the caustic is described by the equations of linear wave acoustics. The calculations are performed for a special case where the acceleration phase is chosen in such a way that the corresponding Mach-cone, modified by the acceleration, is composed of a truncated cone, the lower part of which has a circle like curved surface and the upper part is ordinary straight cone. The proposed theory yields results which are in good agreement with measurements. Author

N74-22660 Institut Franco-Allemand de Recherches, St. Louis (France).
INFLUENCE OF METEOROLOGICAL CONDITIONS ON THE POSITION OF THE GROUND COVERED BY SONIC BOOMS [INFLUENCE DES CONDITIONS METEOROLOGIQUES SUR LA POSITION AU SOL DU TAPIS DE BANG]
M. Schaffar and C. Thery *In* AGARD Noise Mech. Mar. 1974 12 p refs In FRENCH (For availability see N74-22640 14-02)

Numerical methods and theories used to study sonic boom propagation in the real atmosphere are discussed. Special attention was given to the effect of meteorological conditions on lateral and longitudinal extension and the location of the ground focus line. Transl. by E.H.W.

N74-22661 Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Paris (France).
RECENT STUDIES INTO CONCORDE NOISE REDUCTION
R. Hoch and R. Hawkins (Rolls Royce, Ltd., Bristol, Engl.) *In* AGARD Noise Mech. Mar. 1974 14 p refs Prepared in cooperation with Rolls Royce, Ltd., Bristol, Engl. (For availability see N74-22640 14-02)

Recent research is summarized which was conducted over the past two years as part of a continuing noise reduction program on the Concorde powerplant. The studies were aimed at: (1) improving knowledge of certain noise sources of the Olympus 593 turbojet engine and (2) evaluating potential means for noise reduction either at source by alteration to the various engine components, or by addition of attenuating devices. Some of the results of the studies have been applied to the powerplant design standard intended for entry into service, others are mentioned only for their technical or didactic interest, and others after engineering evaluation, may lead to acoustic improvements to the Concorde powerplant after entry into service. Author

N74-22662 Technische Hogeschool, Eindhoven (Netherlands). Fluid Mechanics Lab.
AEROSONIC GAMES WITH THE AID OF CONTROL ELEMENTS AND EXTERNALLY GENERATED PULSES
L. J. Poldervaart, A. P. J. Wijnands, and L. B. Donkhorst *In* AGARD Noise Mech. Mar. 1974 4 p refs (For availability see N74-22640 14-02)

Experiments were conducted which indicate that with the aid of control elements, it is possible to generate the following modes of vibration of a 2-dimensional sonic jet: (1) zero mode; (2) oscillatory mode, natural and forced; (3) pulsatory mode; and (4) coupled pulsatory-oscillatory mode. The experiments also demonstrated that with the aid of externally generated pulses, it is possible to show how the information, near the nozzle tip, is transferred from the pulse into the jet. The nozzle tip as a discontinuity proves to be a dominant factor in the interaction process of the pulse with the boundary layer and with the jet. Author

N74-22663 University of Southern Calif., Los Angeles. Dept. of Aerospace Engineering.
ON THE GENERATION OF JET NOISE
J. Laufer, R. E. Kaplan, and W. T. Chu *In* AGARD Noise Mech. Mar. 1974 8 p refs (For availability see N74-22640 14-02)
(Grant DOT-OS-00002)

It is proposed that the rate of subharmonic production, that is, the rate at which large scale vortex-ring like structures interact with each other, is the primary mechanism responsible for most of the noise generation of a subsonic jet. The interaction consists of simultaneous acceleration and deceleration of vorticity containing coherently moving regions followed by a pairing process. This picture is consistent with Lighthill's quadrupole like sources, as well as with the formulation of Powell's vortex sound theory. It is suggested that more direct experiments are necessary to examine the validity of the above proposition. Author

N74-22664 Naval Ship Research and Development Center, Washington, D.C. Hydroacoustic Branch.

AN EXPERIMENTAL STUDY OF THE INTERMITTENT WALL PRESSURE BURSTS DURING NATURAL TRANSITION OF A LAMINAR BOUNDARY LAYER

Fred C. DeMetz and Mario J. Casarella *In* AGARD Noise Mech. Mar. 1974 18 p refs (For availability see N74-22640 14-02)

The properties of the intermittent wall pressure field were measured in the transition boundary layer on a large flat plate in an anechoic wind tunnel. Natural transition was achieved with a mild favorable pressure gradient at Reynolds numbers, based on downstream distance from the plate's leading edge, in excess of 7 million. The development of the laminar boundary layer prior to transition was in agreement with numerical solutions to the laminar boundary layer equations and with stability criteria for pressure gradient effects. The temporal, spatial, and spectral properties of the transition wall pressure field associated with the natural transition process occurring on the plate are obtained as a function of the intermittency factor, and compared with those of the fully turbulent pressure field. Specifically, the mean-square pressure, spectral densities, convection velocities, distributions of burst periods and burst rates of the intermittent pressure field are computed from the data. Author

N74-22665 Technische Hochschule, Aachen (West Germany). Aerodynamisches Inst.

ON THE INTERACTION BETWEEN A SHOCK WAVE AND A VORTEX FIELD

A. Naumann and E. Hermanns *In* AGARD Noise Mech. Mar. 1974 10 p refs (For availability see N74-22640 14-02)

In a double side shock tube, the flow pattern produced by the interaction of a weak shock wave with a vortex field was observed by means of Mach-Zehnder interferograms; the vortex circulation and the pressure ratio of the shock were varied. An evaluation of the interferograms gives the time dependent density fields. The deformation of the interacting shock leads to a discontinuity in slope of its front and to the formation of a secondary wave from the sharp bending point. With the assumption of linear superposition, the flow pattern is in very good agreement between the theoretical and experimental results. Author

N74-22666 Max-Planck-Institut fuer Stroemungsforschung, Goettingen (West Germany).

INVESTIGATION OF THE INSTANTANEOUS STRUCTURE OF THE WALL PRESSURE UNDER A TURBULENT BOUNDARY LAYER FLOW

R. Emmerling, G. E. A. Meier, and A. Dinkelacker *In* AGARD Noise Mech. Mar. 1974 12 p refs (For availability see N74-22640 14-02)

An optical method was used to investigate the instantaneous structure of the wall pressure under a turbulent boundary layer flow in air. The optical apparatus consisted basically of a Michelson-interferometer. One mirror of the interferometer was replaced by a reflecting flexible wall, which was also part of the wall bounding the flow being investigated. The turbulent wall pressure fluctuations cause the flexible wall to be displaced by several light wave-lengths. The instantaneously occurring fringe patterns were recorded with a high-speed film camera. The wall area observed was 48 mm x 29 mm, and the flow velocity outside the boundary layer was 8.5 m/sec. The optical method used made it possible to determine the instantaneous values of the wall pressure distribution, the convection velocity and the wall pressure gradient. Author

N74-22667 Royal Air Force Central Medical Establishment, London (England).

SOME AEROMEDICAL ASPECTS OF NOISE

P. F. King *In* AGARD Noise Mech. Mar. 1974 6 p refs (For availability see N74-22640 14-02)

The different problems and patterns of noise related to various types of aircraft are considered. The types of aircraft include: (1) fixed wing aircraft, (2) V-STOL aircraft, (3) rotating wing aircraft, and (4) air cushion vehicles. In addition, various measures for conservation and protection of hearing are proposed. D.L.G.

N74-22668* National Aeronautics and Space Administration, Langley Research Center, Langley Station, Va.

CURRENT STRUCTURAL VIBRATION PROBLEMS ASSOCIATED WITH NOISE

John S. Mixson *In* AGARD Noise Mech. Mar 1974 16 p refs (For availability see N74-22640 14-02)

As the performance of aerospace vehicles has increased, the noise generated by the propulsion system and by the passage of the vehicle through the air has also increased. Further increases in performance are now underway for space vehicles such as the space shuttle vehicle and for short distance takeoff and landing (STOL) aircraft, and are being planned for supersonic aircraft. The flight profiles and design features of these high-performance vehicles are reviewed and an estimate made of selected noise-induced structural vibration problems. Considerations for the prevention of acoustic fatigue, noise transmission, and electronic instrument malfunction are discussed. Author

N74-22669 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Berlin (West Germany). Inst. fuer Turbulenzforschung.

RESOLUTION OF TURBULENT JET PRESSURE INTO AZIMUTHAL COMPONENTS

H. V. Fuchs *In* AGARD Noise Mech. Mar. 1974 10 p refs (For availability see N74-22640 14-02)

The results are presented of experiments conducted to analyze the turbulent pressure field with respect to the jet noise problem. The experiments deal specifically with the turbulent pressure field in a fixed plane normal to the jet axis. The findings indicate that at low Mach numbers, considerable turbulent energy is stored in lower order azimuthal components and, in particular, in the large scale coherent axisymmetric type of fluctuation. D.L.G.

N74-22670 London Univ. (England). Dept. of Aeronautical Engineering.

SOME EXPERIMENTAL RESULTS ON EXCESS NOISE

A. D. Young *In* AGARD Noise Mech. Mar. 1974 5 p refs (For availability see N74-22640 14-02)

Compressed air was ducted from a 12 in. diameter pipe into a plenum chamber 24 in. diameter and 4 ft long. This was followed by a contraction leading to a nozzle from which the air emerged into the atmosphere in an anechoic chamber as a jet. The plenum chamber contained a honeycomb and gauze to help reduce the flow turbulence. The resulting jets were very steady and with low turbulence levels. Noise measurements were made at a distance of 6 feet from the nozzle exit. In addition to the measurements on the basic jets, various modifications were introduced upstream of the nozzle exit to produce various intensities and scales of turbulence, and the consequent effects on the noise characteristics were measured. The results are given and their significance is discussed. Author

74 OPTICS

Includes light phenomena.

N75-10774# Advisory Group for Aerospace Research and Development, Paris (France).
OPTO-ELECTRONICS
Sep. 1974 143 p refs In ENGLISH and FRENCH (AGARD-LS-71) Avail NTIS HC $5.75

A study was conducted of the state-of-the-art of electro-optic developments applied to the avionics field of research and development. A review of optics including fiber optical techniques and their exploitation in the avionics field for transmission of information is presented. The capabilities of aircraft using television, low light television, infrared, lasers, and optical methods to sense and display information are analyzed. System designs and problems encountered in applying the sensors are discussed. For individual titles, see N75-10775 through N75-10784.

N75-10775 Ministry of Defence, London (England).
THE IMPACT OF OPTO-ELECTRONICS UPON AVIONICS
F. S. Stringer *In* AGARD Opto-Electronics Sep. 1974 2 p (For availability see N75-10774 01-74)

The military applications of electro-optical equipment are discussed. Emphasis is placed on systems design of sensors and display devices. Specific applications of electro-optic techniques for air navigation, target acquisition, and weapon aiming are examined. The advantages of head-up displays are compared with those of head-down displays. The subjects of fiber optics, optical design, and imaging system techniques are presented. Author

N75-10776 Royal Radar Establishment, Malvern (England).
LASER SOURCES
P. A. Forrester *In* AGARD Opto-Electronics Sep. 1974 9 p refs (For availability see N75-10774 01-74)

The basic physics common to all the different types of laser is discussed to include stimulated and spontaneous emission, population inversion, and resonator modes. Methods of controlling the time variation of the output power by the techniques of Q-switching, cavity dumping, and mode locking are described. The properties of some of the currently available laser devices, based on optically-pumped solids, gaseous discharges, and semiconductor diodes, are analyzed. Author

N75-10777 Services Electronics Research Lab., Baldock (England).
INFRARED AND VISIBLE RADIATION DETECTORS FOR IMAGING AND NON-IMAGING APPLICATIONS
B. R. Holeman *In* AGARD Opto-Electronics Sep. 1974 16 p refs (For availability see N75-10774 01-74)

A general description of a photodetector is presented and, after defining the relevant parameters to describe its operation, the limits set by the quantum nature of the radiation input are outlined. Bolometric detectors are reviewed with particular reference to triglycine sulphate. Photoconductive, photovoltaic and photoemissive detection processes are compared before describing the wide range of single element detectors utilising these effects. The multielement technique, as shown in thermal infrared detectors such as cadmium-mercury telluride and lead-tin telluride, and in visible and near infrared detectors using silicon photosensitive integrated circuits, is described. The principles of electron beam readout are outlined and devices using this technique, such as vidicons, orthicons and isocons are reviewed. Finally, the state of the art in an alternative solid state approach, charge coupled transfer, is discussed. Author

N75-10778 Hughes Aircraft Co., Culver City, Calif. Display Systems Lab.
DISPLAY DEVICES AND THEIR USE IN AVIONICS SYSTEMS
G. K. Slocum *In* AGARD Opto-Electronics Sep. 1974 14 p (For availability see N75-10774 01-74)

The factors which affect the selection of a display for imaging sensors in avionics systems are discussed. The visual characteristics of the observer and the specific task to be accomplished are examined to show the impact on sensor selection. The factors affecting the performance of the operator are examined and the display design requirements are developed. The following systems are analyzed: (1) scan converter tubes, (2) digital scan converter, (3) television frame rate display devices, (4) helmet mounted displays, (5) plasma panel pictorial display, (6) light emitting diode array pictorial display, (7) electroluminescent matrix panel pictorial display, and (8) liquid crystal matrix pictorial display. Author

N75-10779 Plessey Radar Ltd., Havant (England). Plessey Radar Research Centre.
OPTICAL WAVEGUIDE DATA TRANSMISSION FOR AVIONICS
David A. Kahn *In* AGARD Opto-Electronics Sep. 1974 22 p refs (For availability see N75-10774 01-74)

Optical communications and waveguide communications with special reference to optical frequencies are considered. A review of optical waveguides with emphasis on materials, structures, drive circuits, photodiodes and avalanche diodes, low noise amplification, and the waveguide/terminal interface is presented. Transmitting and receiving terminals are described to include examinations of lasers, light emitting diodes, drive circuits, photodiodes and avalanche diodes, low noise amplification, and the waveguide/terminal interface. Various system engineering aspects are examined to include powering arrangements, cableform, and multiplexing techniques. Author

N75-10780 Smiths Industries Ltd., Bishops Cleeve (England). *Aviation Div.*
HEAD-UP DISPLAY OPTICS
R. A. Chorley *In* AGARD Opto-Electronics Sep. 1974 18 p (For availability see N75-10774 01-74)

The factors which influence the definition of the optical system for a Head-Up Display are defined. The conflicting requirements for wide fields of view and compact, easily installed hardware are discussed (with relation to both refractive and reflective optical systems) together with various aspects of optical performance which influence the overall display system performance. The primary reason for installing a HUD system in a military aircraft is the improved weapon-aiming capability it can provide. From this point of view the HUD can be looked upon as a sophisticated descendant of the various forms of optical gunsight which have been in service for a quarter of a century or more. Thus the most basic requirement for a military HUD system is that it should provide the information needed for weapon aiming, and this means that it must provide an aiming symbology display, focussed nominally at infinity, so that the pilot can correlate and utilize the display and the outside world information simultaneously. Author

N75-10781 Optical Industries N. V., Delft (Netherlands).
OPTICS FOR PASSIVE VIEWING DEVICES
J. Becker *In* AGARD Opto-Electronics Sep. 1974 7 p refs (For availability see N75-10774 01-74)

The uses of far infrared detectors for image intensification and low light visibility are discussed. Specific applications of low light level instruments with electron optical intensification of the brightness in astronomy and high speed photography, in industry for non destructive testing by X-ray imaging, in the medical field, and in military situations for passive detection or reconnaissance at night are described. Non scanning thermal infrared devices and systems scanning in the image space of the front optics which operate on the long wave infrared spectrum are analyzed. Photographs and illustrations of typical optical devices are provided. Author

N75-10782 Service Technique des Telecommunications de l'Air, *Paris (France).*
PRINCIPLE AND REALIZATION OF AERONAUTICAL LASER SYSTEMS [PRINCIPE ET REALISATION DES SYSTEMES LASER EN AERONAUTIQUE]
Patrice Mollis and Francois Chabannes (Lab. Central de l'Armement) *In* AGARD Opto-Electronics Sep. 1974 21 p refs In FRENCH; ENGLISH summary (For availability see N75-10774 01-74)

Various typical aeronautical laser systems are described. The effects of various parameters on the design of laser systems are analyzed. Specific applications for range finding, guidance, detection, surveillance, and gyroscopes are examined. Diagrams are provided to show the methods of operating in the active, semi-active, and passive modes for target acquisition and remote control. Author

N75-10783 Royal Aircraft Establishment, Farnborough (England).
LOW LIGHT TELEVISION SYSTEMS
R. J. Corps *In* AGARD Opto-Electronics Sep. 1974 12 p refs (For availability see N75-10774 01-74)

The component parts which constitute a low light level television system are described. The advantages and disadvantages of each unit are analyzed. The characteristics and applications of five specific television systems are examined. The possibility of using active illumination with a gated television system is proposed. Diagrams of the components are provided to show their construction and operation. The components include the following: (1) cascade image intensifier, (2) motion compensated intensifier with gating, (3) channel plate intensifier, (4) proximity diode image intensifier, and (5) image orthicons. Author

N75-10784 Environmental Research Inst. of Michigan, Ann Arbor. Infrared and Optics Div.

PASSIVE INFRARED SYSTEMS

Donald S. Lowe *In* AGARD Opto-Electronics Sep. 1974 15 p refs (For availability see N75-10774 01-74)

Blackbody emission and the nature and characteristics of radiation from targets and backgrounds are discussed. The effect of the atmosphere on the detection process is reviewed. The functions of the components found in optical systems are described. The radiation transfer from the target through the atmosphere and the optical system is developed. Concepts and principles used in designing various types of sensors are analyzed with emphasis placed on trackers and airborne scanners. Author

81 ADMINISTRATION AND MANAGEMENT

Includes management planning and research.

N75-14632 Advisory Group for Aerospace Research and Development, Paris (France).
AGARD HANDBOOK
Aug. 1974 47 p
(AGARD-Handbook-722.28.00-Rev) Copyright. Avail: Issuing Activity

A handbook on the organization and functions of the Advisory Group for Aerospace Research and Development (AGARD) is presented. The subjects discussed are: (1) the AGARD mission, (2) the AGARD staff, (3) the AGARD panels, (4) the consultant and exchange program, and (5) the AGARD publications. P.N.F.

N76-17986# Advisory Group for Aerospace Research and Development, Paris (France).
MEDICAL OFFICER CAREER MANAGEMENT AND RETENTION IN NATO ARMED FORCES: A WORKING GROUP REPORT
G. Zinnemann, ed. Dec. 1975 107 p refs
(AGARD-R-635) Avail: NTIS HC $5.50

The armed forces of most NATO nations experience great difficulty in attracting and retaining young medical officers unless a doctor draft, national service, or pay-back for their medical education makes a period of active military duty a legal requirement. Some of the disadvantages inherent in a military medical career vis-a-vis a civilian practice deter the average young doctor from choosing a career in military medicine voluntarily. Since the ever-present threat of a doctor shortage constitutes a problem of operational significance, the Working Group sought to: (1) define the factors of career motivation, (2) compare approaches, methods, and attempted solutions to the problem in participating countries, and (3) offer a set of recommendations designed to alleviate the situation. Author

82 DOCUMENTATION AND INFORMATION SCIENCE

Includes information storage and retrieval technology; micrography; and library science. For computer documentation see *61 Computer Programming and Software*.

N74-19626# Advisory Group for Aerospace Research and Development, Paris (France).
SEMI-AUTOMATIC INDEXING: STATE OF THE ART
H. Fangmeyer (EURATOM, Ispra) Feb. 1974 26 p refs
(AGARDograph-179, AGARD-AG-179) Avail: NTIS HC $4.50

The state of the art of semiautomatic indexing for information retrieval systems is discussed in the following areas: (1) semiautomatic derivative indexing; (2) machine-aided assignment indexing (including automatic assignment indexing techniques based on previously created manual or semiautomatic indexing aids); and (3) semiautomatic dictionary construction. Semiautomatic indexing is divided into conversational and symbiotic indexing in order to distinguish between indexing by continuous contact with the computer and indexing by integration of the computer in the indexing process for the purpose of performing certain clerical tasks. Author

N74-27457# Advisory Group for Aerospace Research and Development, Paris (France).
HOW TO OBTAIN INFORMATION IN DIFFERENT FIELDS OF SCIENCE AND TECHNOLOGY: A USER'S GUIDE
May 1974 120 p refs
(AGARD-LS-69) Avail: NTIS HC $9.00

The principles of information systems are outlined that provide storage, retrieval, and dissemination of technical information to scientists. For individual titles, see N74-27458 through N74-27464.

N74-27458 Pittsburgh Univ., Pa.
PRESENT KNOWLEDGE DOMAIN OF SCIENTISTS AND TECHNOLOGISTS
A. Debons *In* AGARD How to Obtain Inform. in Different Fields of Sci. and Technol. May 1974 7 p refs (For availability see N74-27457 16-34)

Available data resources in several scientific and technological areas are promoted. Effective use of such data resources depends on some understanding of how information is generated, used and given to others. Influences of organismic variables on our ability to acquire and process data and the direct use of the resulting information in decision making and problem solving are considered. The way certain variables involved in these functions relate to the use of data bases is emphasized. Author

N74-27459 Pittsburgh Univ., Pa.
GENERATION, USE, AND TRANSFER OF INFORMATION
Allen Kent *In* AGARD How to Obtain Inform. in Different Fields of Sci. and Technol. May 1974 7 p refs (For availability see N74-27457 16-34)

The information explosion has produced an effect that has not been widely recognized. The inability of individuals to read all potentially relevant material has changed the nature of questions asked. Now, questions are asked more frequently that relate to a problem, with the aspects of the question derived from the problem at hand rather than recalled from previous contact with specific items of the literature. Information systems have attempted to respond to this change through deeper analysis of materials, and coordination of desired aspects of subject matter using computers. The need for connection between the terminology of questions posed and the available analytics has become more critical. More precise control of vocabulary is needed, leading to the construction of mechanisms such as thesauri. Author

N74-27460 Farbwerke Hoechst A.G., Frankfurt (West Germany).
INTERNATIONAL MEDICAL INFORMATION SYSTEMS
Georg E. Unger *In* AGARD How to Obtain Inform. in Different Fields of Sci. and Technol. May 1974 7 p (For availability see N74-27457 16-34)

The flood of information especially in medical sciences can with no means, and especially not with the well known nonventional means, be accomplished today. Even the creation of localized medical information systems can not cover the demands the medical profession is bringing forward. With the use of computers new ways are opened. Various methods have been developed in order to analyze, organize and evaluate the present voluminous flood of information. Communication between existing printed information and the medical profession in all fields of this science is considered. A new automated on-line terminal oriented storage and information retrieval system is discussed on a worldwide international basis. Author

N74-27461 Rome Air Development Center, Griffiss AFB, N.Y.
FEDERAL INFORMATION SYSTEMS
Fred S. Dyer *In* AGARD How to Obtain Inform. in Different Fields of Sci. and Technol. May 1974 10 p refs (For availability see N74-27457 16-34)

The Federal Technical Information System is the Federal coordinator and distributor of U.S. Government sponsored research and analytical reports to the general public. Inputting or participating with this repository are a number of other Government repositories that are responsible for performing functions parallel to NTIS for the communities they serve and in some cases they also manage the classified/limited portions of their respective collections. Author

N74-27462 Pittsburgh Univ., Pa. Knowledge Availability Systems Center.
THE NASA REGIONAL DISSEMINATION CENTER
Edmond Howie *In* AGARD How to Obtain Inform. in Different Fields of Sci. and Technol. May 1974 7 p (For availability see N74-27457 16-34)

An overview is presented of the Knowledge Availability Systems Center and its role as a National Aeronautics and Space Administration Regional Dissemination Center. Particular emphasis is placed on the marketing, technical analysis, technical operations and engineering consultation functions of the center as they relate to user exploitation of its mechanized information resources. Author

N74-27463 Lockheed-Georgia Co., Marietta. Technical Information Dept.
INTERNATIONAL INFORMATION SYSTEMS FOR PHYSICAL SCIENTISTS
Charles K. Bauer *In* AGARD How to Obtain Inform. in Different Fields of Sci. and Technol. May 1974 60 p refs (For availability see N74-27457 16-34)

The numerous sci-tech information sources are discussed which provide retrieval service to outside users. Description of these sources was made by means of a questionnaire sent to centers throughout the world. Based on the response, information about these sources includes their name and address, subject fields and kind of collection maintained, retrieval systems employed, publications issued, and services supplied. In assessing international information retrieval and transfer, problems of the information seeker, industrial and technological conditions among nations, source selection, accessibility, duplication, standardization, and language barriers as influences upon information receipt and utilization are discussed. A review is given also of cooperative efforts made by government sponsored world organizations and international professional bodies to ameliorate prevailing conditions. Author

N74-27464 Syracuse Univ., N.Y.
ENVIRONMENTAL INFORMATION SYSTEMS
Marta L. Dosa *In* AGARD How to Obtain Inform. in Different Fields of Sci. and Technol. May 1974 18 p refs (For availability see N74-27457 16-34)

Research, academin and popular trends in the environmental fields and characteristics of information users, resources and systems, are explored. The multidisciplinary nature of environmental information is analyzed. The following operational definition is used: Ecology provides an inclusive and consistent structure for perceiving the world and accounts for the behavior of man within the world structure. Systems yielding environmental information are categorized as problem centered or discipline oriented. Author

N74-32399# Advisory Group for Aerospace Research and Development, Paris (France).
A GUIDE TO THE LAYOUT OF TECHNICAL PUBLICATIONS
A. H. Holloway Jun 1974 22 p refs
(AGARD-AG-178; AGARDograph-178) Avail: NTIS HC $4.25

Recommendations are made for the size, shape, layout and content of technical publications. Notes are included to help those responsible for writing, reproducing and handling these documents. A select bibliography and some notes for cataloguers are included. Relevant standards are listed in an appendix with some further notes on bibliographic references. Author

N74-34424# Advisory Group for Aerospace Research and Development, Paris (France).
GLOSSARY OF DOCUMENTATION TERMS. PART 1: GENERAL TERMS
H. A. Stolk, ed. and A. H. Holloway, ed. Jul. 1974 37 p
(AGARD-AG-182-Pt-1; AGARDograph-182-Pt-1) Avail: NTIS HC $5.00

A glossary of scientific and technical terms, arranged in alphabetical order, is presented for use as a reference during documentation activities. A.A.D.

N75-12847# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD INDEX OF PUBLICATIONS, 1952 - 1970. PART 3: AUTHOR INDEX. PART 4: ADDENDUM TO PART 1
J. Foulon, comp. Sep. 1974 66 p
(AGARD-INDEX-52/70) Avail: NTIS HC $4.25

An alphabetical listing of all authors whose papers were documented in the previously published AGARD index of Publications 1952-1970 is presented and, in addition, an addendum containing a listing of the titles of all individual papers that were omitted from the basic document is included. For Vol. 1, see N73-20973; for Vol. 2, see N73-20974. Author

N75-17227# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD INDEX OF PUBLICATIONS, 1971 - 1973
Nov. 1974 420 p *refs*
Avail: NTIS HC $10.50

An index of publications prepared for the Advisory Group for Aerospace Research and Development (AGARD) during the period 1971 to 1973 is presented. The indexes are based on the NASA computerized data base and abstracts from the N 10,000 series (STAR) and X70,000 series of documents. The five indexes used are as follows: (1) personal author, (2) corporate source, (3) report number, (4) accession number, and (5) subject, based on the NASA Thesaurus nomenclature. The 34 NASA categories are used for document location. Author

N75-17228# Advisory Group for Aerospace Research and Development, Paris (France).
THE USE OF MICROFICHES FOR SCIENTIFIC AND TECHNICAL REPORTS. CONSIDERATIONS FOR THE SMALL USER
B. J. S. Williams and R. N. Broadhurst Oct. 1974 27 p refs
(AGARD-AG-198) Avail: NTIS HC $3.75

The report is intended primarily for the small user concerned with the use of microfiches for scientific and technical report material. The small user is considered to be the individual engineer or project worker or, at most, the small company, department or project team handling microfiches on a modest scale. While emphasis has been placed on the use of microfiches-their reading, duplication, print out and storage - some general information was included on the production of microfiches. The type of microfiche containing 60 or 98 frames used for the reproduction of individual reports is considered. These microfiches are also widely used for reproducing journals and periodicals on an issue-by-issue basis, for individual articles, monographs or papers and, less exclusively, for parts lists and maintenance manuals. Author

N75-23372# Advisory Group for Aerospace Research and Development, Paris (France).
NATIONAL AND INTERNATIONAL NETWORKS OF LIBRARIES, DOCUMENTATION AND INFORMATION CENTRES
Mar. 1975 82 p refs In ENGLISH; partly in FRENCH Presented at the Tech. Inform. Panel Specialists' Meeting, Brussels, 2-3 Oct. 1974
(AGARD-CP-158) Avail: NTIS HC $4.75

The interrogation and retrieval methodology, monodisciplinary and multidisciplinary, for designing multinational networks and library systems as a function of user requirements are summarized. Data are also given on hardware and software problems and future trends in the field. For individual titles, see N75-23373 through N75-23382.

N75-23373 Liege Univ. (Belgium).
PROBLEMS OF A BIBLIOGRAPHIC NETWORK AND DOCUMENTATION CENTER IN BELGIUM [LES PROBLEMES DE RESEAUX POUR BIBLIOTHEQUES ET CENTRES DE DOCUMENTATION EN BELGIQUE]
Pierre-andre Piron *In* AGARD Natl. and Intern. Networks of Libraries, Doc and Inform. Centres Mar. 1975 6 p refs In FRENCH; ENGLISH summary (For availability see N75-23372 14-82)

A Governmental committee on scientific policy has undertaken to promote the optimization of some library and documentation activities by networking. Three projects were outlined. Share cataloguing between scientific libraries (such as the Royal Library and Universities), union catalog of the same institutions, information retrieval from bibliographic data bases of international interest. Proposals were made for building up a wide network linking documentation centers throughout the country. Author

N75-23374 Statskontoret, Stockholm (Sweden)
A DATA NETWORK IN THE DOCUMENTATION AND LIBRARY AREA
Rolf Andren *In* AGARD Natl. and Intern. Networks of Libraries, Doc. and Inform. Centres Mar. 1975 5 p (For availability see N75-23372 14-82)

The Swedish Agency for Administrative Development, SAFAD, is developing an experimental network to be used by different education and research institutes to access information retrieval and library systems located at different places. The basic principle is that it shall be possible to communicate with several data bases through one network from one terminal. The network contains functions that make it possible to connect different kinds of terminals, e. g. teletype and various CRT terminals. The users are primarily the Swedish university libraries and the first data bases to be connected are the LIBRIS, the MEDLINE and the ESRO SDS data banks. Operation was started in spring 1974 but before a decision to build out the network is taken, an evaluation will be made of system performance before May 1975. Author

N75-23375 Defense Documentation Center, Alexandria, Va.
LINKING US/DOD AND OTHER SCIENTIFIC/TECHNICAL ON-LINE SYSTEMS
Hubert E. Sauter *In* AGARD Natl. and Intern. Networks of Libraries, Doc. and Inform. Centres Mar. 1975 13 p refs (For availability see N75-23372 14-82)

Several different types of networks will be examined as well as work experiences with them. The concepts and alternative methods for interlinking networks will be described, particularly the rationale for interfacing several networks in the future. An outline of expected benefits to the research community will be given, including suggested actions that might be initiated to develop cooperative networks. Author

N75-23376 Computer Aided Design Centre, Cambridge (England).
DATA BANKS AND NETWORKS FOR ENGINEERING DESIGN PURPOSES
G. C. Freeman *In* AGARD Natl. and Intern. Networks of Libraries, Doc. and Inform. Centres Mar. 1975 6 p refs (For availability see N75-23372 14-82)

Special problems of CAD are discussed and data indicate that because of the hierarchical nature of integrated design systems the local data base will also be hierarchical in structure. Communications with other systems via a computer network make it desirable that application programs and data bases should not be inextricably linked. Such a policy would ensure maximum flexibility, making possible economies of scale through the sharing of expertise and software that could then take place. Author

N75-23377 British Library, London (England). Research and Development Dept.
AN APPROACH TO THE DEVELOPMENT OF LIBRARY AND INFORMATION NETWORKS WITH SPECIAL REFERENCE TO THE UK
P. L. Holmes *In* AGARD Natl. and Intern. Network of Libraries, Doc. and Inform. Centres Mar. 1975 7 p refs (For availability see N75-23372 14-82)

The need for careful preparation and planning of library and information networks is discussed, and the British Library research program explained. Three parallel phases, concerned with assessment of existing on-line bibliographic information services, provision of data for planning of a library and information network in the UK, and examination of computing, telecommunication, and reprographic techniques for their applications to information-handling, are covered. Author

N75-23378 European Space Research Organization, Frascati (Italy). Space Documentation Service.
ON-LINE NETWORKING BETWEEN INFORMATION CENTRES IN EUROPE
D. M. Audsley *In* AGARD Natl. and Intern. Networks of Libraries, Doc. and Inform. Centres Mar. 1975 12 p refs (For availability see N75-23372 14-82)

Future trends in on-line networking for information retrieval purposes and the possibilities of collaboration between networks in Europe are examined. The technical aspects of major on-line networks are mentioned. The development of a special purpose distributed European-wide information network is postulated. The need for extremely close and detailed levels of European coordination during the development and implementation of such a network is anticipated. The possible uses of communications satellites, in particular ESRO projects, are mentioned. Author

N75-23379 Commission of the European Communities, Luxembourg.
INTERNATIONAL NETWORKING: INFORMATION RETRIEVAL REQUIREMENTS
P. L. VanVelze and G. W. P. Davies *In* AGARD Natl. and Intern. Networks of Libraries, Doc. and Inform. Centres Mar. 1975 7 p (For availability see N75-23372 14-82)

A network for scientific and technical information is being developed for the European Community. The authors represent the Commission of the European Communities, which was charged with the task of coordinating the activities of Member Countries to work towards this common network. The main topics discussed are: the goals of the planned network, the project organization, the role of the telecommunications facilities and the factors which are influencing the design of the network. Author

N75-23380 Cegos-Tymshare, Saint Cloud (France).
THE TYMNET NETWORK [LE RESEAU TYMNET]
Michel Raclet *In* AGARD Natl. and Intern. Networks of Libraries, Doc. and Inform. Centres Mar. 1975 4 p refs In FRENCH (For availability see N75-23372 14-82)

A description is given of TYMNET, a time sharing telecommunication network utilized by small data processing centers. Data cover transmission, connection, and surveillance procedures. Network hardware and software are discussed along with advantages to small processing centers using the system.
Transl. by E.H.W.

N75-23381 Association of Special Libraries and Information Bureaux, London (England). Research and Development Dept.
USER REQUIREMENTS IN LIBRARIES, DOCUMENTATION AND INFORMATION CENTERS
Margaret Slater *In* AGARD Natl. and Intern. Networks of Libraries, Doc. and Inform. Centres Mar. 1975 4 p (For availability see N75-23372 14-82)

Surveys of user populations by questionnaire or interview are used with increasing frequency in an attempt to establish user requirements in libraries, documentation and information centres. Although the survey is a flexible and useful technique it does have intrinsic limitations, which do not seem to be fully recognized by all concerned in instigating, executing or interpreting user research in the defined field. A negative defense of the survey method is given. Data outline what the survey can not fairly be expected to accomplish, and indicate areas in which the proper sphere of application would seem to lie. Author

N75-23382 National Center for Scientific and Technical Documentation, Brussels (Belgium).
USER REQUIREMENTS: AUTOMATED SERVICES
Guy M. Vansutryve *In* AGARD Natl. and Intern. Networks of Libraries, Doc. and Inform. Centres Mar. 1975 6 p refs (For availability see N75-23372 14-82)

General user requirements and their effects on the design of automated services in information networks are examined. Data are given on quality control, system interaction, system management and system effectiveness. Author

N77-10945# National Micrographics Association, Silver Spring, Md.
REVIEW OF DEVELOPMENTS IN COMPUTER OUTPUT MICROFILM (COM) AND MICROGRAPHIC TECHNOLOGY, PRESENT AND FUTURE
Sep. 1976 57 p refs Presented at AGARD Lecture Series, Oslo, 25-26 Oct. 1976; Paris, 28-29 Oct. 1976; London, 1-2 Nov. 1976 (AGARD-LS-85; ISBN-92-835-1225-1) Avail: NTIS HC A04/MF A01

An up-to-date review is given of micrographic technology, computer input microfilm (CIM) and computer output microfilm (COM), as well as an indication of the market size and growth rate. After an account of the fundamentals of micrographics, COM recording techniques and recorders are described and CIM techniques reviewed. Other topics cover indexing and retrieval techniques, systems design, alphanumeric and graphic applications. Future trends in micrographic technology are indicated. For individual titles, see N77-10946 through N77-10953.

N77-10946# National Micrographics Association, Silver Spring, Md.
MICROGRAPHICS AND COM: A STATE-OF-THE-ART AND MARKET REPORT
Don M. Avedon *In* AGARD Rev. of Develop. in Computer Output Microfilm (COM) and Micrographic Technol., Present and Future Sep. 1976 6 p (For primary document see N77-10945 01-82)
Avail: NTIS HC A04/MF A01

An overview of micrographics, computer input microfilm and computer output microfilm at jet speed is given. The scope, the boundaries and the use of micrographics are discussed. Author

N77-10947# Baker (G. G.) and Associates, Surrey (England).
MICROGRAPHIC FUNDAMENTALS
G. G. Baker *In* AGARD Rev. of Develop. in Computer Output Microfilm (COM) and Micrographic Technol., Present and Future Sep. 1976 10 p (For primary document see N77-10945 01-82)
Avail: NTIS HC A04/MF A01

A general introduction to the technology of micrographics is given and the microforms in use in Europe, the equipment available and the concepts of recording, film processing and readout are described. Some of the common indexing methods are discussed and illustrated. Details and illustrations are also provided for film cartridges and cassettes, film duplicating equipment, jacketing equipment, fiche production equipment, automated fiche systems, aperture card equipment and microfilm cameras. Methods of computer output microfilm (COM) recording are described and two popular fiche formats used for COM operations are illustrated. Author

N77-10948# Micard Corp., Kingston, N. H.
COM RECORDING TECHNIQUES AND RECORDERS
George H. Harmon *In* AGARD Rev. of Develop. in Computer Output Microfilm (COM) and Micrographic Technol., Present and Future Sep. 1976 6 p (For primary document see N77-10945 01-82)
Avail: NTIS HC A04/MF A01

Various techniques for the conversion of data, techniques for character and vector generation, and the means for implementing the concepts in computer output microfilm recorders are described. Also included is a discussion of the various Computer Output Microfilmers available today. Mention is also made of the concepts of Computer Input from Microfilm. Author

N77-10949# Microfilm Sciences Corp., New York
INDEXING AND RETRIEVAL TECHNIQUES
Franklin I. Bolnick *In* AGARD Rev. of Develop. in Computer Output Microfilm (COM) and Micrographic Technol., Present and Future Sep. 1976 6 p (For primary document see N77-10945 01-82)
Avail: NTIS HC A04/MF A01

A review of the state-of-the-art in available storage and retrieval methods and techniques used with micrographic systems is given. Roll film, fiche and aperture card systems with their manual, semi-automatic and fully automatic retrieval equipment are evaluated, analyzed and compared. The relationship of updatable microfilm to storage and retrieval systems are explained and evaluated. Author

N77-10950# Central Computer Agency, London (England)
THE SYSTEMS APPROACH TO COMPUTER OUTPUT MICROFILM
Bernard Terry *In* AGARD Rev. of Develop. in Computer Output Microfilm (COM) and Micrographic Technol., Present and Future Sep. 1976 5 p (For primary document see N77-10945 01-82)
Avail: NTIS HC A04/MF A01

The use of COM was primarily based on the need to escape from the avalanche of paper emanating from computer systems and to minimize the escalating costs of printing, duplication and distribution. The scope for the systems analyst to apply his experience to the tasks to be 'dumped' to microform was inhibited

by the need to accept existing page layouts in order to effect the transfer from paper with the minimum of time and effort to maximize savings. However even within these limitations there are design options open to the analyst, and these are identified and explored with a view to optimizing benefits and cost savings. The range of COM techniques and hardware features, together with the systems implications, are described. The potential for developing novel output systems utilizing the particular advantages of COM is discussed. Author

N77-10961# Zytron Corp., Menlo Park, Calif
APPLICATIONS: ALPHANUMERIC
Truett E. Airhart *In* AGARD Rev. of Develop. in Computer Output Microfilm (COM) and Micrographic Technol., Present and Future Sep. 1976 7 p (For primary document see N77-10945 01-82)
Avail: NTIS HC A04/MF A01

Alphanumeric applications of computer technology are discussed and the technological advances assessed. L.S

N77-10962# Micord Corp., Kingston, N. H.
COM APPLICATIONS: GRAPHIC
George H. Harmon *In* AGARD Rev. of Develop. in Computer Output Microfilm (COM) and Micrographic Technol., Present and Future Sep. 1976 2 p (For primary document see N77-10945 01-82)
Avail: NTIS HC A04/MF A01

With the advanced design of Computer Output Microfilm recorders the possible applications for use are almost limitless. Nearly any symbol, or character can be created. Application areas discussed range through business, finance, engineering, graphic arts, printing, publishing, education, and scientific research. The types of recordings described range from charts and graphs of financial records, engineering drawings, chemical reports, and satellite recordings, to color charts, printed circuit masters and animated movies. Author

N77-10963# National Micrographics Association, Silver Spring, Md.
BIBLIOGRAPHY OF MICROGRAPHICS
In AGARD Rev. of Develop. in Computer Output Microfilm (COM) and Micrographic Technol., Present and Future Sep. 1976 8 p refs (For primary document see N77-10945 01-82)
Avail: NTIS HC A04/MF A01

A selection of publications, from 1966 to 1975, covering many aspects of micrographics is given. The items are listed chronologically, using the same numbering system as NMA's Micrographics Index, with the first two digits representing the year of publication. Entries have the same accession number in the Bibliography and in the Micrographics Index. Entries are indexed according to subject again using the same system as the Micrographics Index. Additional information on the content is provided in the brief annotation which is a part of each entry. The bibliography does not include journal articles. These, together with additional books, pamphlets and reports, can be found in the Micrographics Index and its Supplement. The Micrographics Index is designed to provide a cumulative and comprehensive information base, with supplements or updates appearing each year Author

N77-11907# Advisory Group for Aerospace Research and Development, Paris (France).
OCR AND ITS APPLICATION TO DOCUMENTATION: A STATE OF THE ART REVIEW
Donald A. Bush (RADC, New York) and J. A. Weaver (Mullard Res. Labs., Surrey, Engl.) Mar. 1976 37 p
(AGARD-AG-216; ISBN-92-835-1211-1) Avail: NTIS HC A03/MF A01

The problems of producing scientific and technical documentation are surveyed in terms of application of Optical Character Recognition (OCR) techniques. The function and method of operation of OCR machines are described in outline, and the limitations are discussed. Recommendations are given for improving documentation production, and areas for further research are suggested. Author

N77-16908# Advisory Group for Aerospace Research and Development, Paris (France).
METHODOLOGY OF LARGE DYNAMIC FILES
A. K. Gillis (Harris Corp., Melbourne, Fla.) Dec. 1976 24 p
(AGARD-R-649; ISBN-92-835-1233-3) Avail: NTIS HC A02/MF A01

Data collection, conversion, storage, and retrieval trends were examined. Entity formatting and element transformation were discussed as well as digital storage alternatives and storage hierarchy. Data base management, management systems software, and implementation considerations concerning data retrieval were investigated. S.M.

N77-16930# Advisory Group for Aerospace Research and Development, Paris (France)
ADVANCEMENTS IN RETRIEVAL TECHNOLOGY AS RELATED TO INFORMATION SYSTEMS
Dec. 1976 154 p refs In ENGLISH; partly in FRENCH Proceedings of Tech. Inform. Panel Specialists Meeting, Arlington, Va., 20-21 Oct. 1976
(AGARD-CP-207; ISBN-92-835-0183-7) Avail: NTIS HC A08/MF A01

Present and future applications of computer technology to information management are explored. For individual titles, see N77-16931 through N77-16946.

N77-16931# Imperial Coll. of Science and Technology, London (England). Dept. of Computing and Control.
THE ROLE OF THE MINICOMPUTER IN THE INFORMATION RETRIEVAL BUSINESS
B. K. Penney *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 8 p refs (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

The difference in characteristics between minicomputers and mainframes are discussed. Various aspects of the use of computers in information retrieval are examined to determine the areas which may be better or more profitably served by minicomputers than by the more usual mainframe system. Author

N77-16932# Defence Research Information Centre, Orpington (England).
THE USE OF A MINI-COMPUTER AT THE DEFENCE RESEARCH INFORMATION CENTRE (DRIC)
George W. Hart *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 13 p refs (For primary
Avail: NTIS HC A08/MF A01

The functions of the Defense Research Information Center (DRIC) are outlined. A minicomputer is used to prepare the 'Abstracts Bulletin' and its indexes, and to provide data on the exchange of reports with foreign countries. Future possible applications for the computer are described. These include a register of the interests of DRIC's customers, a loans control system particularly for classified reports, thesaurus look up to help the scientific staff, and information retrieval (both SDI and retrospective). A brief summary of other uses of computers in the UK Ministry of Defense information and library services is included. Author

N77-16933# Stadt- und Universitaetsbibliothek, Frankfurt am Main (West Germany).
MINICOMPUTERS IN LIBRARY CIRCULATION AND CONTROL
Klaus-Dieter Lehmann *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 5 p refs (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

The growing need for information services poses increasing problems for libraries and documentation centers. Data processing techniques provide several possibilities for improvement, among the most recent techniques are the use of minicomputers. A description of the mode of operation in library loan posting is given, as well as a discussion of the extent and structure of data, linkage possibilities, and special operational features. For these specialized applications a short survey of the hardware configuration and software of minicomputers is also presented. Comparison is made between a stand alone system and a minicomputer connected to a background computer. This study is based on actual projects existing in the Federal Republic of Germany. Author

N77-16934# Zentralstelle fuer Maschinelle Dokumentation (ZMD), Frankfurt (West Germany).
THE MINICOMPUTER'S ROLE IN DATA RECORDING FOR INFORMATION RETRIEVAL PURPOSES AND PRINTED INFORMATION
Horst Zuchel *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 4 p refs (For primary document see N77-16930 07-82)

Avail: NTIS HC A08/MF A01

Possibilities to reduce the mental part in data recording in order to achieve more efficiency are explored. The present state of minicomputer development offers suitable facilities for improving data recording for information retrieval purposes and for printed information. The hardware configuration, the developed program packages and also the experience gained are described. Author

N77-16936# National Physical Lab., Teddington (England).
INTERNATIONAL DATA COMMUNICATIONS: PROSPECTS AND PROBLEMS
D. L. A. Barber *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 8 p refs (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

The evolution of international data communications is reviewed. Future possibilities for development are discussed along with some reference to the European Informatics, and the Euronet Project. A discussion of problems at the user level is included. Author

N77-16936# European Space Agency, Frascati (Italy). Space Documentation Service.
MAXIMISING THE USE OF AN INFORMATION SERVICE IN AN INTERNATIONAL ENVIRONMENT
W. A. Martin *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 18 p refs (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

The development of the European Space Agency Space Documentation Service (SDS) from 1964 to date is briefly reviewed. SDS database policy, which must satisfy the needs of both the agency and its member countries, is explained and utilization trends for all major databases examined. Based on a target of self-support since 1971, the evolution of SDS charging policy and the integration of the recently introduced RTC (remote terminal concentrator) are described. The derivation of database related costs, their potential for reduction, and the useful price reductions which would result from a significant increase in overall system load factor are outlined. The consequences and implications of working in an international environment are reviewed, and the particular problems of data communications in Europe are emphasized. The exponential growth in demand for information services as indicated by recent projections is noted, highlighting the need to improve and simplify current types of service; ongoing experimental work at SDS on an integrated information base is briefly mentioned including some thoughts on the multi-lingual requirement. Author

N77-16937# Paris V Univ. (France).
A HUMAN BIOMETRY DATA BANK
A. M. Coblentz *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 14 p In ENGLISH and FRENCH (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

The collection and use of individual anthropometric measurements gathered over several decades on a large number of world populations is reported. Data recording and reduction methods are described. Use of the data bank in equipment design is discussed. Author

N77-16938# Massachusetts Inst. of Tech., Cambridge.
THE VIRTUAL-SYSTEM CONCEPT OF NETWORKING BIBLIOGRAPHIC INFORMATION SYSTEMS
J. Francis Reintjes *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 7 p ref (For primary document see N77-16930 07-82)
(Grants NSF SIS-74-18165; NSF SIS-75-22946)
Avail: NTIS HC A08/MF A01

From a retrieval effectiveness viewpoint, it is highly desirable to allow the seeker of information to engage the information system himself rather than to have him work through another person. Because of the heterogeneity that presently exists among data bases and systems that contain them; however, placing the seeker directly online is impractical. A system is described which conveys the impression of standardization to the information seeker through use of a computerized interface translator interposed between end users and the systems they wish to access. The interface thus creates a uniform virtual system, and it is this single virtual system that the user engages. Author

N77-16939# National Bureau of Standards, Washington, D.C. Office of Standard Reference Data.
THE NATIONAL STANDARD REFERENCE DATA SYSTEM
Stephen A. Rossmassler *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 4 p refs (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

The National Standard Reference Data System is a coordinated, but decentralized effort to increase the reliability and availability of numerical data used in and produced by the physical sciences and engineering. Individual data projects on specific technical subjects are established to extract, evaluate, and compile, in a systematic manner, all relevant data from the scientific journal and technical report literature. The evaluation process compresses the original data, and the systematic treatment aids the user in filling his data needs. Sophisticated data-handling capabilities including on-line information and data retrieval are developed in individual data centers and also in a central data systems design group. Author

N77-16940*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
SYNTHESIS AND DISTRIBUTION OF ENVIRONMENTAL SATELLITE DATA
James I. Vette *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 11 p refs (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01 CSCL 05B

The activities of two National Oceanographic and Atmospheric Administration and two National Aeronautics and Space Administration facilities involved in the synthesis or distribution of space environmental data are reviewed. The data products, user services, and pertinent publications are given. The computer systems that support three of these facilities are discussed and some details of the synthesis procedures are given. Data from the following satellite series are included in the discussion: TIROS, NIMBUS, ESSA, NOAA, SMS/GOES, ATS, and SOLRAD. Orbital position data for HAWKEYE 1, IMP H and J, VELA 5B, PIONEERS 6-9, PIONEER 11, HELIOS 1 and 2, and SOLRAD 11A and 11B in several coordinate systems are discussed. Author

N77-16941# Oak Ridge National Lab., Tenn. Environmental Sciences Div.
DEVELOPMENT AND APPLICATIONS OF SPATIAL DATA RESOURCES IN ENERGY RELATED ASSESSMENT AND PLANNING
Richard J. Olson, F. Glenn Goff, and Jerry S. Olson *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 7 p refs (For primary document see N77-16930 07-82) (Publ-901) Avail: NTIS HC A08/MF A01

A spatial database for the Eastern United States at the county-subcounty unit level of resolution is described. The database contains information on terrain, water resources, climate, land use, forest resources, agriculture, wildlife resources, critical natural areas, human population and energy uses. A spatial hierarchy of metric, geodetic and geopolitical scales is defined as a framework to organizing the data. Building blocks that can be assembled or aggregated to satisfy analysis needs allow accessing more detailed spatial data by using pointers to information not stored in the database. Uses of the database are related to the capability to cross-reference and integrate information in various subject sectors, utilizing spatial units and temporal periods commensurate with regional themes. An investigation of potential changes in vegetation patterns related to predicted temperature changes from increased atmospheric CO2 is presented to illustrate an ongoing application of data resources. Other themes include coal extraction, landscape patterns, habitat and population dynamics of selected biological species, and energy facility siting. Author

N77-16942# National Bureau of Standards, Washington, D.C. Physical Chemistry Div.
EVALUATED NUMERICAL DATA FOR THE SST AND CHLOROFLUOROCARBON PROBLEMS: A CASE STUDY OF HOW TO HELP THE ENGINEER AND THE MODELLERS
David Garvin and Robert F. Hampson *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 6 p refs (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

Activities of the Chemical Kinetics Information Center in support of the Climatic Impact Assessment Program are reported. These include planning, identification of needed measurements and available measurements, determination of the needs of users, evaluation of data, interpretation of results for non specialists

and distribution of tables of rate data. This type of role is suitable for an information analysis center in any large scale interdisciplinary program. Author

N77-16943# Rome Air Development Center, Griffiss AFB, N.Y.
HOLOGRAPHIC DATA STORAGE AND RETRIEVAL SYSTEM
Fred N. Haritatos and Jack D. Petruzelli *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 17 p (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

A system is described for validating the concept of holographic data storage. The equipment comprises a microfiche recorder, a subsystem controller/computer (PDP 11/15), and a microfiche reader. Input devices include magnetic tape, document digitizer, and modem coupler. Output is in the form of a human readable machine readable (HRMR) microfiche, hard copy, magnetic tape, or digital signal to a host computer via a modem unit. System access and display is through the display terminal. Author

N77-16944# Mitre Corp., Bedford, Mass.
MULTIMODE NETTING BY WIDEBAND CABLE
Victor A. Demarines and George A. Fagan *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 9 p (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

Coaxial cable systems using multimedia bus technology are proposed to support transparent, efficient, expandable, and easily integrable networks needed to exploit new information system concepts. The most appropriate users of the cable system are in large buildings or spatially compact areas where there is need for a wide variety of communications services. Applications cited are military bases, government offices, hospitals, large insurance company headquarters, and highly automated manufacturing complexes. Author

N77-16945# Advisory Group for Aerospace Research and Development, Paris (France).
TERMINAL ACCESS TECHNOLOGY OF THE 1990S
Craig Fields *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 5 p (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

The needs of office workers in the 1990's are predicted. The application of computers to teleconferencing is illustrated in ten examples and shown to be cost effective. Research in applying the electroencephalogram as a communication channel between men and computers is discussed. Geographic data management systems are described for regaining the advantages of paper in document retrieval, source of text authentication, and communication about the sender. Intensive and accessible work environments are also discussed. Author

N77-16946# Informatics, Inc., Woodland Hills, Calif.
IMPLICATIONS OF FUTURE DEVELOPMENTS IN COMPUTING TECHNOLOGY
Frank V. Wagner *In* AGARD Advan. in Retrieval Technol. as Related to Inform. Systems Dec. 1976 12 p refs (For primary document see N77-16930 07-82)
Avail: NTIS HC A08/MF A01

A review is made of cost/performance trends in computing technology, including hardware elements and software development. The resulting impact on computer systems architecture is briefly covered. Particular emphasis is placed on the trend toward decentralization. The development of distributed computing and the use of modern dedicated small computers is examined and analyzed. An explanation is given for Grosch's Law, which has described the relationship of computing power and computer price. Recent developments may invalidate the conclusion based on Grosch's Law that any enterprise should get its data processing done on the largest possible computer that the enterprise can afford to acquire, or to which it can afford to buy access. Conclusions are drawn that a radical revolution in the use of computers has begun, and that in the future, a new principle of decentralized computing may replace Grosch's Law. Author

X77-72041 Advisory Group for Aerospace Research and Development, Paris (France).
A SURVEY OF MECHANIZATION AND DOCUMENTATION ACTIVITIES IN AGARD NATIONAL DISTRIBUTION CENTERS
R. H. Howe Feb. 1976 64 p
(AGARD-R-77) Avail: Advisory Group for Aerospace Research and Development, Paris, France NATO– Classified report

NOTICE: Available to U.S. Government Agencies.

Extent of mechanization of documentation activities was investigated by means of a questionnaire sent to 23 AGARD National Distribution Centers and closely linked centers. Seventeen organizations returned completed questionnaires, and of these, eight had mainly manually operated systems and the remainder mechanized, or partially mechanized, systems. Data on type of input, subject coverage, and method of indexing were compared for all organizations replying. For organizations with mechanized or partially mechanized systems, data were given on hardware configurations, software, applications, network operation, and use of commercial documentation data processing services and data bases. Author

83 ECONOMICS AND COST ANALYSIS

Includes cost effectiveness studies.

N76-19073# Advisory Group for Aerospace Research and Development, Paris (France).

A GUIDE TO REPROGRAPHIC PROCESSES FOR THE SMALL USER

T. Hampshire (Natl. Reprographic Centre for Doc.) Jan. 1975 40 p

(AGARD-AG-199; AGARDograph-199) Avail: NTIS HC $3.75

Detailed information is given on the various reprographic processes and systems available. The information is divided into the three main areas of reprography: photocopying, duplicating and printing, and micrographics. The method of operation of the processes is provided and the various characteristics and application suitability are given for each process. Equipment illustrations are presented to show type rather than specific company's product. A list of major international manufacturers of equipment is included as a guide from where specific information can be obtained. Author

85 URBAN TECHNOLOGY AND TRANSPORTATION

Includes applications of space technology to urban problems; technology transfer; technology assessment; and surface and mass transportation. For related information see *03 Air Transportation and Safety, 16 Space Transportation,* and *44 Energy Production and Conversion.*

N76-25098# Advisory Group for Aerospace Research and Development, Paris (France).
THE PROBLEM OF OPTIMIZATION OF USER BENEFIT IN SCIENTIFIC AND TECHNOLOGICAL INFORMATION TRANSFER
Mar. 1976 116 p refs Presented at Tech. Inform. Panel Specialists' Meeting, Copenhagen, 6-9 Oct. 1975
(AGARD-CP-179; ISBN-92-835-1213-8) Avail: NTIS HC $5.50

The user/information service interface is examined and user problems are defined particularly for aerospace, scientific, and technical information. Topics discussed include: role of communication and direct personal communication in the transfer of technology; influence of information flow on the organization of an industry or research and development institution; information utilization in government and industry research institutions; and user requirements in the various fields. For individual titles, see N76-25099 through N76-25114.

N76-25099 Association of Special Libraries and Information Bureaux, London (England).
THE ROLE OF COMMUNICATION IN TECHNOLOGICAL INNOVATION
John Martyn *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 3 p refs (For availability see N76-25098 15-85)

Communication is described as a two-way process, involving the active participation of both the originator and recipient of a communication. Results of various studies are reviewed indicating that good communications, internal and external, characterize organizations which are successful technological innovators. It is concluded that responsibility for the establishment of good formal (information services) and informal (person to person) communication and information flow rests with management. Author

N76-25100 Massachusetts Inst. of Tech., Cambridge. Sloan School of Management.
THE IMPORTANCE OF DIRECT PERSONAL COMMUNICATION IN THE TRANSFER OF TECHNOLOGY
Thomas J. Allen *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 10 p refs (For availability see N76-25098 15-85)

Technical communication in industrial firms is discussed. Heavy reliance upon face-to-face communication to transfer technology in industry, and interpersonal contacts among scientists, both domestic and foreign, to foster national and international transfer of technology are emphasized. Effective management of information flow for technology acquisition and dissemination is considered. J.M.S.

N76-25101 National Research Council of Canada, Ottawa (Ontario). Technical Information Service.
TECHNOLOGICAL UP-DATING FOR THE MANUFACTURING INDUSTRY
Gerard Kirouac *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar 1976 3 p refs (For availability see N76-25098 15-85)

Information services designed to keep the manufacturing industry technologically up-dated are described. Author

N76-25102 Nord-Video, Stockholm (Sweden).
ALTERNATIVE MEDIA FOR INFORMATION TRANSFER
Bengt-Arne Vedin *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 5 p (For availability see N76-25098 15-85)

Different factors affect the medium to be chosen for the transmission of a message: receiver needs, message contents, channels available, costs, necessity of retrieval, etc. A method for comparing different media is outlined, and the impact or efficiency of different appeals to our senses are reviewed. The analysis is also applied to new media just being introduced. Author

N76-25103 Connecticut Univ., Storrs. New England Research Application Center.
MAXIMIZING USER BENEFIT FROM A TECHNICAL INFORMATION CENTER
Daniel U. Wilde *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 3 p (For availability see N76-25098 15-85)

Dissemination of the results of NASA research to business and industry, colleges and universities, and state and local governments is discussed. The New England Research Application Center's operating procedures and efforts to increase user benefits and thus ensure successful technology transfer are reviewed. J.M.S.

N76-25104 Dansk Teknisk Oplysningstjeneste, Copenhagen.
THE INFLUENCE OF INFORMATION FLOW ON THE ORGANIZATION OF AN ENTERPRISE
Kjeld Klintoe *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 9 p refs (For availability see N76-25098 15-85)

The concept of an enterprise, the role of information, and how the information flow could be organized to make an impact on the performance and result of the operations of an enterprise are discussed. Author

N76-25105 United Nations Educational, Scientific and Cultural Organization, Paris (France). International Social Science Council.
ON THE USE OF QUANTITATIVE DATA IN INFORMATION SCIENCE
Eric DeGrolier *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 9 p refs (For availability see N76-25098 15-85)

The development of information science is briefly considered. Emphasis is placed on the pitfalls encountered in constructing an information system, and suggestions are presented for future research. J.M.S.

N76-25106 Studiengruppe fuer Systemforschung, Heidelburg (West Germany).
THE CHARACTERISTICS REQUIRED TO MAKE A GOOD INFORMATION SPECIALIST
Werner Kunz *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 4 p refs (For availability see N76-25098 15-85)

From the current situation and the nature of problems in the information sciences, the different kinds of information scientists demanded are described. A number of tasks that may be performed by information scientists are listed. Topics to be taught are identified, and proposals are made for organizing the educational course structure for information scientists. Author

N76-25107 Danish Atomic Energy Commission, Risoe.
INFORMATION UTILIZATION IN GOVERNMENT RESEARCH INSTITUTIONS: AN ATTEMPT AT A USER-ORIENTED APPROACH
Eva Pedersen *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 3 p refs (For availability see N76-25098 15-85)

The importance of close cooperation between the research worker and the research library is examined. The requirements to the library from a user point of view are discussed. Direct access for scientists to on-line data bases is stressed, but the human element is advocated as being more important than computerized services. Author

N76-25108 Victoria State Coll., Hawthorn (Australia).
USER RESPONSE TO THE SDI SERVICE DEVELOPED AT AERONAUTICAL RESEARCH LABORATORIES, AUSTRALIA
Margaret O. Sheppard *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar 1976 9 p refs (For availability see N76-25098 15-85)

A computer-based SDI system developed at the Aeronautical Research Laboratories, Australia, using an unsophisticated search logic, has been operating and developing for nearly five years interrogating ADSATIS and U.S. NTIS GRA magnetic tapes for over 130 research oriented users. An analysis was made of use statistics. The response to a recent questionnaire concerning information gathering habits of ARL research staff and the role of ARL SDI service within the overall pattern of information seeking is discussed in some detail. As a result, it is considered that an ARL type SDI system can be recommended when the

system is designed to serve scientific research staff in what may be regarded as a fairly typical research establishment. Once in operation, an ARL type SDI system can be elaborated for those who require a more sophisticated service, but experience at ARL suggests that the needs of the majority will be met by the simpler SDI service. Author

N76-25109* National Aeronautics and Space Administration, Washington, D.C.
LISTENING TO THE USER: A CASE STUDY
Harold E. Pryor *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 7 p (For availability see N76-25098 15-85)

The managers of the NASA Scientific and Technical Information System consistently maintain that whatever scientific and technical information services and products are provided must be geared primarily to user needs and not simply system compatibility and convenience. A system evaluation study begun in 1973 and continued to the present is described. The thrust of this on-going examination is to regularly evaluate the usefulness of the present information system to those it is intended to serve, engineers and scientists working in their professional roles, and to identify areas and ways in which the system can be made more responsive to user needs. Techniques used have covered the range from personal, in-depth interviews to widely distributed questionnaires. The findings have been positive. Many refinements made to on-going programs and projects and new endeavors begun in direct response to stated user needs are discussed. In the main these needs are not unreasonable and thus can be responded to with cost effective system modifications. Author

N76-25110 Department of Industry, London (England). Research Contractors Div.
INFORMATION REQUIREMENTS OF ENGINEERING DESIGNERS
J. R. Sutton *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 8 p refs (For availability see N76-25098 15-85)

The information requirements of engineering designers are examined in the light of several surveys. The information requirements of mechanical engineers differ from those of scientists and the information requirements of designers differ from those of other mechanical engineers. Some of the results of a survey of information requirements of engineering designers are reported. Designers prefer familiar and convenient sources of information. Author

N76-25111 Brown, Boveri und Cie, A.G., Mannheim (West Germany). Zentralstelle fuer Techniuche Dokumentation.
INDUSTRY DOCUMENTATION: A NECESSARY EVIL
Werner Diers *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 10 p refs (For availability see N76-25098 15-85)

Documentation of technical and scientific literature in industry in the Federal Republic of Germany is discussed in terms of user needs. The advantages of a centralized, computerized documentation center are reviewed. J.M.S.

N76-25112 Norwegian Center for Informatics, Oslo.
THE VOICE OF THE USER: HIS INFORMATION NEEDS AND REQUIREMENTS (WHICH ARE NOT WHAT THE INFORMATION SPECIALISTS THINK THEY ARE)
A. Disch *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 8 p refs (For availability see N76-25098 15-85)

Two user studies were carried out in Norway. In the first one 1,400 engineers were asked to list those information sources that they had used lately and which had proved to be of practical value in their daily work. The follow-up study was a detailed study of the information gathering habits of a limited number of users. It was found in both studies that the traditional information channels were of little value to the practical user. Two attempts to remedy these findings are described. Author

N76-25113 Georgetown Univ., Washington, D.C.
THE GATEKEEPER HYPOTHESIS AND THE INTERNATIONAL TRANSFER OF SCIENTIFIC KNOWLEDGE
Arnold J. Herzog *In* AGARD The Probl. of Optimization of User Benefit in Sci. and Technol. Inform. Transfer Mar. 1976 9 p refs (For availability see N76 25098 15-85)

The transfer of information across international boundaries is discussed. Interpersonal contacts, both domestic and foreign are considered the means of diffusing information from the industrial community and the scientific community. Economic factors are included. J.M.S.

N76-25114 Advisory Group for Aerospace Research and Development, Paris (France).
APPLYING THE USER/SYSTEM INTERFACE ANALYSIS RESULTS TO OPTIMIZE INFORMATION TRANSFER Summary of Panel Discussion
E. T. Sharp, ed. (Shape Technical Centre) *In its* The Probl. of Optimization of User Benefit in Sci. and Techol. Inform Transfer Mar. 1976 10 p (For availability see N76-25098 15-85)

A summary is provided of the highlights of the various papers presented. Topics covered include: the role of communication in technological innovation, the importance of direct communication, user requirements, and the market in which the information service should operate. A general discussion of issues is included. J.M.S.

99 GENERAL

N76-15595# Advisory Group for Aerospace Research and Development, Paris (France).
DIRECTOR'S ANNUAL REPORT TO THE NORTH ATLANTIC MILITARY COMMITTEE
1973 83 p refs
Avail: NTIS HC $4.75

The activities of AGARD are reviewed. The following panel programs are discussed: (1) aerospace medicine; (2) avionics; (3) electromagnetic wave propagation; (4) flight mechanics; (5) fluid dynamics; (6) guidance and control; (7) propulsion and energetics; (8) structures and materials; and (9) technical information. The meetings held, the publication produced, and consultant services rendered are presented. J.M.S.

N76-18155# Advisory Group for Aerospace Research and Development, Paris (France).
DICTIONARY OF FRENCH TERMS USED IN DOCUMENTATION [DICTIONNAIRE DE TERMES FRANCAIS UTILISES EN DOCUMENTATION]
J. D. Klopp 1974 94 p In FRENCH
(AGARD-AG-180; AGARDograph-180) Avail: NTIS HC $4.75

A dictionary, covering scientific terms used to document information, is presented. Approximately 1,440 items are listed. Transl. by E.H.W.

N76-18157# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD BULLETIN: MEETING, PUBLICATIONS, MEMBERSHIP
Jan. 1976 73 p
(AGARD-Bull-75-1) Avail: NTIS HC $4.25

The Advisory Group for Aerospace Research and Development (AGARD) bulletin containing information on all planned 1975 meetings is presented. The information includes dates, locations, and descriptions of the themes. A list of all AGARD publications which were released in 1974 and abstracts of the reports is provided. The membership of the various AGARD committees is reported in a document which identified the name of each representative and the country represented. Author

N76-18037# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD BULLETIN; MEETINGS, PUBLICATIONS, AND MEMBERSHIP
Jan. 1976 73 p refs
(AGARD-Bull-76-1) Avail: NTIS HC $4.50

Information on the following was presented: (1) all AGARD meetings planned for 1976, including dates, locations, and brief descriptions of their themes, (2) list of all AGARD publications released in 1975, together with their abstracts, (3) AGARD membership lists as of 1 January 1976. Author

N76-18038# Advisory Group for Aerospace Research and Development, Paris (France).
AGARD BULLETIN. TECHNICAL PROGRAM 1976
Jun. 1975 38 p refs
(AD-A010370; AGARD-Bull-75-2) Avail: NTIS HC $4.00 CSCL 05/2

A chronological listing of meetings scheduled for 1976 is presented. Detailed descriptions of AGARD programs and publications are included; these include panels on aerospace medicine, avionics, electromagnetic wave propagation, flight mechanics, fluid dynamics, guidance and control, propulsion and energetics, structures and materials, and technical information. M.J.S.

N76-19048# Advisory Group for Aerospace Research and Development, Paris (France).
DIRECTOR'S ANNUAL REPORT TO THE NORTH ATLANTIC MILITARY COMMITTEE, 1974
Mar. 1975 80 p refs
Avail: NTIS HC $5.00

A summary of the scientific and technical achievements accomplished during 1974 by AGARD was presented. The following information was given: (1) meetings held, (2) publications produced and consultant services rendered, (3) detailed description of the various individual programs, (4) personnel listing, and (5) budget summary. Author

X76-70672 Advisory Group for Aeronautical Research and Development, Paris (France).
DETECTION AND LOCATION OF SHELTERED AND DISPERSED AIRCRAFT. VOLUME 1: EXECUTIVE SUMMARY. VOLUME 2: APPENDIXES
C. W. Cooper [Jul. 1973] 1 p
(AGARD-AR-59) NATO-Classified report

NOTICE: Available to U.S. Government Agencies and Their Contractors.

The nature of sheltered and dispersed aircraft and their environment is examined. Military requirements for reconnaissance, attack, and damage assessment are reviewed. The test provided a survey of information on a wide range of well established and new sensing techniques. Technique capabilities were considered over a full range of lighting and weather conditions. Combination possibilities of sensors and information retrieval problems in real time were explored. Author

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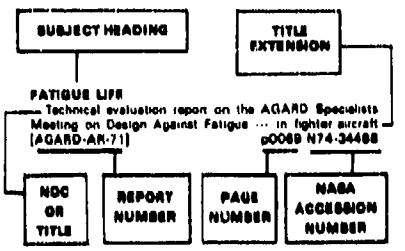

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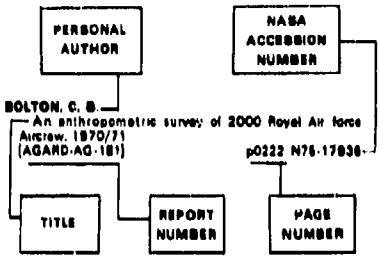

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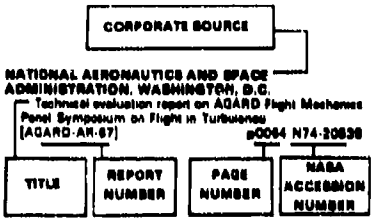

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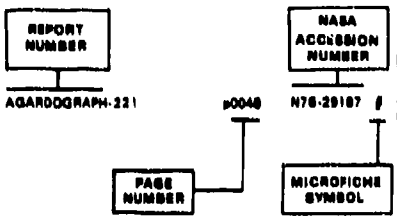

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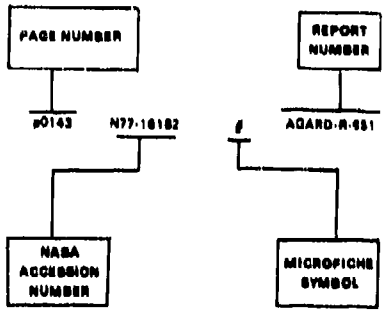

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