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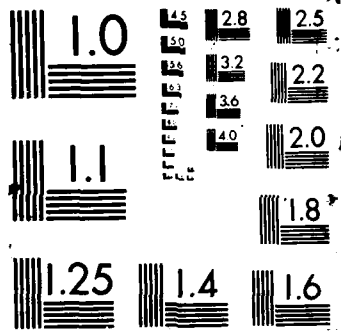
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# A SUMMARY OF THE NAVAL POSTGRADUATE SCHOOL RESEARCH PROGRAM

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## REPORT FOR THE PERIOD OCT 1985 TO SEPT 1986

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## INTRODUCTION

Research activities at the Naval Postgraduate School during the fiscal year 1986 are summarized in this volume. The projects summarized here are primarily sponsored faculty research projects. In many cases the faculty efforts are supplemented by student contributions as they work on thesis projects in pursuit of an advanced degree. A separate volume contains a compilation of abstracts of theses.

The importance of research at the Naval Postgraduate School is recognized in the mission statement:

"..... to encourage a program of research in order to sustain academic excellence."

Research at a graduate institution such as NPS provides intellectual stimulation to faculty, enhances the instructional activities, and contributes directly to the solution of real Navy and other DoD problems. Augmenting research projects with student efforts exposes them to areas of current concern.

The Naval Postgraduate School provides a unique interface between academic institutions and the U.S. Navy. The research projects undertaken are, in general, clearly related to Navy and DoD interests. A substantially larger fraction of the R&D effort at NPS is in the exploratory development category than would be found in most universities. This is a result of student and faculty interests and an institutional requirement to educate officers in areas of direct relevance to the Navy and to support the institutional programs with relevant research.

The Naval Postgraduate School wishes to acknowledge the efforts of Ms. Rachelle Parks of the Research Administration Office for her efforts in the production of this book.

Additional information about research activities at NPS can be obtained from the Director of Research Administration, Code 012, Naval Postgraduate School, Monterey, CA 93943.

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## TABLE OF CONTENTS

### DEPARTMENT OF COMPUTER SCIENCE

Departmental Summary .....	3
A Computer Aided Software Engineering Approach to Software Development for Embedded Systems .....	5
Design Requirements and Definitions for VHSTC Technology .....	6
Investigation of the Relation between the Asymptotic Complexity of a Function and its Asymptotic Complexity on a Subsequence .....	7
Reusability and Portability through Resource Abstraction .....	8
Database System in the Support of Software Engineering Environments .....	10
Emulation of a Multi-Microcomputer Architecture for the SPY-1A Control Computer .....	13
Systems Simulation/Emulation on a Multiple Transputer System .....	15
Combining Object-Oriented and Functional Programming .....	16
Synthesis of an Information Processing Support System for Advanced Applications .....	18
A Feasibility Study for Software Portability and Graphics Capability Enhancements for a Command and Control Workstation .....	21
The Use of VLSI Technology for the Real-Time Generation of Graphics Displays .....	23

### DEPARTMENT OF MATHEMATICS

Departmental Summary .....	29
Mathematical Models for Pattern Formation in Growing Animal Tissues .....	31
Investigation of a Major Result in Operator Theory .....	33
Interpolation of Scattered Meteorological Data .....	34
Despreading Codes .....	35
SDI System Architecture Studies .....	36
Statistical Analyses of Security-Related Data on Armed Services Personnel .....	37

A Variable-Resolution Finite-Element Method for the Shallow-Water Barotropic Model .....	38
An Algorithm for Noisy Function Minimization for Use in Optimal Trajectory Design .....	39
How Good are the Proximal Point Algorithms? .....	41

DEPARTMENT OF ADMINISTRATIVE SCIENCES

Departmental Summary .....	45
An Analysis of Methods for Creating Comparable Databases for Nonrecurring Cost Analysis under Dual Source Competition .....	49
The Effects of Distributed Group Decision Support Systems on Group Problem Solving: An Experimental Investigation .....	50
A Model Management System for Software Engineering .....	52
Evaluation of Minority Recruitment .....	53
Study of Youth Labor Force Behavior: Population Quality and the OMA .....	55
Barriers to Capital Investment .....	57
Depot Maintenance Cost and Production Accounting and Reporting .....	58
An Analysis of the International Energy Agency's Oil-Sharing Agreement .....	61
Estimating the Costs of Alternatives to the Current Military Retirement System .....	62
Pay Comparability: A Case Study of U.S. Navy vs. Civilian Pilots .....	63
Models and Experiments to Investigate Decision Making Performance in Command and Control .....	64
An Analysis of Reasons Defense Contractors Refuse Government Business .....	65
Analytic Capability in Support of the National Communications System .....	66
Task Definition, Decision Criteria and Uncertainty Reduction: The Role of the PPB System .....	67
Army Unit Capability Study .....	69
Army Reserve Market Study .....	70
Optimal Design, Procurement and Support of Multiple Repairable Equipment and Logistic Systems .....	71



Factors Affecting Firms' Choices and Uses of Accounting Methods .....	73
Financial Analyst Earnings Forecasts and Prediction of Corporate Failure .....	74
Predicting Government Contractor Financial Failure .....	75
Collective Power .....	76
Research on Cash Management Program within the Department of the Navy .....	79
Distributed System Software Design Paradigm .....	80
Proposed Technology and Procurement Policy for SNAP 111 .....	81
Software Quality Metrics .....	82
Integrating Expert and Statistical Systems .....	83
Does Seniority Pay? Experience, Performance Ratings and Salary .....	84
Promotions, Pay, Performance Ratings and Probability of Voluntary Separations .....	85
Experimental Functional Skills Project: Mathematics .....	86
The Effect of High-Impact Writing on the Reader's Image of the Writer .....	87
Army Reserve Attrition Study .....	88
Army Reserve Market Study Plan .....	89
Fairness in Testing: Technical and Judgemental Approaches .....	91
The Rasch Model Plus Guessing .....	92

#### DEPARTMENT OF OPERATIONS RESEARCH

Departmental Summary .....	95
Fleet Mission Program Library Algorithm Validation .....	99
Simulation Model Development for Anti-Air Warfare .....	100
Tactical Information Management System Evaluation .....	101
Target Acquisition Analysis .....	102
Large-Scale Optimization .....	103
Large-Scale, Real-Time Network Optimization .....	105

ASW Modelling .....	106
Modelling and Wargame Development .....	107
Modeling of Interferences during Torpedo Salvo Launches .....	108
Statistical Analysis of Multivariate Observations .....	109
Stochastic Modelling and Data Analysis .....	110
Statistical Support Services for the Joint Oil Analysis Program .....	112
Stochastic Modelling, Time Series Analysis and Simulation .....	113
Marine Corps Manpower Research Project .....	115
Airland Research Model (ALARM) .....	117
Test, Analyze and Evaluate the Usefulness of Current Speech Recognition Technology in a Command and Control Work Station Environment .....	119
Attrition Rate Generation for Manpower Models ...	120
Resystemization Modelling Support .....	121
MOE Development for Electronic Warfare Training and Readiness .....	122
Nato SeaGNAT, Ship Launched Electronic Decoy and Counter Arm Decoy Development Program Support .....	123
New Algorithms for the Assignment Problem .....	124
Conceptual Basis for Soviet C <sup>3</sup> (Phase III) .....	125
Cybernetic Concepts .....	126
DEPARTMENT OF NATIONAL SECURITY AFFAIRS	
Departmental Summary .....	129
The Image of War in the West German Armed Forces, 1950-1980 .....	131
The Hashemite Connection: Current Issues in Jordanian-Palestinian Relations .....	132
State Organization as a Political Indicator .....	133
Student Micro Computer Project .....	134
American Strategic Deception in the Pacific 1942-1945 .....	135
Predicting Soviet Non-Compliance with Arms Control Agreements .....	136

Project Lanai: Soviet Perceptions Management Database .....	137
Research on Arms Control (Phase I) .....	138
Preliminary Survey on Naval Grand Tactics .....	139
Analysis of War Games .....	140
French Security Policies .....	141

DEPARTMENT OF PHYSICS

Departmental Summary .....	145
Development of a New Method for Measuring the Characteristic Impedance and Complex Propagation Constant of Porous Acoustic Material .....	149
Directed Energy Test Detection .....	151
Measurement of E.M. Radiation from High Current Electron Beams .....	152
FLIR Performance Model Assessment .....	153
FLIR Performance Model Assessment and Evaluation .....	154
Infra-red Search and Target Designator Research .....	155
Technical Support to Off-Board Counter-Measure Programs .....	157
Fiber Optic Gradient Hydrophone .....	159
Optical Fiber Fusion Splicer .....	160
Reciprocity Calibration in Unconventional Geometries .....	161
The Interaction of Electromagnetic Waves with Rough Surfaces .....	163
Classical Trajectory Simulation Studies of High and Low Energy Particle-Beam Interactions .....	165
C <sup>3</sup> Measures of Effectiveness .....	167
Statistical Mechanics to Options Planning .....	168
Technical Monitoring of Alphatech SDI-BM Methodology .....	170
Synthesis of Minimal Scattering Profiles in Inhomogeneous Anisotropic Material .....	171
Investigation of Roles of Environmental Factors in Generating Infrasonic Ambient Ocean Noise .....	172

Development and Validation of a Navy Chemical Threat Assessment Model for Burst Releases .....	173
Parameterization of Overwater Diffusion .....	174
Space Shuttle Rocket Exhaust Hazard .....	175
Atmospheric Isoplanatic Angle Sensor .....	177
Evaluation of Atmospheric Isoplanatic Angle Measurements .....	178
Remote Atmospheric Optical Turbulence Sensors .....	179
Remote Atmospheric Remote Sensor Development .....	180
Acoustic Multipath Measurements and Analysis .....	181
In-Service Performance Monitoring of Submarine Sonar Hydrophones .....	183
Purchase of Impedance/Gain-Phase Analyzer .....	187
Application of the Parametric Acoustic Array as a Sub-Bottom Sonar .....	189

#### DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Departmental Summary .....	193
Analysis and Experimental Verification of Performance of Coherent and Non-Coherent Binary and M-ary Digital Communication Receivers .....	197
Digital Adaptive Control with Finite Time Persistency of Excitation .....	198
Simulation and Performance of Brushless DC Motor Actuator .....	199
SIGINT, SIGSEC, C <sup>3</sup> CM Research and Support .....	200
VHSIC Design Methodology and System Appli- cations, VHSIC Integration in Tactical Image Processing .....	201
Advance Algorithm and Architecture for Digital Mapping .....	202
Image Registration Using Similarity Counting Method .....	203
Finite Cylinder Scattering .....	204
Aegis System Research .....	206
Common Filtering for Real Time Torpedo Tracking .....	207

EA6B Update .....	208
Evaluation Simulation and Analysis for the Crossbow Committee .....	209
Gaters-RPV-AROD .....	210
NATO SEA GNAT Development Program .....	211
Study and Evaluation of a Miniaturized GPS System with a Guidance Package for Use by Parachutists to Guide them to an Landing Area .....	212
Underwater Acoustic Propagation and Scatter- ing in a Random Ocean-A Linear Systems Theory Approach .....	213

#### DEPARTMENT OF METEOROLOGY

Departmental Summary .....	217
Evaluation of NOGAPS Tropical and Medium Range Forecasts .....	221
Analysis of Surface Winds over Tropical Oceans during TOGA .....	223
Interannual and Spatial Variations of Large-Scale Motions .....	224
Tropical and Monsoon Studies .....	226
Analyses of Atmospheric Measurements (MIZEX) .....	229
Analysis of Atmospheric Measurements Collected on the NOSC Mast .....	231
Analysis/Interpretation of MIZ Atmospheric Mesoscale Features .....	232
Atmospheric Forcing on Ocean-Atmosphere Mixed-Layer Processes .....	233
Droplet Contributions to Humidity Exchanges over the Sea .....	235
FASTNEX Shipboard Meteorology .....	237
Marine Boundary Layer Aerosol Optical Extinction .....	238
Observational Studies of Marine Boundary Layer Processes .....	240
Electronic Weapon System Satellite Support .....	242
Radiometric Detection of Marine Atmos- pheric Boundary Layer (MABL) Character- istics .....	243

Satellite Applications for TESS .....	244
Satellite Detection of Marine Atmospheric Boundary Layer (MABL) Characteristics .....	245
Observational-Numerical Study of Maritime Extratropical Cyclones Using FGGE Data .....	246
Oceanic Response to Atmospheric Forcing .....	247
Rapid Maritime Cyclogenesis Studies .....	248
Tropical Cyclone Motion Studies .....	249
Tropical Cyclone Prediction .....	250
Eddy Generation Mechanisms in Eastern Boundary Current Regions .....	253
G.J. Haltiner Research Chair in Meteorology .....	255
Model Output Statistics for Forecasting Air/Ocean Parameters Important to the U.S. Navy .....	256
Operational Weather Forecasting-- Antarctica .....	258
Regional Synoptic Forecasting: Central America and Adjacent Caribbean Sea/North Pacific Ocean Areas .....	259
Air Flow over Large Scale Topography .....	260
Large-Scale Atmosphere-Ocean Coupling .....	261
Aircraft Measurements in the Frontal Air-Sea Interaction Experiment (FASINEX) .....	262
Investigation of Atmospheric Boundary Layer Processes in the Santa Barbara Channel .....	263
Atmospheric Profiles of Optical Turbulence .....	264
GOES Satellite Data Analysis for Weather Analysis and Forecasting .....	265
Development of Finite Element Prediction Model .....	266
Numerical Modeling of Unique Atmospheric Phenomena .....	267

DEFENSE RESOURCES MANAGEMENT EDUCATION CENTER

Departmental Summary .....	271
Foundations for Functional Manpower Standards .....	273

Designs of Procedures for Public Expenditure Decisions .....	274
Soviet Public Expenditure Decisions .....	275
FORECASTS System .....	276

DEPARTMENT OF AERONAUTICS

Departmental Summary .....	279
Aircraft Combat Survivability .....	283
Electrode Regions in Dense Plasmas .....	284
Compressibility Effects on the Dynamic Stall of Oscillating Airfoils .....	285
Compressibility Effects on the Dynamic Stall of Oscillating Airfoils .....	286
Satellite Vulnerability to High Energy Lasers .....	287
Solar Cell Radiation Damage Effects .....	288
Spacecraft Contamination from Laser Exhaust .....	289
Underwater Shaped Charges .....	290
Ship-Airwake Study .....	292
Simulating the Helicopter/Ship Interface as an Alternate to Current Methods of Determining the Safe Operating Envelopes .....	293
Computer Model for Windstream Test Facility .....	295
Droplet Formation and Motion in an Oscillating Liquid Jet .....	296
Fuel Composition and Additive Effects on Combustor and Augmentor Tube Emissions .....	297
Solid Fuel Ramjet Combustion .....	300
Solid Propellant Combustion/Automated Data Retrieval from Holograms .....	303
Compressor Tip Clearance Effects .....	306
Development of a Transonic Compressor Model .....	307
Transonic Compressor Investigations .....	308
Wave Rotor and Wave Engines .....	309
Wind Tunnel Studies of Compressor Cascade Flows .....	310

Aging Characterization Facilities for Composites .....	311
Composite Reliability Characterization .....	312
Composites Stress Rupture Equipment .....	313

DEPARTMENT OF OCEANOGRAPHY

Departmental Summary .....	317
Wind Forcing of Eddies and Jets in the California Current System .....	319
Chair in Arctic Marine Science .....	321
Marginal Sea-Ice Zone Studies 1986 .....	322
Studies in Support of NSWC .....	324
Bistatic Propagation to Towed Arrays .....	325
Environmental Acoustic Effects on Vertical Line Array Sonobuoys and the ANODE Meter .....	326
Fixed Distributed Systems: Environmental Acoustics and Fiber Optics Communications .....	327
Naval Postgraduate School Ambient Noise Drifter System (NADS) .....	329
Ocean System Performance Assessment and Acoustic Array Characteristics .....	331
The Equatorial Mixed Layer .....	332
Studies of the Oceanic Planetary Boundary Layer .....	333
Tropical Oceanic Boundary Layer .....	335
The Georges Bank Recirculation Experiment .....	336
Arctic Ice-Ocean Model Development .....	337
A Numerical Study of Frontal Instability with Application to the East Greenland Current .....	338
A Numerical Study of Isolated Eddy Interaction with an Oceanic Jet .....	339
Density, Shear and Turbulence Measurements in the Upper Ocean .....	340
Bluff and Dune Recession Along Monterey Bay Coastline .....	342
Modeling of Wave Transformation in Monterey Bay .....	343



Nearshore Wave Properties .....	345
Offshore Historical Wave Climate .....	348
Test and Evaluation of Sea, Swell and Surf Programs (SSSP) .....	349
Support for Commander, Naval Oceanographic Command MC&G (Hydrography) Chair .....	350

DEPARTMENT OF MECHANICAL ENGINEERING

Departmental Summary .....	355
Bench Marks for Micro Computers .....	359
Dynamic Models and Motion Controls of High-Performance Industrial Robots .....	360
Thermal Processes in the Inter-Connection of Semiconductor Devices .....	361
Transient Buoyancy Induced and Mixed Convection Flows .....	362
Field Modeling of Fire and Smoke Spread in Confined Spaces .....	363
Jet Vane Thrust Vector Control System Heat Transfer Modeling .....	364
Laminar/Turbulent Transition in a Curved Channel with Heat Transfer .....	365
Development of Subminiature Multi-Sensor Hot-Wire Probes for Improved Turbulence Measurements .....	366
Effects of Embedded Vortices on Heat Transfer in Film Cooled Turbulent Boundary Layers .....	368
Laminar/Turbulent Transition in a Curved Channel .....	369
Variable Property Effects in Film Cooled Turbulent Boundary Layers .....	370
Enhanced Condensation of Steam on Horizontal Tubes .....	371
Nucleate Boiling Behavior of R114 from Structured Surfaces .....	373
Investigation of the Influence of Porosity on Behavior of M-50 Bearing Steel .....	374
Ultra-Fine Grained Superplastic Aluminum- Magnesium Alloys: Thermomechanical Processing and Microstructure .....	375
Damping Properties and Applications of Quiet Metal Alloys .....	377

Analytic Model of Gas Turbine Engine Installations .....	379
Exhaust Gas Eductor Design .....	380
Three-Dimensional Modeling of Flows within Gas Turbine Engine Test Cells .....	381
Vortex Induced Disturbances on Fluid Interfaces .....	382
Yaw and Current Effects on Hydrodynamic Resistance of Cylinders in Harmonic Flow .....	384
Analytical and Experimental Investigations of the Damping Characteristics of the Bolted and Welded Structural Connections for Plates and Shells .....	387
Conceptual Studies on Dynamic Analysis of Coupled Large Reflector and Boom Interaction in Navy Remote Ocean Sensing System (N-ROSS) Satellite .....	388
Strain Dependent Non-Linear Damping Material Behavior .....	389
Underwater Shock Response of Submerged Structure .....	390
Firefighter Robot Prototype Development .....	392
Optimal Control of Robotic Mechanisms .....	393
INDEX .....	395
DISTRIBUTION LIST .....	402

**DEPARTMENT  
OF  
COMPUTER SCIENCE**

## DEPARTMENT OF COMPUTER SCIENCE

The research in the Computer Science Department consists of student thesis work and faculty research in the core areas of computer science and in the novel use of computer systems for Navy high-tech applications. The Departmental research efforts have allowed the development of computer graphic devices, image and signal processing equipment, workstations, and database computers.

### ANALYSIS OF ASYMPTOTIC BEHAVIOR

Certain techniques for analyzing algorithms depend on deducing the asymptotic behavior of a function. Professor Daniel Davis and a visiting faculty, Professor Hartmut Huber, studied this kind of problems and developed a technique for deciding under what conditions such deductions are possible.

### ENHANCED GRAPHICS SYSTEM

Professor Michael Zyda and his thesis students continued their research in real-time graphics generation. In addition, they have started research to evaluate the portability and enhancibility of the C2 workstations developed by SRI International.

### HIGH PERFORMANCE DATABASE SYSTEM

Professor David Hsiao, Steven Demurjian and their students extended their earlier work to perform research on a database system that provides high performance, multi-lingual interface support, and high portability. A system with these characteristics are needed to support the software engineering environment.

### MULTI-MEDIA DATABASE SYSTEM

Professor Thomas Wu and his students continued their research on multi-media DBMS to support advanced applications. They investigated issues on information modeling and user interface. Their preliminary conclusion on interface design is to adopt a graphical approach.

### MULTI-MICROCOMPUTER ARCHITECTURE

Professor Uno Kodres and Professor Mitchell Cotton, of ECE, together with their students explored the use of multi-microcomputers to control the SPY-1A radar. The operating system for multiple computers developed earlier has been extended to operate in a distributed environment, where clusters of microcomputers are connected via Ethernet to permit physical distribution. Application programs written in both PLI-86 and JANUS/ADA for execution in this operating system need not specify on which computer the processes are to be done. In addition, Professor Kodres and his thesis students investigated the use of single-chip computers to build a larger multi-computer network. Their long-term goal is to create a reliable computer system using the single-chip computers.

## SOFTWARE SPECIFICATIONS AND SOFTWARE METRIC

Professor Daniel Davis and his thesis students continued their research on the problem of portable and reusable software based on the approach of describing computing resources abstractly. Their earlier result has been applied to interfaces such as graphic resources and database resources. As resources are specified independent of implementation, any system depending on these resources is inherently reusable. In another effort, Professor Davis and his students studied software metric and software interfacing and integration.

## ULTRA-HIGH-LEVEL PROGRAMMING

Professor Bruce MacLennan continued his research on programming, based on combining the concepts of object oriented and functional programming, to develop a method that can increase the users' productivity by an order of magnitude. He designed and implemented a prototype system of this kind and evaluated the effectiveness of such an approach. Results to date support the expectation of significant gain using his method.

Title: A Computer Aided Software Engineering Approach to Software Development for Embedded Systems

Investigator: D. Davis, Associate Professor of Computer Science

Sponsor: Naval Weapons Center

Objective: This research is focused on designing and acquiring components for a CASE (Computer Aided Software Engineering) environment appropriate for the development of ADA software for embedded systems.

Summary: With the introduction of more and more digital computers (microprocessors) into weapons, weapon systems, and support systems, the percentage of work involving operational and support software is rising sharply. The cost to design, develop, and maintain this increasingly complex software is rising astronomically. The current software development methodology used for embedded processors is the prime contributor to these rising costs. Current development methods use disjointed processing methods (personal computers and mainframes) and support tools which are inadequate to support efficient design, development and testing of mission-critical software. This project is using the research efforts of NPS students who are interested in this area to assist the Naval Weapons Center to specify and implement prototypes for components of a CASE system appropriate to use for embedded systems. The initial research has been focused on developing a software metric tool component to meet an immediate need at NWC. Further efforts are focusing on a requirements specification for a CASE system and the development of prototype components.

Thesis Directed: K. Fairbanks, LT, USN, and J. Nieder, LT, USN, "An ADA Software Metric," Master's Thesis, in progress.

Title: Design Requirements and Definitions for VHSIC Technology

Investigator: D. Davis, Associate Professor of Computer Science

Sponsor: Naval Weapons Center

Objective: To examine the problems of interfacing and unifying separate design systems into a single integrated environment.

Summary: Design automation systems have been and are being developed in a number of different problem domains, such as software engineering, mechanical engineering, and VLSI design. Each of these systems use a variety of technologies for describing design requirements and designs for system components. An obvious next step in the automation of design is to find ways to interface and integrate these various systems. Existing systems already are based on some similar principles. For example, although requirements are usually described informally, designs are typically described in a formal manner, such as a high level of programming language or a hardware description language. The first objective of this project is to develop an overview of the use of formal languages in systems oriented to software and hardware design. In particular, do an analysis of the requirements for such languages, and examine the merits of some existing languages, such as ADA and VHDL. An allied objective is to determine the feasibility of developing interfaces between the technologies using ADA for software design and VHDL for hardware design.

Publication: D. Davis, "Requirements for Interfacing and Integrating Software and Hardware Design Systems as a Step Towards Integrated Design," in International AGARD Symposium on the Design, Development and Testing of Complex Avionics Systems, forthcoming.

**Title:** Investigation of the Relation between the Asymptotic Complexity of a Function and its Asymptotic Complexity on a Subsequence

**Investigators:** D. Davis, Associate Professor of Computer Science  
H. Huber, Visiting Professor of Computer Science

**Sponsor:** Naval Surface Weapons Center

**Objective:** Certain techniques for analyzing algorithms depend on deducing the asymptotic behavior of a function knowing only its asymptotic behavior on a subsequence. The objective of this research was to determine the general conditions that make this possible.

**Summary:** The analysis of divide and conquer algorithms depend on the ability of deducing the asymptotic complexity of a function from its behavior on a subsequence. After an intensive analysis of the general question of when this is possible, we were able to devise a technique based on the use of generalized inverses of the function defining the subsequence, for deciding under what conditions such deductions are possible. The technique itself leads to other interesting results about the properties of asymptotic order classes. For example we were able to show that between any two such classes, there are incomparable classes. Also we state a theorem concerning the complexity of general divide and conquer algorithms.

**Publication:** D. Davis and H.V. Huber, "Deducing the Asymptotic Behavior of a Function from its Behavior on a Subsequence," Naval Postgraduate School Technical Report, NPS52-85-024, November 1986.



Title: Reusability and Portability through Resource Abstraction

Investigator: D. Davis, Associate Professor of Computer Science

Sponsor: NPS Foundation Research Program

Objective: The problem of finding ways to improve the reusability and portability of system components at various levels of abstraction, from hardware components through high level software, is an important and pervasive one. The objective of the current work is to establish an approach to this problem by developing a rigorous foundation for the formal abstract specification of resource interfaces. Such interfaces can be used to describe the resource requirements of the overlying system independent of the manner in which these resources are implemented, thus providing for portability and reusability of the system above the interface.

Summary: In recent years, some of the discussions underlying the problems of software reusability and portability have moved from the realm of rules of thumb and ad hoc principles to a general discussion of the fundamental issues. The current research done here is to develop a specific approach to the problem that is both rigorous and comprehensive. No distinction is made between the problems of reusability and portability for software and hardware. The essential problems are the same. We propose a theory of resource functional abstraction, describe the precise relation between the specification of abstract resources and their realization by actual resources, and as a prototype application, describe the use of the methodology in the specification and implementation of a portable (reusable), abstract processor. The methodology has subsequently been applied to the specification of other interfaces, such as graphics resources and database resources. An inherent feature of the methodology is that resource interfaces are formally described independently of the means of implementation. Thus any system that depends upon these resources is inherently reusable and portable. In some sense, we achieve portability and reusability in the same way it is achieved for software with a high level language, like ADA. The programs written in ADA are not concerned with how the resources that ADA supports

linguistically are implemented, only that they are implemented to have the same meaning. We have extended this concept to apply to resources that are not just linguistic, but that may be realized at a variety of levels of abstraction. In fact, the reason the methodology was first applied to describe the resources of an abstract processor was to prove its feasibility for low level abstractions.

Publication:

D. Davis and J. Yurchak, "The Specification, Design and Implementation of an Abstract Processor," in Proceedings of the Nineteenth IEEE Asilomar Conference on Circuits, Systems, and Computers, November 1985.

Theses Directed:

H. Zang, LCDR, Federal German Navy, "The Formal Specification of an Abstract Database: Design and Implementation," Master's Thesis, December 1985.

M. Ozisik, LT, Turkish Navy, "The Design and Implementation of a C Compiler for an Abstract Machine," Master's Thesis, June 1986.

R. Grant, LT, USN, "Design and Implementation of a Portable, Reusable Visual Interface for Interactive Computing Systems," Master's Thesis, in progress.

Title: Database System in the Support of Software Engineering Environments

Investigators: D. K. Hsiao, Professor of Computer Science and S. A. Demurjian, Research Instructor of Computer Science

Sponsors: Naval Air Development Center, Naval Ocean Systems Center and DoD STARS Program

Objective: To examine the performance, multi-lingual and portability issues of a modern database system in the support of the Software Engineering environment.

Summary: It is believed that the supporting database system for software engineering environment must be of (1) high performance (since the data collection and database size in an environment may be voluminous and requires rapid processing), (2) multi-lingual (so that it can interface many different data models and languages for diversified software engineering tasks), and (3) high portability (so that every software engineering environment may have a high-performance and multi-lingual database system for the support).

Publications: J. Anand, S. A. Demurjian, D. K. Hsiao, et al "A Research Report on the Laboratory for Database Systems Research: Past, Present and Future," Proceedings of the 6-th Advanced Database Symposium, Information Processing Society of Japan, Aug. 1986.

D. K. Hsiao, "Future Database Machine Architectures," New Directions for Database Systems, (Editors Ariav and Clifford) Ablex Publishing Co., 1986.

D. K. Hsiao "Super Database Computers: Hardware and Software Solutions for Efficient Processing of Very Large Database," Proceedings of the IFIP Congress 1986, Sept. 1986.

S. A. Demurjian, D. K. Hsiao and J. Menon, "A Multi-backend Database System for Performance Gains, Capacity Growth and Hardware Upgrades," Proceedings of the Second International Conference on Data Engineering, IEEE Computer Press, Feb. 1986.

S. A. Demurjian, D. K. Hsiao, et al, "Performance Measurement Methodologies for Database Systems," Proceedings of the National ACM 85 Conference, ACM, Oct. 1985.

S. A. Demurjian, D. K. Hsiao, et al, "Performance Evaluation of a Database System in Multiple Backend Configurations," Database Machines, (Editors DeWitt & Boral) Springer-Verlag, November 1985.

Conference  
Presentations:

D. K. Hsiao, "Future Database Machine Architectures," New Directions for Database Systems," New York University, New York, 1985.

D. K. Hsiao, "Super Database Computers: Hardware and Software Solutions for Efficient Processing of Very Large Databases," IFIP Congress, Dublin, Ireland, September 1986.

S. A. Demurjian, D. K. Hsiao, et al, "Performance Evaluation of a Database System in Multiple Backend Configurations," Database Machine Workshop, Bahamas Island, 1985.

J. Anand, S. A. Demurjian, D. K. Hsiao, et al "A Research Report on the Laboratory for Database Systems Research: Past, Present and Future," The 6th Advanced Database Symposium, Tokyo, Japan, August 1986

Theses Directed:

J. Antony, III and A. Billings, "The Implementaion of an Entity-Relationship Interface for a Multi-Lingual Database System," Master's Thesis, December 1985.

B. Emdi, "The Implementation of a Network Codasyl-DML Interface for a Multi-Lingual Database System," Master's Thesis, December 1985.

C. Feudo, "Modern Hardware Technologies and Software Techniques for On-line Database Storage and Access," Master's Thesis, December 1985.

P. Goisman, "The Design and Analysis of a Complete Entity-Relationship Interface for the Multi-Backend Database System," Master's Thesis, December 1985.

C. Wortherly, "The Design and Analysis of a Network Interface for the Multi-Lingual Database System," Master's Thesis, December 1985.

G. Fenton, "A Computer-Aided Design for the Generation of Transactions and Test Databases and for the Benchmarking of Parallel, Multiple Backend Database Systems," Master's Thesis, June 1986.

S. Holste, "The Implementation of a Multi-lingual Database System-Multi-Backend Database System Interface," Master's Thesis, June 1986.

A. Hunt, "The Implementation of the Primary Operation, Retrieve-Common, of the Multi-Backend Database System (MBDS)," Master's Thesis, June 1986.

B. Rodeck, "Accessing and Updating Functional Databases Using Codasyl-DML," Master's Thesis, June 1986.

B. Silberman, "Software Portability: A Case Study of the Multi-Backend Database System," Master's Thesis, June 1986.

A. Wong, "Toward Highly Portable Database Systems: Issues and Solutions," Master's Thesis, June 1986.

**Title:** Emulation of a Multi-Microcomputer Architecture for the SPY-1A Control Computer

**Investigators:** U. R. Kodres, Professor of Computer Science  
M. L. Cotton, Associate Professor of Electrical and Computer Engineering  
G. S. Baker, Instructor of Computer Science

**Sponsor:** Naval Sea Systems Command

**Objective:** To explore the use of large scale integrated circuit technology in order to control the SPY-1A radar. A multicomputer emulation of the functions of the SPY-1A control computer will be carried out in order to determine the feasibility of such an approach.

**Summary:** A major milestone was reached within the last year. The operating system for a network of multiple computer clusters was completed. This so-called E-MCORTEX (Extended MultiComputer Real Time EXecutive) permits the operation of multiple clusters of single board computers with clusters of up to eight data memory sharing computers operating in a network connected by Ethernet (10 megabits/sec). This executive system permits synchronization and data sharing between user programs in such a way that the applications programmer need not be aware whether the program is being executed in a uniprocessor, a multiprocessor cluster, or a multicluster network.

The lead designer of the system determines how processes are partitioned among the multiprocessor clusters and among the processors within a cluster. A demonstration program was written to show how the system operates and what the lead designer has to do in order to orchestrate an effective use of the network of clusters.

The present programming language for applications programs is PL/I-86. The implementation of the JANUS/Ada language gate to the operating system has been completed, so that future applications can use the Ada language in addition to PL/I-86.

A sequence of projects to explore the use of multi-level Secure Operating System was initiated, and three thesis projects were completed. The Gemini Multilevel Secure Operating System, GEMSOS, was used on a multicomputer cluster system acquired from the Gemini Computers, Inc. and installed in the AEGIS Modeling Project Laboratory.

A microcomputer laboratory, that consists of twenty Zenith Z-100 systems, was installed with a network controller that allows access to the Defense Data Network (DDN) and provides a computer base for developing software for the AEGIS modeling project.

- Publication: U. R. Kodres and R. Bracha, "Implementation of the JANUS/Ada Language Gate to the E-MCORTEX Operating System," Naval Postgraduate School Technical Report, in progress.
- Theses Directed: K. J. Choi, CPT, Korean Army and J. K. Lee, CPT, Korean Army, "Printer Multiplexing among Multiple Z-100 Microcomputers," Master's Thesis, December 1985.
- R. Haeger, LCDR, Federal German Navy, "Process Synchronization and Data Communication between Processes in Real Time Local Area Networks," Master's Thesis, December 1985.
- K. W. Coomes, LT, USN, "Tactical Display Simulation on the H/Z-100," Master's Thesis, March 1986.
- P. J. Corbett, LT, USN, "Multilevel Secure Front End for Data Communications," Master's Thesis, March 1986.
- C. A. B. A. Cavalcanti, LCDR, Brazilian Navy, "Modeling of a Multilevel Secure Tactical Combat Computer System," Master's Thesis, June 1986.
- R. L. Hartman, LCDR, USN and A. F. Yasinsac, CPT, USMC "JANUS/Ada Implementation of a Star Cluster Network of Personal Computers with Interface to an Ethernet LAN Allowing Access to DDN Resources," Master's Thesis, June 1986.
- M. A. Reyes, MAJ, Peruvian Air Force, "Dynamic Sharing of the System Resources in a Multilevel Secure SYstem," Master's Thesis, September 1986.

Title: Systems Simulation/Emulation on a Multiple Transputer System

Investigator: U.R. Kodres, Professor of Computer Science

Sponsor: Strategic Systems Project Office

Objective: The project explores the use of a single chip computer, the so-called transputer, as a component of a larger multicomputer network. The software and hardware design to make such a network a reliable and fault tolerant system is the long term objective of this project.

Summary: A major accomplishment of this project was the installation of a sixteen transputer network, which is connected to the VAX 11/780 system for software development. The system was installed in December 1986 and a series of thesis projects will explore the computational capacity of such a network in solving tactical problems. The transputer is a powerful 32-bit processor that can perform 20 additions per microsecond. Sixteen such processors in a network have the computational capacity of 320 additions per microsecond. This is about 500 times faster than the present Navy standard ANUYK-7 computer, or 350 times faster than the ANUYK-14, the Navy standard aircraft computer.



**Title:** Combining Object-Oriented and Functional Programming

**Investigator:** B. J. MacLennan, Associate Professor of Computer Science

**Sponsor:** Office of Naval Research

**Objective:** Object-oriented programming and function-oriented programming are two recently developed programming paradigms that have the promise of being much more effective than traditional software development methodologies. This project will investigate the foundations of object-oriented and function-oriented programming, and explore means by which the advantage of each can be combined into a unified methodology.

**Summary:** ONR supported research being conducted at the Naval Postgraduate School has made progress in a number of areas pertaining to both the theoretical foundations and practical problems of object-oriented and functional programming. Theoretical results include insights into the relationships among the function-oriented, relation-oriented, logic-oriented and object-oriented programming paradigms, and also mathematical techniques for manipulating programs in these paradigms. For example, preliminary results have been obtained in the development of a mathematical calculus of functional and relational programming. The goal of this calculus is to facilitate the derivation and transformation of programs.

Practical results include the development of a number of programming systems and their use in assessing the practicality of the various paradigms. For example, we have developed an experimental programming system, called Dyad, comprising an applicative language (A) and an object-oriented language ( $\Omega$ ). This system attempts to combine in one system the best features of function-oriented programming and object-oriented programming.

To evaluate Dyad we have used it to prototype a small programming environment for an applicative language. This environment, which comprises an interpreter, debugger, code generator and universal (table driven) syntax-directed editor, is expressed in less than 200  $\Omega$  rules. This result supports the contention that object-oriented languages such as  $\Omega$  can be profitably used for prototyping systems such as programming environments.

Publications:

B. J. MacLennan, "Experience with  $\Omega$ : Implementation of a Prototype Programming Environment, Part II," Naval Postgraduate School Technical Report, NPS52-85-015, December 1985.

B. J. MacLennan, "Experience with  $\Omega$ : Implementation of a Prototype Programming Environment, Part III," Naval Postgraduate School Technical Report NPS52-86-004, January 1986.

B. J. MacLennan, "Experience with  $\Omega$ : Implementation of a Prototype Programming Environment, Part IV," Naval Postgraduate School Technical Report, NPS52-86-007, January 1986.

B. J. MacLennan, "Experience with  $\Omega$ : Implementation of a Prototype Programming Environment, Part V," Naval Postgraduate School Technical Report, NPS52-86-009, February 1986.

B. J. MacLennan, "Experience with  $\Omega$ : Implementation of a Prototype Programming Environment, Part VI," Naval Postgraduate School Technical Report in progress.

B. J. MacLennan, "Three Relational Programs," Naval Postgraduate School Technical Report in progress.

B. J. MacLennan, "Preliminary Investigation of a Calculus of Functional Differences: Fixed Differences," Naval Postgraduate School Technical Report NPS52-86-010, February 1986.

B. J. MacLennan, "What Should Be the Nature of a Computerized Environment to Support a Software Factory?", position paper distributed by (at invitation only) Software Factory Workshop sponsored by the Software Engineering Institute, October 15-17, 1985.

B. J. MacLennan, Functional Programming Methodology: Practice and Theory, Addison-Wesley, forthcoming.

B. J. MacLennan, "Logic for the New AI," Synthese, and Naval Postgraduate School Technical Report, forthcoming.

Title: Synthesis of an Information Processing Support System for Advanced Applications

Investigator: C. Thomas Wu, Associate Professor of Computer Science

Sponsor: NPS Foundation Research Program

Objective: To design, analyze, and develop a true information system that is capable of handling multimedia data. Some of the specific objectives include (a) design of a new information modelling technique, (b) investigation of the implementation issues such as user interface, storage structure, parallel processing, etc., and (c) exploration of application areas such as integrated design and manufacturing, office automation, industrial/experimental robotics, etc.

Summary: Characteristics that a true information system must possess are identified. Preliminary analysis of currently available information modelling techniques was completed. User interface, one of the implementation issues, was investigated and our preliminary conclusion is to adopt a graphical interface for the first prototype system. Design of a new modelling technique is tested by applying it to the engineering database applications.

Publications: C.T. Wu, "A New Graphics User Interface for Accessing a Database," Advanced Computer Graphics, Proceeding of Computer Graphics '86 Conference, Tokyo, Japan, April 1986, pp. 203-219.

C.T. Wu, "The Simplicity Requirement of a CAD/CAM Information Support System," Proceeding of the Workshop on Information System Support for Integrated Design and Manufacturing Processes, Monterey, CA, April 1986.

C.T. Wu, "Multimedia Database: What, Why, Where, and How," Proceedings of Database '86 Colloquium, San Diego, CA, June 1986.

C.T. Wu and D.E. Madison, "Data Modelling Abstractions and Graphical Interface for Supporting the Construction Design Process," Naval Postgraduate School Technical Report, NPS52-86-012, February 1986.

C.T. Wu, J.D. Anand, S.A. Demurjian, D.K. Hsiao, V.Y. Lum, D.E. Madison, and R.G. Marshall, "A Research Report on the Laboratory for Database Systems Research: Past, Present, and Future," Naval Postgraduate School Technical Report, NPS52-86-013, May 1986.

C.T. Wu, "A Unified Interface Method for Interacting with a Database," Naval Postgraduate School Technical Report, NPS52-86-014, January 1986.

C.T. Wu and D.E. Madison, "An Expert System Interface and Data Requirements for the Integrated Product Design and Manufacturing Process," Naval Postgraduate School Technical Report, NPS52-86-015, June 1986.

Conference Presentations:

C.T. Wu, "A New Graphics User Interface for Accessing a Database," Computer Graphics '86 Conference, Tokyo, Japan, April 1986.

C.T. Wu, "The Simplicity Requirement of a CAD/CAM Information Support System," Workshop on Information System Support for Integrated Design and Manufacturing Processes, Monterey, CA, April 1986.

C.T. Wu, "Multimedia Database: What, Why, Where, and How," Database '86 Colloquium, San Diego, CA, June 1986.

Theses Directed:

J. Adcock, LT, USN, "Design of a Graphics User Interface for a Database Management System," Master's Thesis, June 1986.

D. Handgraff, CPT, USMC, "Entity-Relationship Model versus Extended Semantic Hierarchical Model for Conceptual Modelling," Master's Thesis, June 1986.

A. Horasan, 2LT, Turkish Air Force, "Implementation of Graphical Language for Accessing Database," Master's Thesis, June 1986.

E. Jacobson, CPT, USMC, "Fourth Generation Programming Language," Master's Thesis, June 1986.

R. Kauffold, LT, USN, "Entity-Relationship Approach: A Good Tool for Tactical Data System?," Master's Thesis, June 1986.

K. Wartick, CPT, USMC, "A Data Definition Language for GLAD," Master's Thesis, June 1986.

Title: A Feasibility Study for Software Portability and Graphics Capability Enhancements for a Command and Control Workstation

Investigator: M.J. Zyda, Assistant Professor of Computer Science

Sponsor: Naval Ocean Systems Center

Objective: The primary goal of this research was to evaluate the quality, portability, and graphics capabilities of the C2 workstation developed by SRI International for NOSC. There were three subgoals for this project. The first was to determine the quality of the software developed by SRI International. The second subgoal was to evaluate the portability of that software. The third subgoal was to evaluate possible graphics enhancements to the C2 workstation. The work for the project was predicated on the delivery of two of the SRI-developed C2 workstations, the C2 software and the entire system's documentation to the Department of Computer Science at the Naval Postgraduate School.

Summary: During the fiscal year, SRI International completely failed to get their C2 software running. They never delivered the hardware, software or any of the documentation for any part of their efforts to the Naval Postgraduate School. During the year, I participated in several demonstrations, both at SRI's headquarters in Menlo Park and at NOSC in San Diego, of the pieces that SRI had working. The final demonstration of the system for the fiscal year occurred on the 29th of September 1986. The demonstration system showed on that date, while the most stable ever shown by SRI, suffered from serious technical flaws. Most of these flaws are related to poor system performance, in particular graphics performance. The performance problems shown were due to improper computer hardware choice and poor implementation.

Faced with the apparent inability of SRI to deliver on time their C2 workstation, I put two students on an effort to produce a better performing C2 workstation with computer workstation hardware already available in the Graphics and Video Laboratory of the Department of Computer Science at the Naval Postgraduate School. Our preliminary efforts show that there are no inherent performance problems given the appropriate computer graphics hardware. This work continues in an unfunded form today.

Publication: M.J. Zyda, "Final Report, Fiscal Year 1986: A Feasibility Study for Software Portability and Graphics Capability Enhancements for a Command and Control Workstation," Naval Postgraduate School Technical Report, in progress.

Theses Directed: R. Adams, "A Graphics Based Interface for a Tactical Command and Control Workstation," Master's Thesis, in progress.

J. Manley, LCDR, USN, "A Unix Based, Multimedia Computer Conferencing System," Master's Thesis, in progress.

Title: The Use of VLSI Technology for the Real-Time Generation of Graphics Displays

Investigator: M.J. Zyda, Assistant Professor of Computer Science

Sponsor: NPS Foundation Research Program

Objective: This study looked at special purpose VLSI architectures for real-time display generation. The goal was the development of a methodology for taking a selected computer graphics algorithm and producing a silicon system that performs that algorithm. Several graphics algorithms that have the potential for VLSI implementation were identified and studied. Part of this effort was a characterization of the changes in the architecture of the graphics display system made necessary by the addition of such real-time display generators.

Summary: This proposal was for one quarter of clean-up work on the proposal originally funded by the NPS Foundation Research Program entitled "The Effects of Real-Time Display Generation on the Architecture of Graphics Display Systems." The work focused on algorithms that had the capability for implementation with multiprocessor hardware. There were also studies as to how those algorithms fit into special hardware. Several technical memoranda and papers were generated for both parts of the project. The following publications discussed algorithms that have the potential for decomposition into parallel processes: (Zyda, August 84), (Hogan, January 86), (Gaddis, January 86), (Artero, July 86) and (Jones, July 86). The following publications discussed hardware implementations and graphics display system changes required due to the addition of those special purpose real-time display generators: (Zyda, May 86), (Zyda, January 86), (Zyda, April 86), and (Zyda, May 86).

Publications: M.J. Zyda, A.R. Jones, and P.G. Hogan, "Surface Reconstruction from Planar Contours," Naval Postgraduate School Technical Report, NPS52-86-019, July 1986.

M.J. Zyda and J.C. Artero, "Non-Roman Font Generation via Interactive Computer Graphics," Naval Postgraduate School Technical Report, NPS52-86-018, July 1986.



M.J. Zyda and R.A. Walker, "Design Notes on a Single Board Multiprocessor for Real-Time Contour Surface Display Generation," submitted to IEEE Computer Graphics and Applications, May 1986.

M.J. Zyda, "Future Graphics Support for CAD/CAM," in Proceeding of the Workshop on Information System Support for Integrated Design and Manufacturing Processes, Monterey, CA., April 1986.

M.J. Zyda and M.E. Gaddis, "The Fractal Geometry of Nature: Its Mathematical Basis and Application to Computer Graphics," Naval Postgraduate School Technical Report, NPS52-86-008, January 1986.

M.J. Zyda and R.A. Walker, "A Single Board Multiprocessor for Real-Time Contour Surface Display Generation," Naval Postgraduate School Technical Report, NPS52-86-003, January 1986.

M.J. Zyda and P.G. Hogan, "Surface Construction from Planar Contours," Naval Postgraduate School Technical Report, NPS52-86-002, January 1986.

M.J. Zyda, "Workstation Graphics Capabilities for the 1990's and Beyond," in Proceedings of Computer Graphics '86 Conference, Technical Sessions Volume III, p. 442, May 1986.

Conference Presentations:

M.J. Zyda, "Future Graphics Support for CAD/CAM," Workshop on Information System Support for Integrated Design and Manufacturing Processes, Monterey, CA., April 1986.

M.J. Zyda, "Workstation Graphics Capabilities for the 1990's and Beyond," Computer Graphics '86 Conference, Anaheim, CA., May 1986.

Theses Directed:

A. Jones, LCDR, USN, "Surface Reconstruction from Planar Contours," Master's Thesis, June 1986.

J. Artero, LT, USN, "Non-Roman Font Generation via Interactive Computer Graphics," Master's Thesis, June 1986.

M.E. Gaddis, Capt, USMC, "The Fractal Geometry of Nature: Its Mathematical Basis and Application to Computer Graphics," Master's Thesis, December 1985.

P. Hogan, "Surface Construction from Planar Contours," Master's Thesis, December 1985.

P. Smith, "The Design and Implementation of a General Purpose Renderer," Master's Thesis, in progress.

J. Falby, LCDR, USN, "A Data Structure for a General Purpose Renderer," Master's Thesis, in progress.

L. Mason, CDR, USN, "A Computer Graphics Interactive Workshop for Two-Dimensional Fractals," Master's Thesis, in progress.

J.H. Potts, Capt, USMC, "The Decomposition of an Arbitrary, Three-Dimensional, Planar Polygon into a Set of Convex Polygons," Master's Thesis, in progress.

G.W. Taylor, Capt, USMC, "A Software Tool for Generating Filled, B-Spline Surfaces," Master's Thesis, in progress.

P. Collins, "Realistic Fractal Terrain Generation," Master's Thesis, in progress.

DEPARTMENT  
OF  
MATHEMATICS

## DEPARTMENT OF MATHEMATICS

The Mathematics Department at NPS conducted an active research program during the 1986 fiscal year. As in previous years, there was substantial research in statistics, numerical analysis and combinatorial analysis. This year, moreover, research was carried out in orbital mechanics and in thin shell theory, as well as in abstract operator theory, game theory and optimization.

### STATISTICAL ANALYSIS

Richard Franke continued his research into problems of interpolation. The covariance function has proved to be a very effective tool for interpolation of meteorological data.

Toke Jayachandran, working jointly with H. Larson, is currently collecting data for the development of sampling intervals. It is hoped this will produce decision tables for metal analyses.

Professor Jayachandran, working on another project, has studied problems on data selection and statistical techniques to determine potential for spying.

### NUMERICAL ANALYSIS

Beny Neta, working on finite element methods, has developed new routines for trapezoidal elements which accomplish substantial savings in storage requirements.

Neta and Arthur Schoenstadt, working with R. T. Williams and R. Newton, have developed applications of the finite element method to meteorological prediction.

### COMBINATORIAL ANALYSIS

Harold Fredricksen has obtained some results on a class of communication codes. (These results are classified.)

### PHYSICAL MATHEMATICS

Fredricksen, along with James Wayman, Raul Mendez, Bert Russak, Guillermo Owen and Beny Neta, has conducted a large program designed to develop a system of sensor and weapons satellites.

Donald Danielson, using results in thin shell theory, developed a model for predicting the behavior of rotor blades in modern helicopters.

## ABSTRACT LINEAR ALGEBRA

Carl DeVito is developing an extension of the open mapping theorem in operator theory.

## GAME THEORY

Guillermo Owen, working jointly with B. Grofman and S. Feld, has contributed to a mathematical theory of positional choice by political parties.

## OPTIMIZATION

I. Bert Russak, working jointly with A. A. Goldstein, has developed an algorithm for minimization of a function which is known only in terms of its values at a finite set of points. The basic problem here consists in optimal determination of the set of sample points.

Title: Mathematical Models for Pattern Formation in Growing Animal Tissues

Investigator: D.A. Danielson, Associate Professor of Mathematics

Sponsor: NPS Foundation Research Program

Objective: To develop a mathematical theory based on mechanical principles which will agree with existing experimental observations of patterns and of growth in animal embryos and tissues.

Summary: Communication with biologists (including those at the University of California at San Diego and Stanford University) and an intensive survey of the literature indicated that morphogenesis is a complex process in which tension is one contributing factor. The mathematical theory of tension fields may or may not be applicable to this process. Because NPS has no biology department and has limited biological journals, it was decided to abandon this line of research mid-year and to pursue an area that would be of more interest to the people at NPS and of more benefit to the military.

Because of this investigators' previous work in the field of thin shell theory, he received an invitation to spend the spring quarter at the Aeroflightdynamics Directorate of the Ames Research Center from the theoretical group leader, Dr. D. Hodges. The problem posed was to develop a mathematical theory for predicting the mechanical behavior of rotor blades used in modern helicopters. The researchers there had been working on this problem for over two years but were unable to solve it. This investigator, making use of his background in tensor analysis, devised a way to incorporate the necessary effects into a rigorous nonlinear beam theory. In August he was awarded by the Department of the Army an official commendation for the technical excellence of this work.

Publications: D.A. Danielson, D.H. Hodges, "Nonlinear Beam Kinematics by Decomposition of the Rotation Tensor", Journal of Applied Mechanics, forthcoming.

Publications (continuation):

D.H. Hodges, strong acknowledgement to D.A. Danielson, "Nonlinear Beam Kinematics for Small Strains and Finite Rotations", Vertica, forthcoming.

D.H. Hodges, acknowledgement to D.A. Danielson, "Finite Rotations and Nonlinear Beam Kinematics", Vertica, forthcoming.

TITLE: Investigation of a Major Result in Operator Theory

Investigator: C. DEVITO, Adjunct Professor of Mathematics

Sponsor: NPS Foundation Research Program

Objective: To study a signification result in operator theory; the open-mapping theorem. I hope to develop an extension of this result to a class of spaces which have already proved useful in applications.

Summary: We proposed to investigate a major result in the theory of linear operators in connection with an important class of spaces. This class has already been used, by the author, to settle some questions of operator theory.



Title: Interpolation of Scattered Meteorological Data

Investigator: R. Franke, Professor of Mathematics

Sponsor: NAVAIR (transferred to ONR) via NEPRF

Objective: Develop mathematical principles which may be used to interpolated meteorological information from randomly located points to a uniform grid while maximizing observation utility.

Summary: The use of a Statistical Interpolation scheme for objective analysis is planned for the Navy's operational weather prediction code. This scheme requires the specification of the spatial covariance relation for the independent variables being approximated, in this case the forecast errors. A study detailing the properties of classes of suitable functions, their fitting power, and the error due to using such approximate functions has been completed. The covariance function for an autoregressive process of order two (plus a constant) has suitable properties, combined with adequate fitting power, and results in a small contribution to the error in the approximation.

Publication: R. Franke, "Covariance Functions for Statistical Interpolation", NPS Technical Report, NPS-53-86-007, September, 1986.

Title: Despreading Codes

Investigator: H. FREDRICKSEN, Professor of Mathematics

Sponsor: National Security Agency

Objective: To determine despreading properties of a class of codes for use in spread spectrum communications. Expect a long-term project to continue in this area.

Summary: Research results are classified and releasable only by sponsor.

Theses: Robert Horback, CAPT, USA, to graduate 12/86  
Michael Whiting, LT, USN, to graduate 12/86

Title: SDI System Architecture Studies

Investigators: H. FREDRICKSEN, Professor, Principle Investigator  
J. WAYMAN, Adjunct Professor  
R. MENDEZ, Assistant Professor  
I.B. RUSSAK, Associate Professor  
G. OWEN, Professor  
B. NETA, Associate Professor Associate Investigators

Sponsor: Naval Surface Weapons Center

Objective: To determine the effectiveness of a system of space based on sensors and weapons to retaliate against ICBM weapons. This effort will continue. Sponsor anticipates an ongoing effort of several years.

Summary: In a sequence of papers, a system of sensor and weapons satellites is developed, to cover a threat of offensive weapons to be launched against the U.S.. Problems of orbital mechanics are faced and handled. Sensor satellites in radar and IR technologies are developed. Laser weapons are developed for satellites and their effectiveness against platforms determined. Tracking is enhanced by a system using Kalman filtering techniques. Finally, a program coordinating the whole effort was developed and delivered to the sponsor.

Conference Presentation: A session of the upcoming MORS conference (Monterey) will be devoted to a discussion of the program undertaken.

Theses: LCDR Alfred Clark, USN, Implementation of Kalman Filtering to Satellite Positioning. MS Space Systems Engineering. To graduate 12/86.  
LT Mary Crawford, USN

Title: Statistical Analyses of Security-Related Data on  
Armed Services Personnel

Investigator: T. Jayachandran, Professor of Mathematics

Sponsor: Personnel Security Research and Education Center  
(PERSEREC), Monterey, CA

Objective: To provide statistical support for the design and analyses  
of studies to identify factors that may serve as predictors  
of a potential for spying.

Summary: Assisted in the selection of the appropriate data and  
the statistical techniques to investigate if background  
information is a reliable predictor of a less than honor-  
able discharge and also if credit information history can  
be used to predict potential financial difficulties.  
This project is expected to continue into the next quarter.

**Title:** A Variable-Resolution Finite-Element Method for the Shallow-Water Barotropic Model

**Investigator:** B. Neta, Associate Professor of Mathematics

**Sponsor:** NPS Foundation Research Program

**Objective:** The objective of this study is both to analyze and to numerically experiment with two variable resolution finite elements that seem to overcome the major difficulty of the existing method, namely increasing the storage requirements as a result of high resolution forced on the user away from the region of interest. The computer software is also being developed.

**Summary:** During the Spring and Summer of 1986, the following was accomplished. The bilinear basis functions on trapezoidal elements were constructed. The savings in storage requirements was established as being approximately 20% - 25%. One of the subroutines required for the new grid was developed and tested. This subroutine describes the new variable grid to the computer. The second subroutine required was developed and currently under testing. This subroutine supply the computer with information on the neighbors of each grid point. Other results are given in a NPS technical report entitled "Special Methods for Problems whose Oscillatory Solution is Damped". These results were submitted for journal publication in Applied Mathematics and Computations and presented in the 1986 Ordinary Differential Equations Conference in Albuquerque, NM in July 1986.

**Publications:** B. Neta, "Special Methods for Problems whose Oscillatory Solution is Damped", Applied Mathematics and Computation, submitted July 1986.

B. Neta, "Special Methods for Problems whose Oscillatory Solution is Damped", Naval Postgraduate School Technical Report, NPS-53-86-012, September 1986.

**Conference:** B. Neta, "Special Methods for Problems whose Oscillatory Solution is Damped", 1986 Ordinary Differential Equations Conference, Albuquerque, July 28 - August 1, 1986.

Title: An Algorithm for Noisy Function Minimization for use in Optimal Trajectory Design

Investigator(s): I. Bert Russak, Associate Professor of Mathematics, NPS  
A. A. Goldstein, Professor of Mathematics, University of Washington

Sponsor: NUWES Dahlgren VA

Objective: The design of optimal trajectories involves errors (e.g. those inherent in the flight equations model). If an accurate solution is required, then these errors must be taken into account. This project is concerned with continuing the development of an optimization algorithm which considers these errors and assumes knowledge of only the bounds on the error rather than (is often done) the distribution of the error. The former information usually available by knowing e.g. the types of approximations used in the flight equation model construction.

Summary: Development continued of an optimization algorithm for minimizing a function with the only available information being function samples which have noise in them. The basic algorithm uses smoothed derivative information to calculate relaxed newton steps which determine the iterative steps in minimizing the function. The goodness of the algorithm depends upon the error in the smoothing process which in turn depends upon the location of the mesh points used to do the smoothing. Thus there is a secondary optimization problem, namely to locate the mesh points to minimize the smoothing error. This latter optimization is very demanding in the number of data points and hence also the number of function evaluations required. For this reason, the mesh determination is done by three methods referred to as A, B and C. These are of increasing sophistication and expense and are used progressively as needed to provide continued decrease of the function  $f$ . Method A has already been developed and appears in [1]. Method B is the subject of this project and appears with associated results in [2] and [3]. Method C will be discussed in a future paper.

Publications: [1] "GGOPT, An Unconstrained Non-Linear Optimizer", Bassingthwaite, J.B., Chan, J.S., Goldstein, A.A., Russak, I.B., submitted to Computations in Bio-Medicine.

[2] "Mesh Construction for Efficient Derivative Calculation", Bassingthwaite, J.B., Chan, J.S., Goldstein, A.A., Russak, I.B., submitted to SIAM Journal on Scientific and Statistical Computing.

- [3] "An Algorithm for Noisy Function Minimization for use in Determining Optimal Trajectories", Russak, I.B., Goldstein, A.A., Chan, J.S., Bassingthwaite, J.B., NPS Report #NPS-53-86-014.

Title: How Good are the Proximal Point Algorithms?

Investigators: I.B. Russak, Associate Professor of Mathematics, NPS  
A.A. Goldstein, Professor of Mathematics, University of Washington

Objective: Proximal point algorithms (the minimization of a function  $f$  by solving a sequence of modified minimization problems) form an important class of algorithms in optimization. It is desirable to determine potential advantages of these algorithms.

Summary: A class of proximal point algorithms using gradient minimization on  $C^2$  convex functions is considered. This is compared to the direct use of the same gradient method. The comparison is made by computing estimates of the number of steps required to minimize the function to within a prescribed tolerance

It was found that for starting values far from the minimum, proximal point algorithms require fewer steps than the direct method. However, there is no essential improvement in the complexity - only in the numerical factors. However, there is a restricted class of  $C^2$  convex functions in which an essential improvement is possible.

Publication: "How Good are the Proximal Point Algorithms?" Goldstein, A.A., Russak, I.B., submitted to Journal of Complexity.



**DEPARTMENT  
OF  
ADMINISTRATIVE SCIENCES**

## DEPARTMENT OF ADMINISTRATIVE SCIENCES

The Department of Administrative Sciences is responsible for academic programs designed to educate officers and DoD civilian employees in a variety of functional management specialties. The diversity of faculty's professional expertise is reflected in the wide variety of research projects conducted in the department.

In addition to the permanent staff, the department research effort was augmented by, and has benefitted from, the presence of a number of adjunct professors. The research projects span broad spectra of public sector management issues, ranging from basic scholarly pursuits to applied research designed to assist policy and operational decision making. For ease of exposition the research projects may be grouped into the following areas: acquisition; logistics; information systems; communication systems; financial management; manpower analysis; personnel, training and testing; and organization and other general management.

### ACQUISITION

Research in acquisition covers a wide range of issues facing acquisition managers. Dan Boger and Shu Liao continued their study under the sponsorship of Naval Air Systems Command. The focus is on examining the nature of nonrecurring cost items and developing systematic procedures for the government and contractors to follow in order to generate a database of development of parametric models. David Lamm developed an empirical model of defense contractor and subcontractor behavior concerning principal reasons for discontinuing participation in DOD contract business. Douglas Moses and Shu Liao developed a bankruptcy prediction model for evaluating potential contractors during the source selection process.

### LOGISTICS

In collaboration with Professor Richards of the OR Department, Professor McMasters continued his long term project supported by the Navy Fleet Material Support Office. Current effort was devoted to the modification of the multi-echelon repairables model developed last year to reflect current demands. Tom Moore developed a concept for the mathematical modeling of multiple repairable equipment and logistic systems.

### INFORMATION SYSTEMS

Tung Bui continues his research on group decision support systems. Current focus was on defining a theoretical framework to assess the effectiveness of group decision support systems. Dan Dolk began a multi-year project with Army TRADOC Systems Analysis Activity to design and implement a prototype system which facilitates the description and manipulation of combat simulations models. Professor Sivasankaran continued his project on integrating expert and statistical systems. Carl Jones was supported by the Officer of Naval Research in his investigation of models and experiments to understand decision making performance in command and control, with

a particular focus on the MIT's Laboratory for Information and Decision Systems performance-workload and stochastic petri net models.

With the support of Naval Sea Systems Command, Norman Schneidewind analyzed and recommended technology to be used in shipboard non-tactical applications in the next decade. Professor Schneidewind also developed a standard for software quality metrics for IEEE Computer Society Standards Activity Board. The third project undertaken by Professor Schneidewind was to completed the development of a paradigm for the development of software for distributed systems.

#### COMMUNICATION SYSTEMS

J. W. LaPatra, C. R. Jones, J. Wozencraft (Department of Computer and Electrical Engineering), Norman Lyons, and J. Yee (Dept. of Operations Research) continued their study of the demand for services for the National Communications Systems (NCS) and provide recommendations regarding the development, acquisition, and operation of the Nationwide Emergency Telecommunications Network.

#### FINANCIAL MANAGEMENT

Jerry McCaffery continued his study of the PPBS process, focusing on the potential consequences of the introduction of the biennial budget system into DoN patterns. Joseph San Miguel continued his research on the efficiency and effectiveness of the cash management systems within the Department of the Navy. Ken Euske and S. L. Ansari completed their project on depot maintenance cost and production accounting and reporting. Professors Euske and Boger undertook a project examining the improvement of productivity enhancement programs at field activities. Douglas Moses continued his research on factors affecting firms' choices and uses of accounting methods. Professor Moses also began a project to determine if measures developed from earnings forecasts made by financial analysts can be exploited to predict bankruptcy for firms.

#### MANPOWER ANALYSIS

George Thomas continued to undertake several projects, all sponsored by the U.S. Army Recruiting Command. The first was the second phase of a three year project designed to construct a study plan for developing Army Reserve manpower supply and unit location models. The second project, with Kathy Kocher, determined the various factors that affect Army Reserve attrition. The third, with Stephen Mehay, was designed to develop a local labor market data base that will support reserve recruiting.

The U.S. Army Recruiting command also sponsored Mark Eitelberg's project on participation by Hispanics in the American military. With support from Navy Personnel Research and Development Center, Professor Eitelberg examined the military's demand for high quality recruits and the nation's supply. David Henderson's research focused on military compensation. The first of Professor Henderson's

projects was designed to estimate the costs of alternatives to the current military retirement system. The second was related to pay comparability between Navy and civilian pilots. Loren Solnick also had two research projects. The first was to develop and test models to determine the relationship between seniority, performance ratings and salaries. The second examined the quitting behavior among professional and managerial employees and its relation to pay promotions and performance ratings.

#### PERSONNEL, TRAINING AND TESTING

R. A. Weitzman continued his research on the fairness in testing. The first deals with the effect of maximizing test validity on test bias and the second incorporates the effect of guessing into the Rasch model when applied to multiple-choice items. Professor Weitzman also collaborated with T. G. Sticht and L. A. Armijo in the development and evaluation of functional reading materials for Navy enlisted personnel.

#### ORGANIZATION AND OTHER GENERAL MANAGEMENT

Nancy Roberts continued her multi-year study of collective power. The project was started before she joined the faculty this year. The project involves theoretical as well as laboratory study to measure collective power using network analysis.

Professors McMasters and Moore provided TRADOC Research Element Monterey (TREM) assistance with the maintenance and development of Army models of military organizational effectiveness.

James Suchan studied the effect of high-impact writing on the reader's image of the writer.

David Henderson analyzed the oil-sharing formula agreed to by the U. S. government and the governments of the other 20 nations in the International Energy Agency.

Title: An Analysis of Methods for Creating Comparable Databases for Nonrecurring Cost Analysis under Dual Source Competition

Investigator: D.C. Boger, Associate Professor of Economics and S.S. Liao, Professor of Accounting

Sponsor: Naval Air Systems Command, Cost Analysis Division

Objectives: This study examines the nature of nonrecurring cost items and develops systematic procedures for the government and contractors to follow in order to generate a database of nonrecurring costs which is both consistent and comparable.

Summary: This study involves field trips to major aerospace defense contractors to assess the following:

1. the criteria for classifying nonrecurring costs in setting up production facilities,
2. the classification of nonrecurring cost items as variable or fixed costs,
3. the method of tracking and accounting nonrecurring costs to segregate set-up costs from follow-on production efforts.

Publications: A technical report is in progress.

Thesis Directed: A thesis by LT Margaret Kerr will be completed in December 1986.

Title: The Effects of Distributed Group Decision Support Systems on Group Problem Solving: An Experimental Investigation

Investigator: Tung Bui, Assistant Professor of Information Systems

Sponsor: NPS Foundation Research Program

Objective: To define a theoretical framework to assess the effectiveness of Group Decision Support Systems (GDSS). In particular, to measure the extent to which a computerized GDSS influence the confidence and participative behavior of the participants during the group decision making process.

Summary: A predictive model of effective GDSS use was developed to constitute a foundation for experimental research. The model is based on two interdependent organization parameters: the complexity of relative task and interpersonal relationship problems that the decision group must solve for the organization. The model suggests that GDSS use is recommended for problems high in task complexity and low in interpersonal relationship. Also, it does not recommend the use GDSS.

Publications: "GDSS Effectiveness: Identifying Organizational Opportunities", forthcoming Proceedings of the 20th Hawaii International Conference on System Sciences, 6-9 January, 1987, Kailua-Kona, Hawaii.

"Organizational Decision Making: When Can DSS Help?" forthcoming, Proceedings of French Association of Organizational Sciences (AFCET), March 10-12, 1987, Paris, France.

Identifying Organizational Opportunities for GDSS Use: Some Experimental Evidence", article in progress.

Conference Presentation: "GDSS Effectiveness: Identifying Organizational Opportunities" forthcoming International Conference on System Sciences, 6-9 January, 1987, Kailua-Kona, Hawaii.

"Organizational Decision Making: When Can  
DSS Help?" forthcoming Colloque sur le  
Development des Sciences et Pratiques de  
L'Organisation, March 10-12 1987, Paris,  
France.

**Title:** A Model Management System for Software Engineering

**Investigator:** Daniel R. Dolk, Associate Professor of Information Systems

**Sponsor:** U.S. Army TRADOC Systems Analysis Activity (TRASANA)

**Objective:** The overall objective of this multiyear project is to design and implement a prototype system which facilitates the description and manipulation of combat simulations models. The focus of this first year's effort is to assess the suitability of Geoffrion's structured modeling formalism for representing discrete event simulation models. Comparison of structured modeling with the Jackson System Development methodology will form part of this assessment process.

**Summary:** A relational information resource dictionary system (IRDS) was designed and implemented. The IRDS is compatible with Federal standards and also accommodates structured model representations. Structured modeling was compared with Jackson System Methodology and found wanting in terms of representing dynamic, process-oriented environments. Finally, a structured model representation of an existing combat simulation model was developed. Further work will concentrate on strengthening the link between structured modeling and discrete event simulation.

**Publications:** Dolk, D.R., and Kirsch R.A. A relational information resource dictionary system. Communications of the ACM, Forthcoming.

**Conference Presentation:** Dolk, D.R. and Noel, A.F. A relational information resource dictionary system. Mini-conference on Structured Modeling, UCLA, August 20-22 1986.

Dolk, D. R. and Noel, A.F. A relational dictionary prototype for implementing model management. Proceedings of the Nineteenth Hawaii International Conference on System Sciences, Honolulu, HI, January 86, 405-415.



Title: Evaluation of Minority Recruitment

Investigator M. J. Eitelberg, Adjunct Research Professor of Public Administration

Sponsor: U. S. Army Recruiting Command (USAREC)

Objective: To develop an annotated reference data base on participation by Hispanics in the American military; to examine the effects of aptitude and education standards on the military eligibility of Hispanic youths; and to conduct an exploratory analysis of alternative selection criteria for Hispanics that could be used to replace or supplement existing aptitude and education standards.

Summary: Work progressed on a forthcoming study of "Hispanics and the Military."

A revised research data base was created. The data base includes the most comprehensive collection of material on the subject to date. It was produced in a printed version and in computer format (which will allow periodic update).

An exploration of the literature suggested that current educational screening criteria may not measure the predicted "adaptability" of Hispanic recruits in the same manner or degree as currently shown for members of other racial/ethnic groups. A significant portion of Hispanic youth do not obtain a high school diploma for reasons rooted in their cultural or social background, and these reasons are often unrelated to factors that may influence an individual's military performance. An examination of longitudinal data from the Defense Manpower Data Center (DMDC) supported this point: The high school diploma was consistently less effective as a predictor of "success" in military service for Hispanics than for mainstream population groups. The study recommended that certain background information (such as social or economic history, school records and coursework, and employment experiences) be routinely used in the screening process and be given more importance in evaluating the eligibility of Hispanic applicants for enlistment.

Publications: M. J. Eitelberg and J. R. Wood, Hispanics and the Military, Washington, DC: Office of the Assistant Secretary of Defense (Force Management and Personnel), forthcoming.

J. R. Wood, Hispanics and the Military: A Reference Data Base, USAREC-RM-86-1, Fort Sheridan, Illinois: U. S. Army Recruiting Command, February 1986.

J. R. Wood, The High School Diploma: Is It a Consistent Performance Indicator for Hispanic Recruits?, BDM/MRY-TR-0083-86, Monterey, California: The BDM Corporation, November 1986.

J. R. Wood, Enlistment Standards: Additional Information Could Refine the Selection Process, Consulting Report, Monterey, California: The BDM Corporation, November 1986.

Title: Study of Youth Labor Force Behavior: Population Quality and the QMA

Investigator: M. J. Eitelberg, Adjunct Research Professor of Public Administration

Sponsor: Navy Personnel Research and Development Center (NPRDC)

Objective: To derive estimates of the population considered "qualified military available" (QMA) and segments who would be eligible for occupational assignment at various levels of required aptitude; to examine relationships between the military's demand for "high quality" recruits and the nation's supply; and to recommend possible improvements in related screening procedures and policy.

Summary: The history of the military work force was first studied with data from the Civil War to present. The various standards used for selection and assignment of new recruits were chronicled; and current methods were evaluated for their strengths and weaknesses. Computer algorithms were developed and linked with data from the "Profile of American Youth" to estimate the effects of aptitude/education standards on (1) basic enlistment eligibility and (2) military job eligibility of persons in different population groups--focusing on racial/ethnic groups (white, black, and Hispanic) and the sexes. Researchers then examined the influence of current selection and classification standards on the actual participation of women and minorities, including that which occurred during the period of the enlistment test misnorming (1976-80). A final report documents the results of the study and presents a detailed technical appendix with the expected "qualification rates" of American youth (18-23 years old) for every occupation in each of the four military services.

In a related effort, researchers studied population "representation" in the active duty military (fiscal 1985) and analyzed the current recruit quality requirements of the Army and the Marine Corps. Both of these supplementary studies were undertaken at the request of Congress.

Publications: M. J. Eitelberg with M. E. Lathrop and J. H. Laurence, Manpower for Military Occupations, Washington, DC: Office of the Assistant Secretary of Defense (Force Management and Personnel), forthcoming.

M. J. Eitelberg, Representation and Race in America's Volunteer Military, Naval Postgraduate School Technical Report, NPS54-86-010, September 1986.

Department of Defense, A Comparison of Current Army and Marine Corps Recruit Quality Requirements, Washington, DC: Office of the Assistant Secretary of Defense (Force Management and Personnel), May 1986.

Department of Defense, Population Representation in the Active Duty Military Services, Fiscal Year 1985, Washington, DC: Office of the Assistant Secretary of Defense (Force Management and Personnel), June 1986.

Conference  
Presentations:

M. J. Eitelberg, "And They Shall Turn Their Guns Into Umbrellas: Today's High-Tech Military and Its Changing Workforce," Forty-Seventh National Conference of the American Society for Public Administration (ASPA), Anaheim, California, 14 April 1986.

M. J. Eitelberg, "Job Placement in Today's Military: Who Gets What and Why (and, Boy, Have Times Changed)," Ninety-Fourth Annual Convention of the American Psychological Association (APA), Washington, DC, 25 August 1986.

Title: Barriers to Capital Investment

Investigators: K. J. Euske, Associate Professor, and D. C. Boger, Associate Professor

Sponsor: Director, Requirements and Analysis, Office of the Assistant Secretary of Defense

Objective: The improvement of productivity enhancement programs at field activities.

Summary: The research project is designed to examine a number of different type of field activities to determine what actual and perceived conditions exist which may limit the purchasing of capital equipment. Data from field investigations will be used to develop recommendations to improve the functioning of productivity enhancement programs at field activities.

Publications: A technical report is in progress.

Theses Directed: C. S. Badger, "An Analysis of Impediments to the Productivity Enhancing Capital Investment Programs at the Naval Air Station, Alameda, and the Naval Air Rework Facility, Alameda, California," Master's Thesis, December 1985.

W. J. Marshall, III, "An Evaluation of the Productivity Enhancing Capital Investment Process at the Shore Intermediate Maintenance Activity, Little Creek, Virginia," Master's Thesis, December 1985.

C. M. Moe, "Generic Obstacles and Difficulties Associated with the Measurement and Enhancement of Productivity in Shore Intermediate Maintenance Activity (SIMA), Norfolk, Virginia," Master's Thesis, December 1985.

D. A. Wolfe, "Capital Equipment Acquisition Procedures for Enhancing Productivity at PWC San Francisco," Master's Thesis, December 1985.

**Title:** Depot Maintenance Cost and Production Accounting and Reporting

**Investigators:** K. J. Euske, Associate Professor of Accounting and S. L. Ansari, Adjunct Professor of Accounting

**Sponsor:** Director, Logistics and Material Management, Office of the Assistant Secretary of Defense (A & L)

**Objective:** The documentation, evaluation and validation of the cost accounting systems used by depots.

**Summary:** The purpose of this project is to document, evaluate and validate the cost accounting systems used by depots. Of particular interest is the compilation of cost information for reporting to OASD. The study attempted to determine if the depot cost system provides information which is consistent with the requirements of OASD or whether the two cost information systems are "disconnected". The study was designed to use both thesis students and the co-investigators in the research process.

**Conference:** S. L. Ansari and K. J. Euske, "Use of the Accounting System for Measuring Productivity in a Large Scale Organization", Seventeenth Annual National American Institute of Decision Sciences Conference, Las Vegas, Nevada, November 11-13, 1985.

**Theses Directed:** K. J. Jargowsky, "The Uniform Cost Accounting System and Atabilized Rates at Anniston Army Depot, Anniston, Alabama", Master's Thesis, December 1985.

D. R. O'Brien, "Evaluation fo Uniform Cost Accounting System to Fully Capture Depot Level Repair Costs", Master's Thesis, December 1985.

J. W. Orrison, "Documentation and Analysis of Rate Development and Cost Accumulation at Naval Air Rework Facility, Norfolk", Master's Thesis, December 1985.

T. A. Bragg, "Cost Accumulation within the Puget Sound Naval Shipyard", Master's Thesis, June 1985.

H. S. Guess, Jr., "Documentation and Evaluation of Depot Maintenance Cost System Coding and Reporting by Department of Defense Depots", Master's Thesis, December 1984.

A. I. Kanellos, "Documentation and Evaluation of the Depot Maintenance Interservicing", December 1984.

E. W. Law, "An Interservice Comparison of Cost Accounting Under Department of Defense Instruction 7220.29-H, Department of Defense Depot Maintenance and Maintenance Support Cost Accounting and Production Reporting Handbook", Master's Thesis, December 1984.

S. E. Lehr, "Documentation and Analysis of the 'Miscellaneous' Account Category within the DoD Instruction 7220.29-H Depot Level Maintenance Cost Accounting System. Master's Thesis, December 1984.

W. T. Parker, "Documentation and Evaluation of Comparability of Overhead Costs Reported for Depot Level Maintenance", Master's Thesis, December 1984.

W. D. Vandivort, "Documentation and Evaluation of Uniform Cost Accounting for the F-14A Aircraft in Fiscal Year 1983", Master's Thesis, June 1984.

J. L. Burnett, "Documentation and Evaluation of Depot Maintenance Cost Accumulation and Reporting at the Naval Air Rework Facility, Jacksonville, Florida, Master's Thesis, June 1984.

F. D. Gorris, "Documentation and Evaluation of Depot Level Maintenance Cost Accumulation and Reporting at the Air Force Logistics Command Sacramento, California", Master's Thesis, June 1984.

K. J. Tackett, "Documentation and Evaluation of Depot Maintenance Cost Accumulation and Reporting at the Sacramento, California, Master's Thesis, June 1984.



**Title:** An Analysis of The International Energy Agency's Oil-Sharing Agreement

**Investigator:** David R. Henderson, Adjunct Research Professor of Administrative Sciences

**Sponsor:** None

**Objective:** To analyze the oil-sharing formula agreed to by the United States government and by the governments of the other 20 nations in the International Energy Agency

**Summary:** The oil-sharing agreement, commonly believed to require the United States to share oil with its allies when world supplies fall, is shown not to have that effect. This result is shown to hold under a wide range of assumptions.

**Publications:** David R. Henderson, "The IEA Oil-Sharing Agreement: Who Shares with Whom?", submitted to Energy Journal. Decision pending.

**Title:** Estimating the Costs of Alternatives to the Current Military Retirement System

**Investigators:** David R. Henderson, Adjunct Research Professor of Administrative Sciences, and David R. Whipple, Professor of Administrative Sciences

**Sponsor:** Deputy Chief of Naval Operations (Manpower)

**Objective:** To estimate the costs of alternatives to the current military retirement system.

**Summary:** The Bonus Reenlistment Force Transition (B/REFT) model was used to estimate the loss in retention due to proposed cuts in military retirement benefits. The cost of using Selective Reenlistment Bonuses (SRB) to make up for the loss in personnel was then estimated. It was shown that reducing retirement pay and making up for the loss in retention with SRB could save the Navy \$391 million per year.

Estimates were also made of the gains to the Navy by exploiting differences in discount rates. The idea is that if the Navy's discount rate exceeds the individual's, then the Navy can save money and still leave the individual better off by paying a lump sum retirement.

**Thesis Directed:** Robert S. Tallerico, "Selective Reenlistment Bonuses: Used as an Alternative to Current and Proposed Retirement Plans," Master's Thesis, December 1985.

**Title:** Pay Comparability: A Case Study of U.S. Navy versus Civilian Pilots

**Investigator:** David R. Henderson, Adjunct Research Professor of Administrative Sciences

**Sponsor:** Deputy Chief of Naval Operations (Manpower)

**Objective:** To compare career earnings of pilots who stay in the U.S. Navy with earnings of pilots who leave.

**Summary:** Contrary to what is often believed, pilots who stay in the U.S. Navy have lifetime earnings somewhat higher than those who leave to fly with airlines. This result is shown to hold even under assumptions less favorable to the Navy option. It is shown to hold a fortiori under more plausible assumptions.

**Publications:** David R. Henderson and David A. Kriegel, "Pay Comparability: A Case Study of U.S. Navy versus Civilian Pilots," submitted to Defense Analysis. Decision pending.

**Theses Directed:** David A. Kriegel, "An Examination and Comparison of Airline and Navy Pilot Career Earnings," Master's Thesis, March 1986.

**Title:** Models and Experiments to Investigate Decision Making Performance in Command and Control

**Investigator:** C.R. Jones, Professor of Information and Telecommunication Systems

**Sponsor:** Office of Naval Research

**Objective:** Investigate models and experiments to understand decision making performance in command and control with a particular focus on the Massachusetts Institute of Technology's Laboratory for Information and Decision Systems performance-workload and stachastic petri net models.

**Summary:** The information processing paradigm is investigated as an approach to understanding command and control in the tactical environment. The paradigm includes the degree of uncertainty and stability in the environment, the analyzability and variability of tasks to be preformed, the "grouping" of tasks into organizational decision tasks and units. Measures of effectiveness include efficiency and behavioral types. The Massachusetts Institute of Technology's Laboratory for Information and Decision Systems models use a subset of these concepts to model command and control. In particular tasks and decision makers are modelled within an organizational structure with individual decision makers exhibiting bounded rationality. Performance is measured by response time and accuracy. This results in the performance-workload locus which can be experimentally studied. Initial work was completed on the feasibility of using the Naval Postgraduate School War Laboratory to investigate the performance-workload locus using war gaming technology.

**Title:** An Analysis of Reasons Defense Contractors Refuse Government Business

**Investigator:** David V. Lamm, Adjunct Professor of Administrative Sciences

**Sponsor:** NPS Foundation Research Program

**Objective:** To Develop an empirical model of defense contractor and subcontractor behavior concerning principal reasons such contractors do not want to participate in DOD contract business.

**Summary:** A questionnaire was mailed to 1,316 companies with 429 returned. The questionnaire sought to determine whether or not companies were doing/wanted to do DOD business and key reasons why they may not wish to be in DOD business. In depth interviews were conducted with 15 respondents. Additional interviews are yet to be conducted. An analysis of questionnaire responses is in process.

**Title:** Analytic Capability in Support of the National Communications System

**Investigators:** Jack LaPatra, Adjunct Professor of Systems Analysis, Carl R. Jones, Professor of Information and Telecommunication Systems, Jack Wozencraft, Professor of Electrical Engineering, Norman Lyons, Associate Professor of Information Systems and James Yee, Adjunct Professor of Operations Research.

**Sponsor:** National Communications System

**Objective:** To provide recommendations regarding the development, acquisition, and operation of the Nationwide Emergency Telecommunications Network (NETS)

**Summary:** The development, acquisition and operation of the NETS can be analyzed in terms of the supply of services and the demand for those services. The supply of services and flow control procedures that will maximize connectivity in a post attack environment. Since the surviving assets of the nation wide telecommunications system are uncertain, the procedures must be robust and the prior attack location of post attack system reconstruction equipment prior to attack must be carefully chosen. The demand for services can be studied based on the mission and planned organization structure and processes post attack. This will involve in depth interviews in addition to analysis of planning documents. Work to date has involved the development of a method to obtain measures of demand, adaptive, decentralized routing and flow control procedures and the proper sizing of NETS, and the development of a decision support system called FAMIS.

Title: Task Definition, Decision Criteria and Uncertainty Reduction: The Role of the PPB System

Investigator: Jerry McCaffery, Professor of Public Budgeting

Sponsor: NPS Foundation Research Program

Objective: This study is part of a continuing program to familiarize the researcher with the changing nature of the PPB system as it is used by the Department of the Navy. Short term objectives include an appraisal of strengths and weaknesses and an investigation into the use of a biennial budgeting system for DoD. Comparisons were made to certain biennial budget procedures in the American states.

Summary: Research efforts focused this past year on Department of Navy budget system into DON patterns. Comparisons were made to certain states. In terms of Navy patterns, early results indicate that the Navy engenders a high level of conflict in its budget process in order to scrub the proposed budget before it is reviewed at the OSD/OMB level. This partly explains the dual nature of the comptroller's office in NAVCOMPT. Further research is needed to compare Navy budget patterns to the other services. A review of the biennial thrust indicates that the probable outcome of this pattern change will be to exchange time spent justifying the proposed budget for time spent reacting to the DoD/DON budget pattern. At the state level early results indicate that state systems efficiently allocate resources using interim committees to allow for changes within biennia. Very preliminary returns from one state indicate that the biennial format varies more over a longer period of time than does the annual format: i.e. the spending curve is smoother for the annual state, while the biennial state tended to have large increases for the first year of the biennium. This may depend on revenue elasticity. More research is needed on state profiles.

Publications: "Budget Reform: The Road to Reform of Process" International Journal of Public Administration, 1/2 Winter, 1985, pp. 78-85.

Conference  
Presentations:

"Biennial Budgeting and the Department of Navy" presented at the annual meeting of the Western Political Science Association, Eugene, OR., March 20, 1986.

"Comparative Budgeting and the Department of Navy Budget Process", presented at the annual meeting of the Western Social Science Association, Reno, Nevada, April 24 1986.

"Biennial Budgeting: An Examination of Some State Patterns", presented at the annual meeting of Regions IX/X of the American Society for Public Administration, Portland, OR, Oct. 9 1986.



Title: Army Unit Capability Study

Investigators: A. W. McMasters, Associate Professor of Operations Research and Administrative Science and T.P. Moore, Assistant Professor of Management Science

Sponsor: US Army TRADOC Systems Analysis Activity

Objective: To provide the TRADOC Research Element Monterey (TREM) assistance with the maintenance and development of Army models of unit effectiveness.

Summary: This was a continuing project from AY85. Interviews were conducted with Army force designers at eight of thirteen TRADOC schools and two of three TRADOC coordinating centers. It was found that force designers are not using the Army's two existing models for estimating force design resiliency except under special circumstances, due to the difficulty of use and the input data requirements for the models. The interviews lead to the development of a proposal to create and test a TOE resiliency screening process for use by force designers. This project has been undertaken by Professor T. P. Moore. Two models were examined which bear upon the force design process. The existing Army Unit Resiliency Analysis (AURA) model was examined. This model may be a very useful design tool once it is made user-friendly, and a means for easily providing input data can be found. The proposed Systematic Organizational Design (SORD) model was examined and found to have considerable development work remaining.

Publications: Analysis of Military Organizational Effectiveness (AMORE) User's Handbook, completed.

Technical Report, "An Investigation of the Use of Resiliency Analysis by U.S. Army Force Structure Designers", in progress.

**Title:** Army Reserve Market Study

**Investigator:** Stephen L. Mehay and George Thomas

**Sponsor:** U.S. Army Recruiting Command

**Objective:** The objective is to develop a local labor market data base that will support reserve recruiting.

**Summary:** The project involves first identifying sources of data that can be used to profile the local civilian labor market. The focus is on those civilian labor market. The focus is on those civilian market factors that directly affect reserve market penetration and USAR fill rates. The data will be drawn from numerous sources and concatenated into a master data base so that standard data/extractive statistical packages may be utilized.

**Publications:** S. Mehay, J. Borack, and G. Thomas, "Estimating Local Area Manpower Supply for the Reserves," Naval Postgraduate School Technical Report, NPS 54-85-0006 Sept 1980.

**Conference:** S. Mehay, ONR Conference on Naval Reserve Research, "Modeling Local Market Potential for the U.S. Army Reserve," Monterey, CA, June 1986.

Title: Optimal Design, Procurement and Support of Multiple Repairable Equipment and Logistic Systems

Investigators: T. P. Moore, Assistant Professor of Management Science

Sponsor: None

Objective: To develop a concept for the mathematical modeling of multiple repairable equipment and logistic systems (MREAL systems)

Summary: This is the completion of dissertation research in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Industrial Engineering and Operations Research at Virginia Polytechnic Institute and State University. This was a continuing project from AY85. MREAL systems consist of multiple populations of repairable equipment, and their associated design, procurement, maintenance, and supply support. These systems present management and design problems which parallel the management and design of multiple, consumable item inventory systems, with the added complication of equipment maintenance. An orderly structure for the actual MREAL system planning problem was developed. Based on this structure, a mathematical model of a simplified MREAL system was developed. Two different optimization procedures were developed from non-linear, combinatorial and integer programming methodologies. Both procedures were implemented in FORTRAN on an IBM mainframe computer system, and were tested on a minimal test problem.

Publications: T. P. Moore, "Optimal Design, Procurement and Support of Multiple Repairable Equipment and Logistic Systems" (Doctoral Dissertation, VPI&SU, 1986).

T. P. Moore and W. F. Fabrycky, "Modeling Multiple Repairable Equipment and Logistic Systems", Proceedings, 20th International Symposium, Society of Logistics Engineers, San Diego, CA, August, 1985.

M. H. Agee, K. W. Brammer, W. J. Fabrycky, C. J. Malmborg, and T. P. Moore, "Predicting Life Cycle Costs and Maintenance Requirements", Proceedings, 1985 Federal Acquisition Research Symposium, Fort Belvoir, VA, 1985.

Conference

Presentations:

T. P. Moore, "Modeling Multiple Repairable Equipment and Logistic Systems", SOLE Annual Symposium, San Diego, CA, August 20-22, 1985.

T. P. Moore, "A Classification Hierarchy for Repairable Equipment Logistic Systems", TIMS/ORSA Joint National Meeting, Boston, April 29 - May 1, 1985.

Title: Factors Affecting Firms' Choices and Uses of Accounting Methods

Investigator: O. D. Moses, Assistant Professor of Accounting

Sponsor: Un-sponsored

Objective: The objective of this research is to identify and investigate economic incentives that affect what accounting methods and procedures are used by firms and determine how those methods and procedures may be used to influence accounting numbers.

Summary: This project represents a continuing ongoing interest of the investigator rather than a single discrete research effort. Work to date has investigated a) the use of accounting procedures by firms to reduce fluctuations in, or smooth, their reported income series over time, b) the firm-specific factors that provide incentives for firms to smooth income, and c) the role of certain firm-specific incentives in the implementation of changes in accounting procedures by firms.

Publications: O. D. Moses, "Income Strategy and Non-Tax Influences on the Switch to LIFO," The Economics of Accounting, Proceedings of the American Accounting Association Western Regional Meeting, pp. 132-141, edited by Marc Massoud, 1986.

O. D. Moses, "Income Smoothing Research: Methodology and Models," Naval Postgraduate School Technical Report No. NPS54-86-004, May 1986.

O. D. Moses, "Income Smoothing and Incentives: Tests Using Accounting Changes," submitted to the Accounting Review.

Reference: O. D. Moses, "Income Strategy and Non-Tax Influences on the Switch to LIFO," American Accounting Association Western Regional Meeting, Costa Mesa, CA., April 24-26, 1986.

Title: Financial Analyst Earnings Forecasts and Prediction of Corporate Failure

Investigator: O. D. Moses, Assistant Professor of Accounting

Sponsor: NPS Foundation Research Program

Objective: The objective of this research is to determine if measures developed from earnings forecasts made by financial analysts can be exploited to predict bankruptcy for firms.

Summary: Five properties of earnings forecasts were identified: forecast level, forecast error, forecast bias, forecast dispersion and forecast revisions. Tests were conducted to determine if there are systematic differences in these properties between groups of failing and healthy firms. Findings indicate the existence of statistically significant group differences for all five properties. Models using measures of the five properties were constructed to discriminate firms and predict group membership. Results indicate that the measures developed from earnings forecast data do have some ability to identify failing firms prior to bankruptcy, but are not superior to traditional bankruptcy prediction models that use financial statement data.

Publication: O. D. Moses. "Tests of the Usefulness of Analyst Earnings Forecast Data in Predicting Bankruptcy of Public Corporations," Naval Postgraduate School Technical Report, NPS54-86-011, October 1986.

O. D. Moses, "Analysts Earnings Forecasts: An Alternative Data Source for Failure Prediction," in progress.

Title: Predicting Government Contractor Financial Failure

Investigators: O. D. Moses, Assistant Professor of Accounting  
S. S. Liao, Professor of Accounting

Sponsor: Un-sponsored

Objective: The objective of this research was to develop a bankruptcy prediction model that would be particularly suitable to evaluating small, private firms that are government contractors.

Summary: Accounting data for a sample of failed and healthy government contractor firms was collected from documents submitted to contracting agencies during the pre-award survey. Financial ratios were computed from the accounting data. Three types of models for classifying sample firms into failing and healthy groups were constructed using the ratio measures: univariate models, multiple discriminant models and "index" models. Results indicate that a useful model can be developed to predict contractor bankruptcy and that a model combining financial ratios into a "failure index" is most appropriate for this task.

Publications: O. D. Moses and S. S. Liao, "Predicting Contractor Financial Stability: New Insight for Source Selection," (Naval Postgraduate School Technical Report NPS54-86-003), Program Manager, forthcoming.

O. D. Moses and S. S. Liao, "On Developing Models for Failure Prediction," submitted to the Journal of Commercial Bank Lending.

O. D. Moses and S. S. Liao, "Predicting Bankruptcy of Private Firms: A Simplified Approach," Department of Administrative Science Working Paper No. 86-18.

**Title:** Collective Power

**Investigator:** Professor Nancy Charlotte Roberts  
Associate Professor  
Department of Administrative Sciences

**Sponsor:** NPS Foundation Research Program

**Objective:** This research is part of a continuing research program that has four basic objectives:  
(1) A theoretical statement on the concept of collective power derived from case studies; (2) the refinement and development of a research methodology derived from laboratory studies to measure collective power using network analysis; (3) the study of collective power in organizations using the theoretical and methodological tools developed in 1 and 2 above; and  
(4) the organization of a national conference and the editing of a book on the concept of collective power.

**Summary:** The concept and the term collective power is new to the management literature, but it is an extremely potent force in the world for productivity and change. It has tremendous potential for destruction (Jim Jones; Khomeini) and for creativity and productivity (high performing military units and temporary project units and temporary project teams in business). We know little about how to create it, manage it, or avoid its destructive consequences. Understanding collective power, however, would enable us to harness the enormous amounts of energy generated through collective experience, and to channel that energy for productive purposes.

Collective power is defined as a special type of power in which social actors share their resources, and cooperate to achieve ends they have collectively defined,. It is important for our understanding of management in all types of organizations, for it derives from working with others rather than against them.



Unlike other forms of power, collective power evolves from a merging or fusion with others to create a whole that is more than the sum of the parts. It is built on positive affect and feelings of unity and oneness with others. It differs from other traditional forms of power that conceptualize power as dominance and control (e.g. power is the ability to get what one wants despite the resistance of others).

In this past year, work on objectives 1 through 4 has been proceeding as planned. A theoretical paper on Collective Power has been written and now is being revised for publication. The research done on 40 work groups to develop a new methodology to measure collective power is progressing. The data collected (40 work groups over nine waves using relational analysis) has now been coded and entered into the computer. Computer programs have also been written. Analysis on this new data set will begin in January 1987. Research on collective power in organizations has yielded evidence that collective power is associated with higher productivity, stages of ego development, and organizational types. And finally, one conference was held in June of 1986 and another scheduled for March 1987.

Publications:

N.C. Roberts, "Transforming Leadership: A Process of Collective Action," Human Relations, 1985, 38(11):1023-1046.

N.C. Roberts, "Organization Power Styles: Collective and Competitive Power Under Varying Organizational Conditions," Journal of Applied Behavioral Science, 1986, 22(4), (forthcoming)

N.C. Roberts, "Toward a Synergistic Model of Power," In Shared Power, J.M. Beyson University Press of America, (forthcoming)

R.T. Bradley, and N.C. Roberts, "The Dynamics of Charismatic Transformation: Paradox of Love and Power," in Paradox and Transformation, Robert E. Quinn and Kim S. Cameron (Eds.). New York: Ballinger (forthcoming).

N.C. Roberts, and P. King, "Policy Innovation and the Role of the Policy Entrepreneur", In Process Innovation, Andy Van de Ven and Scott Poole (Eds.) New York: Ballinger, (forthcoming).

N.C. Roberts, "Collective Power," (in progress).

N.C. Roberts, "Multi-Organizational Analysis of the Determinants of Managerial Power," Working paper 86-10, Department of Administrative Sciences, Naval Postgraduate School, April 1986.

N.C. Roberts, and P. King, "The Stakeholder Audit: A Key Political Tool in the Change Process. Working paper 86-11, Department of Administrative Sciences, Naval Postgraduate School |April 1986.

Conference:

N.C. Roberts, "Holonomic Power Structures and Cognitive Maps," Paper presented to the symposium Participant Perceptions of Network Structures, at Sunbelt VI, Social Network Conference, Santa Barbara ,CA, February 13-16 1986.

N.C. Roberts. Conference Director, Invited Conference on Holonomic Processes in Social Systems, Carmel Valley, CA, June 13-15 1986.

Title: Research on Cash Management Program within the Department of the Navy

Investigator: Joseph G. San Miguel, Professor of Accounting

Sponsor: Navy Accounting and Finance Center

Objective: The aim of this continuing research was to investigate the design and implementation of Department of the Treasury cash management improvement programs within the Department of the Navy.

Summary: While improvement of overall efficiency and effectiveness of cash management was the primary objective of this research, assessment of potential for fraud, waste, and abuse of the collection, safekeeping, and disbursement of cash was also performed where possible. DON cash management systems were reviewed for compliance with Department of the Treasury rules and regulations. Where applicable, recommendations for improving existing cash management, changes in policies, rules, and regulations were made.

**Title:** Distributed System Software Design Paradigm

**Investigator:** Norman F. Schneidewind, Professor of Computer Science, Department of Administrative Sciences

**Objective:** Develop software design approaches for distributed systems.

**Summary:** Completed the development of a paradigm for the development of software for distributed systems.

**Publications:** Norm Schneidewind, "Tutorial on Software Engineering for Distributed Computing Systems," Pacific Computer Communications Symposium, October 21, 1985, Sheraton Walker Hill Hotel, Seoul, Republic of Korea. (Invited Tutorial).

N.F. Schneidewind, "Distributed System Software Design Paradigm with Application to Computer Communications Symposium, Korea Advanced Institute of Science and Technology, Seoul, Republic of Korea, October 21-25 1985, pp. 80-89. (Invited paper).

**Conferences:** N.F. Schneidewind, Chairman, "Design Optimization" Session, Pacific Computer Communications Symposium, Seoul, Republic of Korea, October 21-25 1985.

Title: Proposed Technology and Procurement Policy for SNAP III

Investigator: Norman F. Schneidewind, Professor of Computer Science, Department of Administrative Sciences

Sponsor: Naval Sea Systems Command

Analyze and recommend technology to be used in shipboard non-tactical applications in the next decade. Recommend a procurement policy to support acquisition of the technology.

Summary: During the past fiscal year the following was accomplished:

1) Recommendations were presented to the Naval Sea Systems Command (later SPAWARS) for the types of technology which are considered applicable for non-tactical shipboard use in the next decade. In addition, recommendations were made for changing current Navy procurement policy so that it can be supportive of acquiring the new technology.

Publications: Norman F. Schneidewind, "Proposed Technology and Procurement Policy for SNAP III, Naval Postgraduate School Technical Report, 1 October 1986.

Title: Software Quality Metrics

Investigator: Norman F. Schneidewind, Professor of Computer Science , Department of Administrative Sciences

Sponsor: IEEE Computer Society Standards Activity Board

Objective: Develop a standard for software quality metrics.

Summary: As Chairman of the IEEE Software Quality Metrics Working Group, held four meetings at various locations in the U.S. for the purpose of developing the standard. A description of this standard group's activities has appeared in IEEE Software, September 1986.

Publications: Raghu Singh and Norman Schneidewind, "Concept of a Software Quality Metrics Standard", Digest of Papers, Thirty-First IEEE Computer Society International Conference, San Francisco, CA, March 3-6, 1986, pp. 362-368.

Norman F. Schneidewind, "Quality Metrics Standards Applied to Government Software," (Abstract), Proceedings, Computer Standards Conference 1986, (Addendum), San Francisco, CA, May 13-15 1986. (Invited Panelist)

Conferences: Panel Session, "Software Quality Metrics," N. Schneidewind, Chairman, Thirty-First IEEE Computer Society International Conference, San Francisco, CA March 3-6 1986.

Norman F. Schneidewind, "Application of Software Quality Standards to the Acquisition and Development Phases'" DoD Software Technology for Adaptable, Reliable Systems (STARS) Business Practices Area Management Workshop, Los Angeles, CA, November 18-22 1985.

Invited participant of Software Standards Panel, NASA Space Station Software Issues Workshop, NASA Marshall Space Center, Huntsville, AL, October 1985.

Title: Integrating Expert and Statistical Systems

Investigator: Taracad R. Sivasankaran

Sponsor: NPS Foundation Research Program

Objective: To investigate methods by which the symbolic reasoning in an Expert System can be integrated with the numerical computing involved in a Statistical System.

Summary: The investigation resulted in a framework that can be applied in the design and development of a symbolic-numeric interface. It was successfully tested using Arity Prolog and GAUSS softwares. The concept was also extended with slight variations in integrating Expert Systems with Database Systems.

Publications: "Coupling Expert Systems and Actuarial Pricing Models," in Coupling Symbolic and Numerical Computing Expert Systems (Ed., J.S. Kowalik), North-Holland, 1986, (with M. Jarke), pp 263-271.

Conference "A Rule-Based Bayesian Architecture for Monitoring Learning Process in ICIA Systems," Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, October 1986, (with T. Bui), pp. 932-936.

**Title:** Does Seniority Pay? Experience, Performance Ratings and Salary

**Investigators:** Loren M. Solnick, Associate Professor of Labor Economics, and Robert Kaestner, doctoral candidate, C.U.N.Y.

**Objective:** To develop and test models to determine whether the wages of nonunion, professional and managerial employees are influenced by length of service, independently of differences in productivity.

**Summary:** Recent research has found that experience appears to have an independent effect on wages, after controlling for productivity (proxied by performance ratings). One implication is that the on-the-job training theory, which links productivity (and thus wages) to experience, does not provide a satisfactory explanation of experience/wage differentials. This study explores this issue in greater detail, utilizing data for professional and managerial employees of a large firm, including the simultaneous determination of wages and salary grade. In general the results show that experience has an independent effect on both wages and wage growth. However, that effect is found to be quite small. Given the magnitude of the experience effect, and other possible explanations of the divergence of pay from productivity, it is concluded that the evidence against the on-the-job training theory is persistent but not overwhelming.

**Publications:** L. M. Solnick and R. Kaestner, "Experience, Performance Ratings and Salary," in progress.



**Title:** Promotions, Pay, Performance Ratings and Probability of Voluntary Separations

**Investigator:** Loren M. Solnick, Associate Professor of Labor Economics

**Sponsor:** NPS Foundation Research Program

**Objective:** To develop and estimate a model that explains quitting behavior among professional and managerial employees, utilizing data available from company personnel records. Key concerns are the effects of management decisions, such as rates of pay, performance ratings and promotions.

**Summary:** The study investigates the determinants of quits among professional and managerial employees of a large manufacturing firm. The major hypothesis is that the heterogeneity of the sample gives rise to non-competing groups, which have different promotion rates, and that the absence of promotion increases the probability of quitting. The theory is tested on a sample of about 8500 white males. Absence of promotion is found to significantly increase the probability of quitting. However, among more homogeneous subsamples of employees, defined by either major field of study or functional area of employment, the promotion effect is much smaller, and mostly not significant. The results support the basic thesis of the study, although the small size of some subsamples may have contributed to the lack of a significant promotion effect.

**Publications:** L. M. Solnick, "Promotions, Pay, Performance Ratings and Quits," Naval Postgraduate School Technical Report, forthcoming.

**Conference Presentation:** L. M. Solnick, "Promotions, Pay, Performance Ratings and Voluntary Separations," Twelfth Annual Convention, Eastern Economic Association, Philadelphia, April, 1986.

Title: Experimental Functional Skills Project: Mathematics

Investigators: T. G. Sticht (Principal Investigator), Adjunct Research Professor; L. A. Armijo, Adjunct Research Professor; R. A. Weitzman, Associate Professor

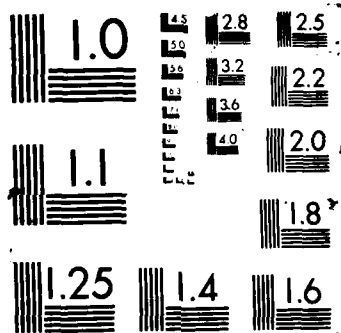
Sponsor: CNET

Objective: To develop and evaluate functional mathematics materials for Navy Enlisted Personnel

Summary: The project is completed. Two mathematics tests, each consisting of 75 items selected to fit the Rasch item-response model were constructed. All item fits, taking guessing into account, were at least satisfactory if not excellent. Scores reported are equated to the scale of the California Adult Student Assessment System. Use of the Rasch model, uniquely, makes such equating possible.

Publications: A book describing the project has been published in 10,000 copies.





**Title:** The Effect of High-Impact Writing on the Reader's Image of the Writer

**Investigator:** J.E. Suchan, Associate Professor of Managerial Communications

**Sponsor:** NPS Foundation Research Program

**Objective:** This project will determine if sex characteristics of high-impact writing--bottom-line organization, contract sentences, the active voice, sublet-verb-object word order, quick sematic closure, and short paragraphs--result in low and mid-level managers in the private sector perceiving writers as forceful, well organized leaders.

**Summary:** An extensive survey and review of managerial communications literature on reader analysis and role adaption was completed. After the review, a test instrument was constructed and field tested on a corporate environment and the relative power position between the writer and reader had a significant impact on whether readers perceived writers of high-impact documents as clear-thinking decision makers. The test instrument has been revised. It has been sent to 300 lower and middle level managers. Further results will be available within three to five months.

**Conference:** J.E. Suchan, "The Effect of High Impact Writing on the Reader;s Image of the Writer," Southwestern Federation of Administrative Disciplines," Dallas, March, 1986.

**Title:** Army Reserve Attrition Study

**Investigator:** G. Thomas, Associate Professor  
K. Kocher, Labor Economics

**Sponsor:** U.S. Army Recruiting Command

**Objective:** To determine the various factors that affect Army Reserve attrition.

**Summary:** The purpose of this research is to tract attrition over time and to isolate factors that are associated with reservists not completing their first terms. The outcome is to develop models that will assist U.S. Army Recruiting command in predicting reserve attrition. The study will be conducted in two phases. Phase I will be a review and critique of DMDC and USAREC data to support attrition analysis. Phase II will be the development of non-prior service attrition models.

**Publications:** Final report has been submitted and is being prepared for Army Recruiting Command Publication

**Presentations:** Presentation at 1986/87 ORSA/TIMS meeting anticipated.

**Title:** Army Reserve Market Study Plan

**Investigator:** G. Thomas, Associate Professor

**Sponsor:** U.S. Army Recruiting Command (USAREC)

**Objective:** This is a three year study from AY 85 through AY 88. The objectives of the full project are as follows:

- (1) to develop an integrated local labor market geo-demographic/attitudinal data base to support reserve recruiting efforts;
- (2) to develop techniques for defining and estimating relevant reserve geo-demographic market areas and market segments;
- (3) to develop a prior service supply model;
- (4) to develop a non-prior service supply model;
- (5) to develop models for optimal allocation of authorizations and recruiters across alternative sites and reserve centers;
- (6) to integrate the non-prior service, prior service, and optimal allocation models; and
- (7) to test and evaluate the final integrated model at USAREC

**Summary:** Objective (1) above was funded for FY 86. Data files such as those listed below will be obtained. Relevant data elements will be extracted from these data files and concatenated into master data bases so that standard data extraction/statistical packages may be utilized. The resultant data bases will be made available on the Recruit Marketing Network so that the RAMIS data management system may be utilized.

- (a) 1979 Rand Reserve Forces Survey
- (b) 1980/81 USAREC Reserve Market Survey
- (c) Reserve Component Attitudes Study 1978-82
- (d) Youth Attitude Tracking Studies 1983-1985
- (e) DMDC Reserve Components Common Personnel Data System
- (f) National Longitudinal Survey of Youth Labor Market Experience (1979-85)
- (g) Census Bureau, Current Population Survey
- (h) Census Bureau, Public Use Microdata Sample
- (i) Census Bureau, Summary Tape Files I-IV

- (j) Census Bureau, Country Business Patterns
- (k) Bureau of Labor Statistics, Area Wage Surveys
- (l) Bureau of Labor Statistics, Unemployment in States and Local Areas
- (m) Bureau of Labor Statistics, Employment and Earnings
- (n) University of Michigan, Panel Study of Income Dynamics

Publications:

G.W. Thomas, S.L. Mehay, J.I. Borack,  
"Estimating Local Area Labor Supply" in  
progress



Title: Fairness in Testing: Technical and Judgmental Approaches

Investigator: R.A. Weitzman, Associate Professor

Sponsor: None

Objective: To show the effect of maximizing test validity on test bias

Summary: This research supports the position that judgmental approaches to test bias need to be informed by technical approaches, the particular example cited showing the technical effect of maximizing test validity on test bias. The research is completed, and the report is in preparation.

Title: The Rasch Model Plus Guessing

Investigator: R.A. Weitzman, Associate Professor

Sponsor: None

Objective: To incorporate the effect of guessing into the Rasch model when applied to multiple-choice items

Summary: . The standard Rasch model has a single parameter, representing item difficulty. This research has added a guessing parameter, equal for all items, and has evaluated the model so revised on actual test data. The results are good, and a report is in preparation.

**DEPARTMENT  
OF  
OPERATIONS RESEARCH**

## DEPARTMENT OF OPERATIONS RESEARCH

Sponsored research conducted by members of the Department of Operations Research (OR) spans a wide range of topics, consistent with the multi-disciplinary nature of the Operations Research field. Specialization areas include optimization, stochastic models, statistics, simulation and modeling. Applications of work in these areas include reliability, mathematical programming, search, stochastic modeling, data analysis, statistics, warfare modeling (ASW, EW, and AAW modeling), inventory, manpower modeling and simulation models.

### OPTIMIZATION

Professors G. G. Brown and G. H. Bradley (Computer Science Department) have continued their work on large-scale optimization, under Office of Naval Research sponsorship. Their current work involves development of specialized algorithms which exploit the structure in large mixed integer models arising in certain applications such as refinery scheduling and design of electrical transmission systems. Brown and Bradley have developed a mathematical programming modeling system to allow direct execution of optimization models.

Professor Brown has also collaborated with Professors R. E. Rosenthal and K. Wood on a Defense Nuclear Agency sponsored project to study a class of pure network assignment and transportation problems with the aim of developing an entirely new family of "super speed" algorithms for their solution.

Professor R. E. Rosenthal has been conducting research on the classical "assignment" problem. Even though there exist efficient algorithms for solving practical assignment problems, there is need for more efficient algorithms. The objective of this research has been to develop and test improved algorithms for this problem.

### STOCHASTIC MODELING, DATA ANALYSIS AND STATISTICS

Distinguished Professor D. P. Gaver and Professor P. A. Jacobs are working on the use of robust estimation methods for solving the problem of combining several multivariate observations on location (the "location fusion" problem). This work has been sponsored by the National Security Agency.

Professors Gaver and Jacobs also continued their research on development of new methods of statistical data analysis and probability modeling. They have had Office of Naval Research sponsorship for this work.

Professor R. R. Read has had U. S. Marine Corps funding for research on the use of shrinkage type estimators for forecasting the attrition loss rates used in the USMC manpower planning models.

Professor D. R. Barr has continued his research on target acquisitions made in multi-target situations. The purpose of this work is to determine ways to extend single-target models to the multi-target scenario. This work has been sponsored by the U. S. Army TRADOC Operations Research Activity.

Professor J. D. Esary received Naval Undersea Warfare Engineering Station funding to investigate tradeoffs between redundancy in launches of torpedoes and interferences between simultaneously running torpedoes.

Professors H. J. Larson and T. Jayachandran (Mathematics Department) have continued their work on enhancing the effectiveness of the Joint Oil Analysis Program, under U. S. Air Force sponsorship.

Professor P. A. W. Lewis has been conducting research, under Office of Naval Research sponsorship, on several new time series models for non-normal variables. He has also been working on new statistical methodologies for use in simulations of time series processes, and in analyzing large scale non-normal time series.

#### SIMULATION AND MODELING

Professors J. N. Eagle, R. N. Forrest and H. Eldor have had Naval War College funding to support several projects related to wargame development at the Naval War College. Professor Eagle evaluated the submarine engagement model SUBSUB, and suggested several modifications for its improvement. Professor Forrest proposed and analyzed an active acoustic detection model, and compared it with the currently used NWGS model. Professor Eldor developed and analyzed a microcomputer based decision aid for umpires conducting seminar wargames.

Professor S. H. Parry has continued his work on the development of a Corps level force-on-force airland combat model, called ALARM. Topics included development of algorithms for a generalized value system, avenue of approach generation, maneuver force allocation on the transportation network and investigation of the use of distributed processing in the model.

#### WARFARE MODELING

Professors Forrest and Eagle also collaborated with Professor R. Shudde on investigations of existing integrated battle group tactical decision aid model algorithms. This work was sponsored by the CNO Director of Tactical Readiness.

Professor A. Andrus also received CNO Director of Tactical Readiness research sponsorship. This work included review of the system capabilities and the economic and technical feasibility of the proposed development plan for the Tactical Information Management System. Professor Andrus also developed a simulation model for assessing air target penetration through surface-to-air missile defenses.

Adjunct Professor E. B. Rockower conducted statistical studies and developed models related to the measurement, assessment, and identification of effectiveness measures relating to EW training and readiness. This work was sponsored by CNO Director of Electronic Warfare. Professor Rockower also had Space and Naval Warfare Systems Command support to investigate the use of off-board decoys in single and multiple ship missile engagements.

## INVENTORY AND PROCUREMENT

Professors F. R. Richards and A. W. McMasters used funding by the Navy Fleet Material Support Office to continue their research on wholesale inventory models for the U. S. Navy. Modifications of the multi-echelon repairables model developed earlier were made to reflect current demands at the Inventory Control Point level.

## MANPOWER MODELING

Professors P. R. Milch and R. K. Wood investigated two problems under sponsorship by Headquarters, Marine Corps. One problem concerned the development of a computer based algorithm to determine selective reenlistment bonus multipliers which minimize deviations from a target force. The second problem was to develop a model for assigning, under mobilization, active, reserve and retired officers.

## SOVIET MILITARY OPERATIONS RESEARCH

Professor J. G. Taylor has continued his research on Soviet Cybernetic concepts. His work was directed to determining the concepts that are critical for American understanding of the design and operation of the Soviet automated troop control system. This work was sponsored by the USAF Systems Command, Headquarters Foreign Technology Division.

Professor Taylor also had C<sup>3</sup> Counter Measures Joint Test Force support to develop a conceptual basis for Soviet command, control and communications.

## HUMAN FACTORS

Professor G. K. Poock continued his work on speech input systems, sponsored by the Naval Ocean Systems Command. This year, the speech input system built by SRI was examined to determine whether it is suitable for use in Navy command and control workstations.

**Title:** Fleet Mission Program Library Algorithm Validation

**Investigators:** A. Andrus, Associate Professor of Operations Research  
R. Shudde, Associate Professor of Operations Research  
J. Eagle, Assistant Professor of Operations Research  
R.N. Forrest, Professor of Operations Research

**Sponsor:** CNO OP-953: Director of Tactical Readiness  
Director: Fleet Mission Program Library Central  
Development Agency

**Objective:** Review and technically validate Integrated Battlegroup  
Tactical Decision Aid Model algorithms

**Summary:** Algorithms for Anti-Air Warfare, Anti-Submarine Warfare  
and motion analysis for the Fleet Mission Program Library  
Integrated Battle Group Tactical Decision Aid have been  
evaluated. This decision aid is a CNO sponsored and funded  
project for the support of active fleet units. Model  
development is managed by the Fleet Mission Program Library  
Central Development Agency at the Naval Air Development  
Center. Most of the development is under contract to  
civilian industry contractors. The faculty and students of  
the Naval Postgraduate School play an important role in  
providing independent technical assessments and evaluations  
of model algorithms.

**Publications:** A. Andrus and R. Shudde, "Computer Aided Stationing Tool  
(CAST) Preliminary Technical Evaluation," Naval Postgraduate  
School Technical Report NPS55-85-027, November 1985.

R.N. Forrest, "An Analysis of Some Anti-Submarine Warfare  
Related Tactical Decision Aid Models," Naval Postgraduate  
School Technical Report NPS71-86-001, February 1986.

R. Shudde, "Some Tactical Algorithms for Spherical  
Geometry," Naval Postgraduate School Technical Report  
NPS55-86-008, March 1986.

**Thesis Directed:** D. Yoshihara, "An Evaluation of the Joint Operational  
Tactical System's Anti-Air Warfare Screen Tactical Decision  
Aid," Master's Thesis, March 1985.

**Title:** Simulation Model Development for Anti-Air Warfare

**Investigator:** A. Andrus, Associate Professor of Operations Research

**Sponsor:** No Sponsor

**Objective:** Develop a simulation model for assessing air target penetration through surface-to-air missile defenses.

**Summary:** Model development has been completed. NPS technical report documentation is being completed and will include an example of model application. Model will be used for instructional purposes in simulation and wargaming courses and for research in analyzing missile fire procedures. The model is written in FORTRAN-77 for the NPS mainframe IBM-3033 computer. Model output includes tabulated summaries of shots and kills and a tabulated and graphic battle history of events.



**Title:** Tactical Information Management System Evaluation

**Investigator:** A. Andrus, Associate Professor of Operations Research

**Sponsor:** CNO OP-953: Director of Tactical Readiness

**Objective:** Review and evaluate development plan for the Tactical Information Management System.

**Summary:** The Tactical Information Management System is a CNO sponsored hardware/software system for automated Anti-Submarine Warfare exercise reconstruction. The system is installed and used in fleet command centers world wide. The system is limited by it's current hardware configuration and the resulting constraints on software development and applications. The Navy Tactical Support Activity has developed a plan for system improvements that is currently on "hold". This research reviewed the system capabilities and the economic and technical feasibility of the proposed development plan.

**Publication:** A. Andrus, "Review and Recommendations for Tactical Information Management System II Proposed Development," Naval Postgraduate School Technical Report NPS55-86-019, October 1986.

**Title:** Target Acquisition Analysis

**Investigator:** D.R. Barr, Professor of Operations Research & Statistics

**Sponsor:** U.S. Army TRADOC Operations Research Activity

**Objective:** The objectives of this research were to develop analysis methodology appropriate for use with multi-target acquisition processes encountered in U.S. Army Field Experiments, and to apply these methods to selected data sets. The main purpose of this work is to determine ways in which models used for single-target situations might be extended to fit multi-target engagements. This work is a continuation of a project begun last year.

**Summary:** Generally, inferences about acquisition processes based on data from experiments with tanks are complicated by several factors, including data censoring, data omissions, gunner and tank commander tactics and learning factors. In an ongoing project, an investigation is being made of analysis methods which can be used to assess target acquisition characteristics in recent field experiments, such as the Thermal Pinpoint and the Anti-armor Systems Detectability (AASD) study experiments. These methods, as well as classical methods, were applied to selected portions of the Thermal Pinpoint and AASD data sets to determine some of the joint effects of the design variables and covariables on acquisition dependent variables. This revealed interesting joint interrelationships not detected in the marginal (single variable) analyses that were conducted earlier.

Understanding of the target acquisition process has been enhanced by analyses of accumulated times each target was in the field of view of each tank sight system in the Thermal Pinpoint and AASD experiments. This analysis suggests a model to allow multi-target evaluations of continuous times to acquisition similar to those suggested by the U.S. Army's Night Vision and Electro-Optics Laboratory for single target situations.

**Publications:** Letter report to sponsor, forthcoming.

**Theses Directed:** L.M. DuBois, "Comparison of Time to Detect Definitions," Master's Thesis, June 1986.

R.S. Alexander, "An Investigation of Target Detectability Phenomena," Master's Thesis September 1986.

Title: Large-Scale Optimization

Investigator(s): G.G. Brown, Professor of Operations Research  
G.H. Bradley, Professor of Computer Science

Sponsor: Office of Naval Research

Objective: Develop theory and algorithms for solution of large-scale optimization models.

Summary: A continuing research effort emphasizing exploitation of special problem structure. Decomposition and relaxation methods are being developed and applied in concert with specialized algorithms to solve the subproblems produced. The main impetus of this work is provided by large mixed integer models arising in diverse contexts ranging from capital budgeting to refinery scheduling. Large nonlinear and network models are also addressed for electrical transmission systems, chemical equilibria problems, and the like. Special integer enumeration control structures are being developed which employ a novel elastic model formulation especially useful for difficult integer master problems generated by primal or dual decomposition schemes. A mathematical programming modeling system to allow direct execution of optimization models is being developed. Each major avenue of research is thoroughly tested on real-life problems provided by other researchers, government agencies and commercial sources.

Publications: G. Brown, R. McBride, and K. Wood, "Extracting Embedded Generalized Networks from Linear Programming Problems," Mathematical Programming, 32, 1985, pp. 11-31.

G. Brown, G. Graves, and M. Honczarenko, "Design and Operation of a Multicommodity Production/Distribution System Using Primal Goal Decomposition," Management Science, forthcoming.

G. Brown and R. McBride, "Solving Generalized Network Problems," Management Science, 30, 1984, pp. 1497-1523, (Lanchester Prize Finalist).

G. Brown, G. Graves and D. Ronen, "Scheduling Ocean Transportation at Crude Oil," Management Science, forthcoming.

G. Brown, C. Ellis, G. Graves, and D. Ronen, "Wide Area Dispatch of Mobil's Tank Trucks," Interfaces, forthcoming. (International Management Science Achievement Award Finalist).

G. Brown and W. Wright, "Automatic Identification of Embedded Network Rows in Large-Scale Optimization Models," Mathematical Programming, 29, 1984, pp. 41-56.

G. Bradley, "Optimization of Capital Portfolios," Proc. of the National Communication Forum 86, Sept 29, 1986, Chicago, IL.

Conference  
Presentations:

G. Brown, "Set Partitioning Applied To Optimizing Fleet Activities," Pennsylvania State University Lecture Program, State College, Pennsylvania, February 15, 1985.

G. Brown, "Scheduling Ocean Transportation of Crude Oil," Stanford University Colloquium, Palo Alto, California, March 6, 1985.

G. Brown and C. Ellis, "Real-Time, Wide Area Dispatch of Petroleum Tank Trucks," CPMS Summer Workshop, Golden, Colorado, July 29, 1985.

G. Brown, L. Dewald, and K. Wood "Network Specialization of Non-Cycling Primal Simplex Methods," ORSA/TIMS, Boston, Massachusetts, April 30, 1985.

G. Brown, C. Goodman, and K. Wood, "Annual Scheduling of Atlantic Fleet Naval Combatants," 12<sup>th</sup> International Symposium on Mathematical Programming, Boston, Massachusetts, August 6, 1985.

G. Bradley and R. Clemence, "Implementation of a Structured Modeling Language for Optimization", 12<sup>th</sup> International Symposium on Mathematical Programming, Boston, Massachusetts, August 7, 1985.

G. Bradley, "Cognitive Science View of Software Engineering," Proc of the Software Engineering Education Workshop, Pittsburgh, February 1986.

G. Brown, C. Goodman, and K. Wood, "Annual Scheduling of Surface Combatants at the U.S. Atlantic Fleet," ORSA/TIMS, Miami, October 27, 1986.

Theses Directed:

G. Breitschnieder, "Solving Linear Programs with the Projective Algorithm," Master's Thesis, September 1985.

P. Dorin, "How Cognitive Processes Aid Program Understanding", Master's Thesis, June 1985.

C. Murnan, "Reusable Software: Trade-off Analysis and a New Approach", Master's Thesis, June 1985.

**Title:** Large-Scale, Real-Time Network Optimization

**Investigators:** G.G. Brown, Professor of Operations Research  
R.E. Rosenthal, Associate Professor of Operations Research  
K. Wood, Assistant Professor of Operations Research

**Sponsor:** Defense Nuclear Agency

**Objective:** Develop theory and algorithms for solution of Large-Scale Network Optimization Models.

**Summary:** A class of pure network assignment and transportation problems has been studied with the view of developing an entirely new family of "super speed" algorithms. Extensive computational work has shown that the implemented methods are at least an order of magnitude faster than their predecessors, and may be even faster on larger real-life problems.

**Title:** ASW Modelling

**Investigators:** J.N. Eagle, Professor of Operations Research, R.N. Forrest, Professor of Operations Research, and H. Eldor, Professor of Operations Research

**Sponsor:** Naval War College

**Objective:** To support seminar wargame development for the Naval War College

**Summary:** Professor Eagle's Research: At the request of the Wargaming Center of Naval War College, Newport, RI, an examination was made of the submarine engagement model SUBSUB. In this model, engagements are considered from search through detection, classification, localization, closure, attack and counterattack. The submarine missions modelled are barrier patrol, area patrol and transit. All sections of the model were evaluated and several modifications suggested.

Professor Forrest's Research: Professor Forrest proposed and analyzed an active acoustic detection model. Analytical and experimental comparisons were made and the new model was suggested to replace the currently used NWGS active sonar model.

Professor Eldor's Research: A microcomputer-based decision aid for umpires conducting seminar wargames was designed and analyzed.

**Publications:** R.N. Forrest, "An Active Acoustic Detection Model Analysis", Naval Postgraduate School Technical Report NPS55-86-024, November 1986.

J.N. Eagle, "SUBSUB -A Submarine Engagement Model", Naval Postgraduate School Technical Report NPS55-86-005, March 1986.

H. Eldor, "Kinematics/Detection Model for a Naval Seminar Game", Naval Postgraduate School Technical Report NPS55-86-020, October 1986.

**Title:** Modelling and Wargame Development

**Investigator:** J.N. Eagle, Professor of Operations Research  
R.N. Forrest, Professor of Operations Research  
H. Eldor, Adjunct Professor of Operations Research

**Sponsor:** Naval War College

**Objective:** To develop modules for the on-going program at the Naval War College, for development of a Naval Wargaming System (NWGS)

**Summary:** Haim Eldor's work concentrated on the first phase of the wargame, i.e. the kinematics to detection (inclusive) stage. In the report a computer program is described which is intended to provide real-time support for umpires conducting two-sided seminar wargames. The program is designed to operate on a microcomputer.

The game is assumed to take place between players at the Battle Force or Fleet Commander level. The commander controls the movements and operations of battle groups, and in some cases task forces, at the theatre level. The group in each case will be those of the highest possible level that still maintains the unique detection capabilities of the individual group. The groups are represented either by a collection of point units (say a carrier escorted by several other platforms), or by an area (circular or rectangular) patrolled and/or screened by any type of platforms (submarines, aircraft, etc.). The whole group moves on its track as one unit.

The model presented performs the following analyses:

- a) Plans the tracks for all groups according to the players specifications.
- b) Controls the timing for status changes: courses, speeds, EMCON plans, etc.
- c) Investigates possible detection opportunities among all groups by checking intersections among all relevant opposing "area groups" and/or ranges to the opponent's detection systems.

The final decision as to the actual detection (the realization of the detection opportunity) is left to the control (the umpire), using a display of any combination of groups desired. Once a detection is achieved, the model exits (at the umpire's instruction) to an engagement model (not discussed in this report). After the engagement results are determined, a return is made to the kinematics/detection model.

**Publications:** H. Eldor, Kinematic/Detection Model for a Naval Seminar Game, Naval Postgraduate School Technical Report NPS55-86-020, October 1986.

**Title:** Modeling of Interferences During Torpedo Salvo Launches

**Investigator:** J.D. Esary, Professor of Operations Research

**Sponsor:** Naval Undersea Warfare Engineering Station

**Objective:** To explore, at the event sequence level of probability modeling, trade-offs in salvo torpedo launches between redundancy against material and tactical failures, and interferences between simultaneously running torpedoes.

**Summary:** The feasibility of salvo launch tactics can be addressed by actual testing; by detailed simulations incorporating search and honoring geometries along with interferences and material failures; or by probabilistic modeling of the interaction of launch, search, acquisition, closure, interference and material failure events. The latter approach is apt to be the least definitive, but most immediate way to review the trade offs between the negative possibilities of interferences between simultaneously running torpedoes, and the positive possibilities of redundancy against torpedo failures and multiple hits. The approach being followed is to analyze very simple event sequence models initially, moving towards greater sophistication.



**Title:** Statistical Analysis of Multivariate Observations

**Investigators:** D.P. Gaver, Distinguished Professor of Operations Research, and P.A. Jacobs, Professor of Operations Research

**Sponsor:** National Security Agency

**Objective:** To consider the combination ("Fusion" or "Pooling") of several multivariate observations on location as a problem of robust estimation in the presence of various noise sources.

**Summary:** A small number of observers measure with error one or more parameters of a signal from one object of a known group of objects. Several linear and nonlinear algorithms that combine observer measurements to identify the signaling object are presented and studied. Robustness of the algorithm to outlying and long-tailed measurement errors are studied using Monte Carlo simulation. Results demonstrate that maximum likelihood estimators based on Cauchy or mixed ("contaminated") normal measurement errors are satisfactory for both robust and nonrobust (outlier-prone) situations while classical linear methods perform poorly if outliers are present.

**Publications:** D.P. Gaver, P.A. Jacobs, I.G. O'Muircheartaigh, and A. Meldrum, "Problems of Identification," Naval Postgraduate School Technical Report, NPS55-86-021, November, 1986.

**Conference:** D.P. Gaver, P.A. Jacobs, I.G. O'Muircheartaigh, and A.G. Meldrum, "Emitter Identification Using Robust Statistics: Theory and Examples," Specific Emitter Identification Symposium, Maryland, July 1986.

**Thesis Directed:** A.G. Meldrum, "Transmitter Identification with a Small Number of Independent Observers," Master's Thesis, September 1986.

**Title:** Stochastic Modelling and Data Analysis

**Investigators:** D.P. Gaver, Distinguished Professor of Operations Research, and P.A. Jacobs, Professor of Operations Research

**Sponsor:** Office of Naval Research

**Objective:** To develop, apply and test and validate new methods of statistical data analysis and probability modeling for solving problems arising in applications, with special reference to problems in the Navy, and the government and military in general.

**Summary:** Estimation procedures have been developed for pooling data from different sources. Probabilistic models have been proposed and studied for resource conflict resolution and processor-sharing time-sharing computer systems. Procedures for the nonparametric estimation of the probability of a long delay in queueing systems have been developed.

**Publications:** D.P. Gaver and G. Fayolle, "A Resource Conflict Resolution Problem Formulated in Continuous Time," Modeling Techniques and Tools for Performance Analysis, 85 ed. N. Abu ET Ata. Elsevier Science Publishers R.V. (North-Holland), 1986, pp. 359-365.

D.P. Gaver and P.A. Jacobs, "On Inference and Transient Response for M/G/1 Models," Teletraffic Analysis and Computer Performance Evaluation, ed. O.J. Boxma, J.W. Cohen, H.C. Tijms. Elsevier Science Publishers B.V. (North-Holland), 1986, pp. 163-170.

P.A. Jacobs, "First Passage Times for Combination of Random Load," SIAM Journal of Applied Mathematics, 46 (1986) pp. 643-656.

D.P. Gaver and P.A. Jacobs, "Processor-shared Time-sharing Models in Heavy Traffic," SIAM Journal on Computing, forthcoming.

D.P. Gaver and I.G. O'Muircheartaigh, "Robust Empirical Bayes Analysis of Event Rate," Naval Postgraduate School Technical Report NPS55-86-007, 45 pp. Technometrics, forthcoming.

I.G. O'Muircheartaigh and D.P. Gaver, "Estimation of Sea Surface Wind Speed from White Cap Cover: Statistical Approaches Compared Empirically and by Simulation," International Journal of Remote Sensing, forthcoming.

I.G. O'Muircheartaigh and D.P. Gaver, "The Prediction of Sea Surface Wind Speed from Whitecap Cover and the Evaluation of the Performance of Various Calibration Methods,"  
Proceedings 9th Conference on Probability and  
Statistics in Atmospheric Sciences, American Meteorological  
Society, Boston, Mass., 1985.

**Title:** Statistical Support Services for the Joint Oil Analysis Program

**Investigators:** H.J. Larson, Professor of Operations Research  
T. Jayachandran, Professor of Mathematics

**Sponsor:** Kelly AFB TX

**Objective:** To support and enhance the effectiveness of the Joint Oil Analysis Program in support of on condition maintenance of DOD equipment.

**Summary:** Completed review and analysis of field test data collected for the Portable Wear Metal Analyses (PWMA). Reviewed the literature on using rational equations for instrument calibration and examined the properties of several calibration procedures. Reviewed the literature for statistical fitting of spline functions and procedures for easily estimating their coefficients. Completed a review of the current Joint Oil Analysis Correlation Program and made initial suggestions regarding its possible improvement. Prepared more example data sets for testing the CEMS IV implementation on the Z100 microcomputer.

**Publications:** T. Jayachandran, H.J. Larson, "PWMA Field Test", Naval Postgraduate School Project Report, NPS-53-86-002PR.

**Title:** Stochastic Modelling, Time Series Analysis and Simulation

**Investigator:** P.A.W. Lewis, Professor of Statistics and Operations Research

**Sponsor:** Office of Naval Research

**Objective:** The purpose of this research is to develop models and theory for time series and stochastic point processes, develop new statistical methodology for use in the simulations which are required in mathematical statistics and in the analysis of stochastic systems, and develop methods for the analysis, display and editing of large scale, non-normal time series.

**Summary:** Several new time series models for non-normal variables have been developed. One is the square-root-Beta-Laplace process, which is a broad, autoregressive alternative to the usual normal AR(1) model. Extensions of this model to bivariate time series have been undertaken. To discriminate between the many known time series with identical marginal and second order structure, a higher order residual analysis has been developed. It is based on the idea that the forward and background residuals in processes with autoregressive structures are incorrelated, but not independent unless the process is Gaussian. In simulation several new ideas for variance reduction using conditional sampling are being explored. One of these ideas involves representing random variables as exponential time independent random variables. The other uses piecewise linear control variables and the ACE methodology of Friedman and Berman. In addition the simulation testbed program, SIMTBED, has been extended in several ways.

**Publications:** P.A.W. Lewis and L. Breaker, "On the Detection of a 40 to 50 Day Oscillation in Sea Surface Temperature Along the Central California Coast, Naval Postgraduate School Technical Report NPS55-85-025, September 1985.

P.A.W. Lewis, L. Dewald, and E. McKenzie, "A Bivariate Autoregressive Exponential Time Series Model", in progress.

P.A.W. Lewis, "Higher Order Residual Analysis for Nonlinear Time Series with Autoregressive Correlation Structures", Naval Postgraduate School Technical Report NPS55-85-030, December 1985.

P.A.W. Lewis, E. McKenzie, D. K. Hugus, "Gamma Time Series", Naval Postgraduate School Technical Report NPS55-86-002, January 1986.

P.A.W. Lewis, "Graphical Analysis of Some Pseudo-Random Number Generators", forthcoming.

Conferences:

P.A.W. Lewis, "Box Plotted Tables and the Graphical Analysis of Panel Data", IBM Research Center, New York, October 25, 1985.

P.A.W. Lewis, "Gamma Processes", Harvard Biostatistics Department Seminar, Massachusetts, October 23, 1985.

P.A.W. Lewis, "Laplace Processes", Harvard Biostatistics Department Seminar, Massachusetts, October 24, 1985.

P.A.W. Lewis, "Higher-Order Residual Analysis for Time Series with Autoregressive Correlation Structure ", Harvard Biostatistics Department Seminar, Massachusetts, October 25, 1985.

P.A.W. Lewis, "Elements of Simulation Methodology", International Conference on Simulation Dissimulation, Venice, Italy, November 13, 1985.

P.A.W. Lewis, "Introduction to Simulation", Computer Sciences and Statistics: The Symposium of the Interface, Colorado, March 18-22, 1986.

P.A.W. Lewis, "Gamma Processes", ORSA Annual Meeting, California, April 19-21, 1986.

Thesis Directed:

J. Isusi, "Boxplotted Tables and Other Graphical Techniques for Exploratory Data Analysis, Master's Thesis, September 1986.

**Title:** Marine Corps Manpower Research Project

**Investigator:** P.R. Milch, Professor of Operations Research, and  
R.K. Wood, Assistant Professor of Operations Research

**Sponsor:** Headquarters Marine Corps

**Objective:** Two separate projects were to be investigated:

**The Selective Reenlistment Bonus Program:** The development of a computer-based algorithm to determine selective reenlistment bonus multipliers which minimize a weighted manpower deviation from a target force, subject to both annual budget constraints as well as DoD and Marine Corps specified constraints.

**Mobilization Assignment Model:** Initiation of a new research effort (to be continued in FY87) towards the development of an assignment model, under mobilization, of active, reserve and retired officers of the Marine Corps.

**Summary:** Selective Reenlistment Bonuses (SRBs) are offered to improve retention in designated military occupational specialties (MOSs) for specified years-of-service intervals (zones). The amount of the bonus is set by assigning an "SRB Multiplier" for each MOS and zone combination (cell). Determination of multipliers was modeled as a nonlinear knapsack problem which was then linearized to a special generalized assignment problem. The objective is to minimize the sum over all cells of a weighted squared deviation from the reenlistment target in each cell. Lagrangian relaxation provides lower bounds and feasible solutions. The best feasible solution is improved using a greedy heuristic to apportion unexpended funds. The procedure was implemented with a FORTRAN program. Data for FY86 yielded a 0-1 integer programming problem with 4895 binary variables and 980 constraints. A solution within .01% of optimality was obtained on an IBM 3033AP in 1.7 seconds and on an IBM PC in four minutes.

**Mobilization Assignment Model:** Information gathering, fact finding and initial problem definition have been accomplished. Two problem areas have been identified:

- (a) Optimal distribution of Marine Corps Officers (active, reserve and retired) under mobilization, and
- (b) Construction of an algorithm to analyze the "Dictionary", the collection of Marine Corps policies, rules and regulations governing officer distribution. The purpose of this analysis will be to both uncover inconsistencies among the regulations and to discover hidden, de facto, rules that have arisen as the result of the combination of several new regulations added to the "Dictionary" at various points in time. These efforts will be continued in FY87.

**Publications:** D.D. DeWolfe and R.K. Wood, "Optimal Determination of Selective Reenlistment Bonus Multipliers in the United States Marine Corps," in progress.

**Conference Presentations:** D.D. DeWolfe and R.K. Wood, "Optimal Allocation of Selective Reenlistment Bonuses in the U.S. Marine Corps," TIMS/ORSA Joint National Meeting, Miami, October 27-29, 1986.

**Thesis Directed:** D.D. DeWolfe, "Determination of Selective Reenlistment Bonus Multipliers in the United States Marine Corps," Master's Thesis, March 1986.



**Title:** Airland Research Model (ALARM)

**Investigator:** S.H. Parry, Associate Professor of Operations Research,  
and A.L. Schoenstadt, Professor of Mathematics

**Sponsor:** U.S. Army TRADOC Operations Research Activity

**Objective:** The overall objective of ALARM is to develop, implement and validate several new methodologies for a Corps level force-on-force airland combat model. The specific objectives for this third year of research are to develop algorithms for a generalized value system, avenue of approach generation, maneuver force allocation on the transportation network, field artillery maneuver and engagement decisions, maintenance and recovery modules, and initial investigations of distributed processing.

**Summary:** The initial two years of research are summarized in prior research activity reports. The third year of research essentially showed that methodologies previously postulated as possible approaches were demonstrated to be both feasible and workable. In particular, three thesis efforts have demonstrated that the Generalized Value System as originally postulated is, indeed, an appropriate tool for future state decision making as it relates to allocation of assets to targets (see Ref. 3, 7, 8, 9). An operational model to allocate direct fire and supporting assets to an actual network was developed and executed (see Ref. 2). Several important algorithms regarding the use of indirect fire assets were developed and demonstrated (see Ref. 1 and 4). A high resolution model representing battlefield maintenance and recovery was developed, programmed, and run with a database derived from historical battles (see Ref. 5). The initial design of information flow from the Execution to Planning Model Components of ALARM was completed (see Ref. 6). Finally, the initial conceptual design of ALARM was completed and documented (see Ref. 10). In summary, this third year of research continued the development of modules for ALARM. Most importantly, however, the research represented a transition from hypotheses concerning various new methodologies for the future generation of AIRLAND Combat Models into implementation of demonstrated concepts. An integral part of the research is the conclusion that all future models must possess a distributed processing architecture as a fundamental component of the initial design. The goal of the next year of research is to produce an operational model which brings together the various research efforts previously accomplished.

Publications: S.H. Parry, A.L. Schoenstadt, "Toward An Axiomatic Generalized Value System", Naval Postgraduate School Technical Report NPS53-86-008, May, 1986.

Rolands and Associates, "Preliminary Conceptual Design for the Airland Research Model", August, 1986.

Conference Presentations: "Network Methodology for the Airland Research Model", Samuel Parry, 54th Military Operations Research Symposium, Ft. McNair, Washington, D.C., 24 June 1986.

Thesis Directed: L.M. Finley, "A Field Artillery Module for the Airland Research Model", Master's Thesis, March 1986.

J. McLaughlin, "The Extension of Unit Allocation and Countermobility Planning Algorithms in the Airland Research Model", Master's Thesis, March 1986.

R.A. Kilmer, "The Generalized Value System and Future State Decision Making", Master's Thesis, March 1986

R. Lindstrom, "Extensions of Field Artillery in the Airland Research Model", Master's Thesis, March 1986

A.W. Olsen, "Battlefield Maintenance and Recovery Module for the Airland Research Model", Master's Thesis, March 1986.

C. Smith, "Foundations of the Intelligence Module for the Airland Research Model", Master's Thesis, September 1986.

D. Fletcher, "Models for Avenue of Approach Generation and Planning Processes for Ground Combat Forces", Master's Thesis, September 1986.

J. Geddes, "An Algorithm for Allocating Artillery Support in the Airland Research Model", Master's Thesis, September, 1986.

**Title:** Test, Analyze and Evaluate the Usefulness of Current Speech Recognition Technology in a Command and Control Work Station Environment

**Investigator:** G.K. Poock, Professor of Operations Research

**Sponsor:** Naval Ocean Systems Command

**Objective:** To examine a speech input system built by SRI for use in Navy Command and Control Workstations.

**Summary:** Background information was read related to development of a special speech processing board capable of handling up to 1000 utterances in discrete speech input mode. Experiments were carried out showing the accuracy of the system, human factors needs and limitations needing improvement for operational Navy use.

**Publications:** G.K. Poock, "Final Report, Fiscal Year 1986: Test, Analyze and Evaluate the Usefulness of Current Speech Recognition Technology in a Command and Control Work Station Environment," Internal Research Memo, 1986, 19 pages.

**Thesis Directed:** M.A. LeFever, "Speech Recognition in a Command and Control Work Station Environment," Masters Thesis, March 1987.

**Title:** Attrition Rate Generation for Manpower Models

**Investigator:** R.R. Read, Professor of Operations Research Department

**Sponsor:** U. S. Marine Corps, Headquarters, MPI 40

**Objective:** To explore the efficacy of the James-Stein and other shrinkage type estimators for forecasting the numerous and various attrition loss rates that appear in the Marine Corps manpower planning models.

**Summary:** This is a continuing project. The class of James-Stein estimators has been applied in a variety of ways. The following steps have been identified: i) the aggregation of internally homogenous, ii) the application of a variance stabilizing transformation to the empirical rates of each group, iii) the estimation of the shrinkage parameters for each group, iv) the application of the shrinkage technique, and v) The inversion of the transform to return to the original scale.

The efficacy of a candidate technique is measured using a sum of squares deviation of forecast rates from recent year actuals. The validation procedure is applied to the transformed quantities as well as to the rates in the general Fortran software and the extension of our pilot calculations to much larger data bases.

Thus far, the indications provided by the pilot calculations are confirmed. The technique is a viable one and we should prepare to implement. The limited translation technique of Efron and Morse is not useable. Exponential smoothing was tried as a yearly update technique with modest success.

**Thesis Directed:** D.D. Tucker, "Loss Rate Estimation in Marine Corps Manpower Officer Manpower Models," Naval Postgraduate School, Master's Thesis, September 1985.

H. Elseramegy, "CART Program: Implementation on the IBM3033 and Application to Marine Corps Manpower Data, Master's Thesis, December 1985.

J.R. Robinson, "Limited Translation Shrinkage Estimation of" Loss Rates in Marine Corps Manpower Models," Master's Thesis, March 1986.

D.L. Hogan, "The Use of Exponential Smoothing to Produce Yearly Updates of Loss rate Estimates in Marine Corps Manpower Models," Master's Thesis, June 1986.

**Title:** Resystemization Modelling Support

**Investigator:** F.R. Richards, Associate Professor of Operations Research  
A.W. McMasters, Associate Professor of Operations Research  
and Administrative Sciences

**Sponsor:** Navy Fleet Material Support Office

**Objective:** This is a continuing research effort to develop improved  
wholesale inventory models for the U.S. Navy.

**Summary:** The multi-echelon repairables model developed last year was  
modified to reflect current demands at the Inventory Control  
Point (ICP) level. This was done by aggregating all the  
demands at the lower echelons. Two formulations of the ICP  
level model were then proposed. One was to minimize investment  
levels (Navy Stock Fund levels) subject to an upper bound on  
mean supply response time (MSRT); the other was to minimize  
MSRT subject to a constraint on investment levels. Workload  
constraints from the Navy's ICPs were also added. Using data  
provided by the sponsor, evaluation of both models has begun.  
As this evaluation progresses it is expected that additional  
constraints will be added by the ICPs.

**Publication:** A.W. McMasters, "Wholesale Provisioning Models: Model  
Evaluation," Naval Postgraduate School Technical Report,  
NPS55-86-011, May 1986.

**Thesis Directed:** R.B. Gormly, "Analysis of An Aggregate Demand Repairables  
Model," Master's Thesis, December 1985.

Title: MOE Development for Electronic Warfare Training and Readiness

Investigator: E.B. Rockower, Adjunct Professor of Operations Research

Sponsor: Chief of Naval Operations, Director of Electronic Warfare

Objective: Provide support through modelling and statistical studies addressing measurement, assessment and identification of effectiveness measures relating to EW training and readiness. Tasks relate to the study and development of appropriate MOE's for the eventual goal of providing control mechanisms for monitoring and improving EW training and readiness. Support is mainly for the EW students and curriculum.

Summary: I hosted the EW Continuum Assessment (EWCAP) Working Group Meeting at NPS on 24-25 Sep 86. LT Michael Gainok, USN, whose thesis research was supported by this contract, presented a summary of his thesis applying multidimensional scaling techniques to EWCAP. Several NPS students were provided thesis related travel funds under this contract. My participation in the EWCAP-MOE Meeting in San Diego was also supported.

Thesis Directed: M. Gainok, "An Application of Multidimensional Scaling to Electronic Warfare Operator Proficiency Assessment", Masters Thesis, September, 1986.

**Title:** Nato SeaGNAT, Ship Launched Electronic Decoy and Counter Arm Decoy Development Program Support

**Investigator:** E.B. Rockower, Adjunct Professor of Operations Research

**Sponsor:** Space and Naval Warfare Systems Command

**Objective:** To provide support to each of the above project offices through modelling studies addressing employment tactics for off-board decoys in single and multiple ship missile engagements. Study and develop appropriate MOE's for the operational analysis of employment tactics, as required. Stochastic modelling methods and codes to be developed and evaluated for this area.

**Summary:** Evaluations of the Stochastic Infrared Engagement Model (SIREM) and the Full Engagement Decoy Simulator Model (FEDS) were carried out. Other methods, both analytic and computational, for assessing potential decoy tactics were investigated. Some innovative new modelling techniques were developed which show promise for addressing complex stochastic systems performance.

**Publications:** E. Rockower, "Integral Identities for Random Variables", Naval Postgraduate School Technical Report, NPS55-86-017.

E. Rockower, "Reliability in a Random Environment", Naval Postgraduate School Technical Report, NPS55-86-018.

**Title:** New Algorithms for the Assignment Problem

**Investigator:** R.E. Rosenthal, Associate Professor of Operations Research

**Sponsor:** NPS Foundation Research Program

**Objective:** The research is concerned with the classical optimization problem known as the assignment problem. In this problem a set of tasks and a set of agents is given. Each task must be assigned to exactly one agent and each agent must be assigned at most one task. There is a cost given for each possible task-agent pairing, and total cost is defined as the sum of the given costs over the chosen pairings. A large combinatorial number of assignments is possible. It is so large that it is impossible to enumerate all possibilities for most practical applications, even with the most powerful computers available. Fortunately, there exist efficient algorithms that enable us to solve practical applications on most computers. Nevertheless, the frequency and size of assignment problems encountered in many military and civilian applications is so great that there is a need for more efficient algorithms. The objective of this research is to devise, implement and test an improved algorithm.

**Summary:** Professor R. K. Wood brought to the author's attention an algorithmic idea appearing in the Soviet literature, which involves the successive solution of shortest path problems. Wood interpreted the algorithm in terms of a dual relaxation, and we developed an alternate interpretation based on the premise that primal algorithms have outperformed dual-based methods on related problems in the past. To implement this primal approach we designed data structures and subprocedures for (a) identifying an advanced starting solution and computing its associated basis, (b) a highly specialized partial pricing heuristic, (c) resolving degeneracy, and (d) preventing cycling, i.e., guaranteeing finite (in fact, polynomial) convergence. A valuable theorem was proven which shows that every pivot is either degenerate or degeneracy-inducing. This fact was used throughout the implementation to save steps or to anticipate needs. The final result of the effort is a computer program that outperformed a state-of-the-art program by a factor of over 200: on each example in a suite of standard test problems.



Title: Conceptual Basis for Soviet C<sup>3</sup> (Phase III)

Investigator: J.G. Taylor, Professor of Operations Research

Sponsor: C<sup>3</sup>CM Joint Test Force

Objective: To develop the conceptual basis for Soviet command, control, and communications (C<sup>3</sup>), its implementation, and susceptibility to counter measures. The third phase of this work was to further study and elaborate upon the nature and content of the Soviet theory of troop control.

Summary: Soviet concepts for what Americans call command, control, and communications (C<sup>3</sup>) are fundamentally different from American ones. For example, the Soviets use the term upravleniye voyskami (troop control) to refer to C<sup>3</sup> for a troop unit and have developed a theory of troop control. The third phase of this work investigated basic Soviet concepts of troop control. Previous research had identified these basic concepts, and the work at hand started to investigate them in depth.

Publication: J.G. Taylor, "Initial Examination of Soviet Concepts for the Control for the Control of Military Systems," Naval Postgraduate School Letter Report, September 1986.

Theses Directed: A.M. Cogliandro and F.R. Prautzsch, "Identification and Assessment of Joint Exercise Command, Control, and Communications (C<sup>3</sup>) Failures," Master's Thesis, March 1986.

T.K. Littlefield, "Control of Military Operations with PERT," Master's Thesis, March 1986.

M.T. Winger, "Survivability of Mobile Ground Control Intercept Early Warning Radars in a Central European Conflict," Master's Thesis, March 1986.

D.A. Sandvigen, "Alfred Thayer Mahan and Space: A Necessary Unity," Master's Thesis, June 1986.

Conference Presentation: J.G. Taylor, "Soviet Theory of Troop Control: The Soviet View of Command and Control," 54th Military Operations Research Symposium, National Defense University, Washington, D.C., June 26, 1986.

Title: Cybernetic Concepts

Investigator: J.G. Taylor, Professor of Operations Research

Sponsor: Headquarters Foreign Technology Division/TQFO, USAF  
Systems Command

Objective: To investigate Soviet cybernetic concepts that are critical for American understanding of the design and operation of the Soviet automated troop-control system, its evaluation, and the forecasting of future developments.

Summary: Soviet concepts for what Americans call command, control, and communications (C<sup>3</sup>) are fundamentally different from American ones. For example, the Soviets use the term upravleniye voyskami (troop control) to refer to C<sup>3</sup> for a troop unit and have developed a theory of troop control. Past research had revealed that the Soviets studied control (upravleniye) under the rubric of cybernetics (kibernetika). Consequently, the work at hand investigated Soviet views on cybernetics and troop control.

Publication: J.G. Taylor, "Initial Examination of Cybernetic Concepts in Soviet Military Affairs", Naval Postgraduate School Letter Report, December 1985.

Conference Presentation: J.G. Taylor, "Soviet Theory of Troop Control", Fourth Annual FTD/NPS C<sup>3</sup> Workshop, Monterey, CA, October 8, 1986.

Theses Directed: R.E. Orcutt, "Soviet Military Thought - Concepts of War", Master's Thesis, March 1986.

R. J. Tekel, "Russian Language Translation in the U. S. Intelligence Community", Master's Thesis, March 1986.

G.M. Waltensperger, "On Limited War, Escalation Control, and Command, Control and Communications", Master's Thesis, March 1986.

**DEPARTMENT  
OF  
NATIONAL SECURITY AFFAIRS**

## NATIONAL SECURITY AFFAIRS

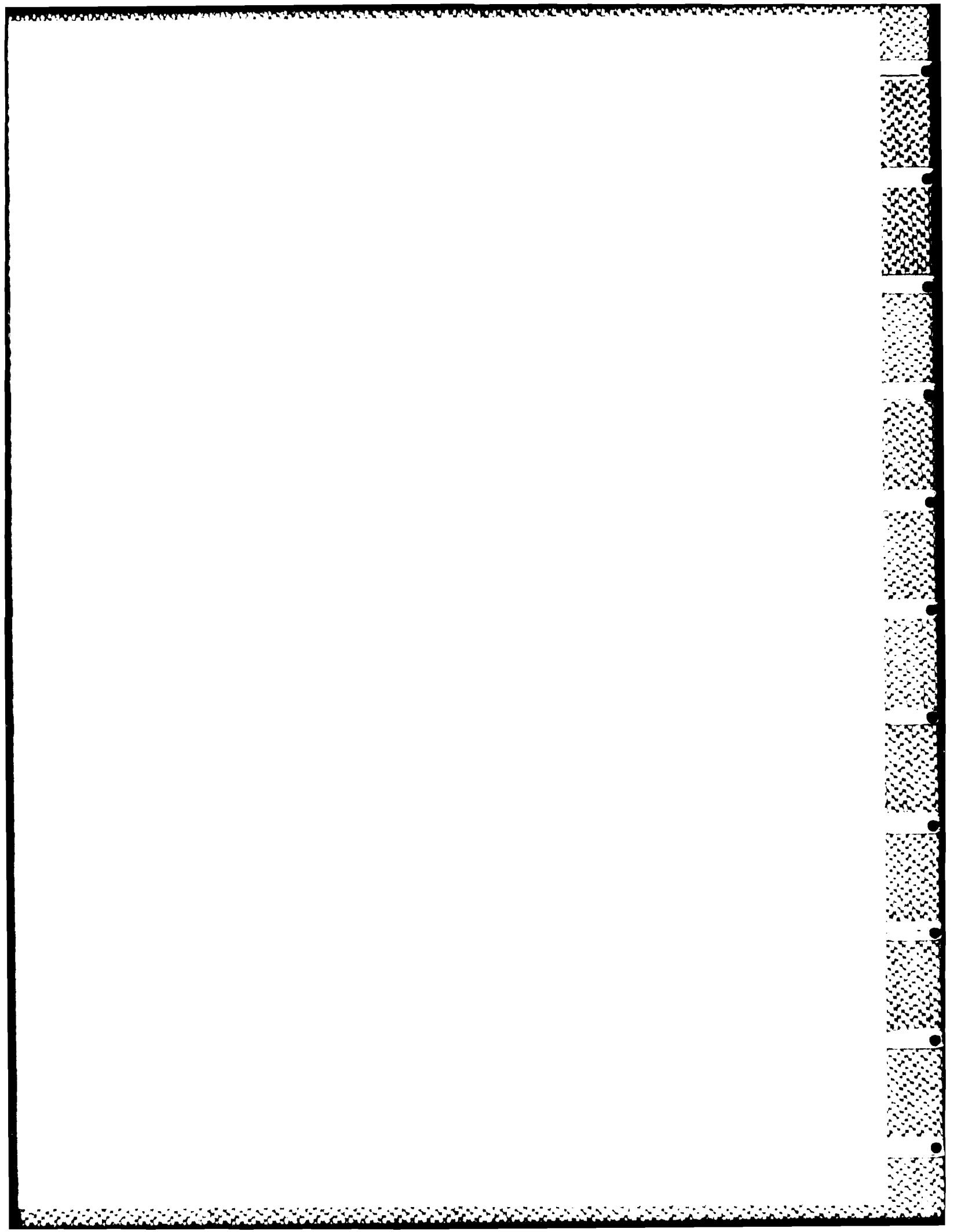
The National Security Affairs Department has adopted an innovative application of microcomputer technology to integrate automatic data processing into its multidisciplinary curricula. It has also initiated a microcomputer pilot project employing both the computer resources of the school as well as a new computer laboratory within the department. The department's involvement in advanced quantitative methodologies and techniques will increase next year with the installation of the Rand Strategy Assessment System (RSAS). This RSAS will allow NPS to operate at the cutting edge of politico-military gaming in the United States.

To assist in the transition to a new focus for departmental research, the Director of Net Assessment in the Office of the Secretary of Defense, sponsored an analysis of a series of nuclear strategy development group seminar games. The Defense Nuclear Agency sponsored two research projects on arms control and strategic nuclear weapons systems procurement.

Two additional research projects were supported by the Department of Defense that had to do with strategic deception. The first was a historical assessment of American deception efforts in the Pacific theater during World War II. The second involved the creation of a computer data base dealing with Soviet political and military deception and disinformation.

Four faculty members conducted research projects that dealt with specific foreign areas of the world. The Office of the Secretary of Defense supported an analysis of the multi-faceted Jordanian-Palestinian relationship over time. The Fritz Thyssen Foundation and the International Institute for Strategic Studies sponsored an analysis of French political military policies and interests.

The Naval Postgraduate School Foundation supported research by one faculty member who was concurrently awarded a Fullbright Fellowship to study in Argentina and Brazil. This research project will result in the publication of a major book on the subject of authoritarian regimes in those nations. The Foundation also supported research into the perceptions of the German Bundeswehr on the nature of war in the modern world.



Title: The Image of War in the West German Armed Forces, 1950-1980

Investigator: D. Abenheim, Adjunct Professor, National Security Affairs

Sponsor: NPS FOUNDATION RESEARCH PROGRAM

Objectives: To survey the relevant literature on West German military thought and practice in the era of the world war and after. It considers the West German military perspective on such issues as the lessons of World War II, coalition warfare, cooperation with the United States armed forces and nuclear weapons.

Summary: The method of this study is one historical analysis of the hypothesis that the West German military was divided into a school of reformers, who stood in opposition to a group of traditionalists in thinking about modern war. The investigator has examined the relevant public statements of leading West German military leaders as well as theoretical and practical writings about questions of warfare in the context of NATO. The results of the work thus far indicate the intense interconnection of military issues of strategy and operations with greater political problems of international dimension. Although the West Germans regained an army in the 1950s, this army existed within a nexus of political and social control quite remarkable in the history of war and armies. This circumscribed field of activity for German professional officers had profound impact on the nature of their craft and their ability to perfect it.

Publications: None thus far. Chapter in preparation for a conference on the West German Armed Forces to be held at Johns Hopkins in October 1987, which in turn will appear as the first anthology on the West German military in English.

Conference: As above

Thesis Directed: Michael Burns, "The Bundeswehr in American Perspective," Master's Thesis, 1986.

**Title:** The Hashemite Connection: Current Issues in Jordanian-Palestinian Relations

**Investigators:** J.W. Amos, Associate Professor of National Security Affairs, and R.H. Magnus, Associate Professor of National Security Affairs

**Sponsor:** Undersecretary of Defense for Policy

**Objective:** This project seeks to define and then analyze those factors which, over time and in the contemporary context, have promoted both cooperation and conflict in the Jordanian-Palestinian relationship.

**Summary:** The project is still in the process of gathering data, with an estimated date of completion of September 1987. There are no publications, conference presentations, theses directed or patent applications to date.

Title: State Organization as a Political Indicator

Investigator: P.G. Buchanan, Assistant Professor of National Security Affairs

Sponsor: NPS Foundation Research Program

Objective: Identify structure characteristics of National State apparatus under different Latin American regime types. Develop methodology and analytical framework for evaluating and predicting impact of regime type on state apparatus.

Summary: Developed analytical framework methodology for evaluating impact of regime change on Latin American state-created and source data file and began primary source collection.

Publication: Authoritarian regimes in transition: Argentina and Brazil state, labor, capital.



Title: Student Micro Computer Project

Investigator: R.L. Forney, Instructor, National Security Affairs

Sponsor: Air Force Office of Special Investigation

Objective: Provide Micro Computers to students for use while attending Naval Postgraduate School.

Summary: On going. During 1986 academic year, initial student group were issued Z100 Micro Computers and training was provided between the groups arrival and the first quarter.

Publication: Status report in progress. Final report on evaluation of pilot project to be accomplished next year.

Title: American Strategic Deception in the Pacific 1942-1945

Investigator: K.L. Herbig, Adjunct Research Professor of National Security Affairs

Sponsor: Director of Net Assessment, Office of the Secretary of Defense

Objective: To investigate the role American strategic deception efforts played in the course and outcome of the war in the Pacific during World War II.

Summary: American strategic deception was slow to develop in the Pacific Theater, but with the support of the British allies, U.S. commanders directed more resources to planning and implementing strategic deception as the war went on. During 1944 and 1945 deception showed important effects on the course of several campaigns, notably in the North Pacific, in the invasion of the Mariana Islands and of Formosa.

Publications: "American Strategic Deception in the Pacific, 1942-44," Intelligence and National Security: An Interdisciplinary Journal, Vol. 2, No. 1, April 1987, forthcoming.

Conference Presentations: "American Strategic Deception: The Case of BLUEBIRD," Naval History Symposium, U.S. Naval Academy, September 30-October 1, 1985.

"American Strategic Deception: The Beginnings in Case WEDLOCK," Conference on Intelligence and Deception, U.S. Army War College, April 1986.

Title: Predicting Soviet Non-Compliance with Arms Control Agreements

Investigators: P.J. Parker, Professor of National Security Affairs (Principal Investigator), B.D. Dailey, Adjunct Professor of National Security Affairs, P.J. Garrity, Adjunct Professor of National Security Affairs, K.M. Kartchner, Assistant Professor of National Security Affairs

Sponsor: Defense Nuclear Agency

Objective: Determine and analyze Soviet strategic weapon procurement priorities and objectives based on an examination of the U.S.-Soviet arms control negotiating record, and subsequent Soviet (non) compliance behavior.

Summary: Research objectives and requirements were elaborated and substantiated. Data sources were identified and preliminary investigation was begun. Research was conducted at the Foreign Systems Research Center in Denver, Colorado, and in Washington, D.C. Initial findings were briefed to sponsors and interested contractors.

Title: Project Lanai: Soviet Perceptions Management Database

Investigators: P.J. Parker, Professor of National Security Affairs, B.D. Dailey, Adjunct Professor of National Security Affairs, and K.M. Kartchner, Assistant Professor of National Security Affairs

Sponsor: U.S. Government Agency

Objective: Research, code, abstract, develop and consolidate a computerized, random-access database of references relating to Soviet military and political deception, disinformation, and active measures.

Summary: Research was coordinated and designed. Data sources in California, Texas, Washington, D.C., and Western Europe were investigated and researched. 2000 bibliographic worksheets were processed. New data sources were identified and tagged for future research. Computer software was mastered and integrated. Printed references were edited, alphabetized, and coded. Sponsor personnel were trained and advised on system integration and maintenance.

Publications: SOVX Database User's Guide, 25 page classified guide describing the purpose, organization, methodology, and operation of the database.

Title: Research on Arms Control (Phase I)

Investigators: P.J. Parker, Professor of National Security Affairs, B.D. Dailey, Adjunct Professor of National Security Affairs, P. Garrity, Adjunct Professor of National Security Affairs, and K.M. Kartchner, Adjunct Professor of National Security Affairs

Sponsor: Defense Nuclear Agency

Objective: Determine and analyze Soviet strategic weapon procurement priorities and objectives based on an examination of the U.S.-Soviet arms control negotiating record, and subsequent Soviet (non) compliance behavior.

Summary: Research was coordinated and designed. Research objectives and requirements were elaborated, substantiated, and assigned to the various associate researchers. Data sources were identified and preliminary investigation was begun. Research was conducted at the Foreign Systems Research Center in Denver, Colorado, and in Washington, D.C. Initial findings were briefed to sponsors and interested contractors.

Title: Preliminary Survey on Naval Grand Tactics

Investigators: R.S. Stolfi, Professor of National Security Affairs,  
and D. Abenheim, Adjunct Professor of National  
Security Affairs

Sponsor: Deputy Under Secretary of Navy (Policy)

Objectives: To obtain expert opinion on the content and  
direction for a study on the application of grand  
tactics (operational art) to the U.S. Navy Today.

Summary: Project results pending. Visits to Washington,  
D.C., and Newport, RI, will take place in Jan-Feb  
87.

Publications: Report forthcoming.

Conference: Pending

Title: Analysis of War Games

Investigator: J.J. Tritten, Assistant Professor and Chairman  
of National Security Affairs

Sponsor: Director of Net Assessment, Office of the Secretary of  
Defense

Objective: Analysis of fourteen Nuclear Strategy Development  
Group seminar games, preparation of lessons learned,  
analysis of methodology, presentation of results,  
preparation of research design for nex series.

Summary: Prepared research designs for games 9-14 and  
supervised conduct of these games during 1985-1986.  
Prepared lessons learned in 1985-86 and widely  
distributed within OSD, the Joint Staff, the services  
and intelligence community. Current work to finish the  
analysis of final games conducted in first series, to  
create overall lessons, and prepare plan for 1987.

Publications: J.J. Tritten, "NSDG SAS Games 1-9 lessons learned;  
Issues Surfaced During NSDG SAS Games 1-9" attached to  
Director, Net Assessment Memo of 6 January 86; 19 pp.

J.J. Tritten, "Final Report Game 10," 11 February  
1986, 35 pp.

J.J. Tritten, "Final Report NSDG SAS Game 11," 5 May  
1986, 26 pp.

J.J. Tritten, "Final Report NSDG SAS Game 12," 22 July  
1986, 34 pp.

J.J. Tritten, "Draft for Comments -NSDG Game 13  
Results," 1 August 1986, 30 pp.

Conference Presentation: Briefing to CNO Executive Panel Task Force on  
Strategic Defense and Naval Warfare, 5 February 1986.

Title: French Security Policies

Investigator: D.S. Yost, Associate Professor of National Security Affairs

Sponsors: Fritz Thyssen Foundation and International Institute for Strategic Studies

Objective: To advance understanding of French policies in several areas, including nuclear weapons programs, interventionary forces, arms control, and European security.

Summary: Research to date had focused on the French strategic studies community, policy-making processes, interventionary capabilities and contingencies in Africa, nuclear weapons targeting, and policies regarding European security. In each of these areas, the existing literature in French and English has been thoroughly reviewed, and numerous interviews with French officials have supplemented and clarified published sources.

Publications: D.S. Yost, France's Deterrent Posture and Security in Europe, Part I: Capabilities and Doctrine, Adelphi Paper No. 194, London: International Institute for Strategic Studies, Winter 1984-1985.

D.S. Yost, France's Deterrent Posture and Security in Europe, Part II: Strategic and Arms Control Implications, Adelphi Paper No. 195, London: International Institute for Strategic Studies, Winter 1984-1985.

D.S. Yost, France and Conventional Defense in Central Europe, Boulder, Colorado: Westview Press, 1985.

D.S. Yost, La France et la securite europeene, Paris: Presses Universitaires de France, 1985.

D.S. Yost, "French Nuclear Targeting," in Strategic Nuclear Targeting, pp. 127-156, edited by D. Ball and J. Richelson, Ithaca, New York: Cornell University Press, 1986.

D.S. Yost, "Radical Change in French Defense Policy? A Review Essay," Survival, 28 (January/February 1986), pp. 53-68.



DEPARTMENT  
OF  
PHYSICS

## SUMMARY OF RESEARCH ACTIVITIES OF THE PHYSICS DEPARTMENT IN FY86

During FY86, the sponsored research activities in the Physics Department consisted of 27 individual projects.

Of these 27 projects, 21 (77%) were funded by the Navy, including ONR, NUWES, NAVSEASYSKOM, NSWC, NEPRF, NAVSPAR, NADC, NOSC, and NPS-Foundation. Two projects each were sponsored by AF and DARPA, one each by MIT-LINCOLN and NRC-NAS.

These projects can be grouped into six groups. These are:

- (1) Acoustics/Underwater Acoustics
- (2) Atmospheric Physics
- (3) Directed Energy Beam Physics/Electromagnetic Phenomena
- (4) Infrared Technology
- (5) Non-Equilibrium Statistical Mechanics Application to Complex System Dynamics and Theory of C<sup>3</sup> Systems.
- (6) Surface Physics

Although broadly based, this research program is the result of a long-term carefully orchestrated evolution, designed to explore the physics in those areas where modern weapon technology, particularly Naval Weapon Technology, interfaces and is limited by properties of the natural environment. One can state that the Department as a group specializes in Weapon System - Environment Interface Physics.

Some details about the nature of the research in each of these areas is given here.

### Acoustics/Underwater Acoustics

The work in this area falls easily into the following two categories: Propagation related issues and transducer/sonar systems topics. In the propagation area, propagation in fluid filled porous media (Prof. Baker), Mechanisms of generation of Infrasonic ambient ocean noise (Prof. Nichols), multipath acoustic propagation (Prof. Wilson) were investigated. In the transducer and sonar system area the development of transducer calibration technique for special purposes and the design of a novel hydrophone using fiber optic principles have been pursued vigorously (Prof. Garrett). Direct support in the performance evaluation of sonar systems and the development of a new sub bottom sonar was provided to the Navy by our team. (Profs. Wilson, Baker, Coppens, Garrett and Yoon).

## Atmospheric Physics

Our work in Atmospheric Physics has two focal points which are complementary to each other. Prof. Schacher, in cooperation with the Meteorology Department, has continued the investigation of turbulent and diffusive transport of contaminants in the near-surface atmosphere and application of this to some special urgent defense related problems like rocket exhaust hazard and problems related to chemical warfare. The other focal point is Prof. Walter's work concerning the properties of laser beam propagation in the turbulent atmosphere and the development of techniques to measure atmospheric turbulence remotely. This work has gained additional importance through its relevance to problems connected with the Strategic Defense Initiative.

### Directed Energy Beam Physics/Electromagnetic Phenomena

The electromagnetic radiation signatures from high energy high current electron beam pulses have been investigated continuing our investigation of the complex interaction of the beam pulses with the embedding dielectric. This issue relates to SDI problems as well as future possible tactical beam weapons (Profs. Buskirk and Neighbours). The other area of electromagnetic interface phenomena is the investigation of the scattering of electromagnetic waves from rough surfaces (Prof. Glass) and the low radar cross section related issue of minimal scattering from inhomogeneous layered materials (stealth technology) (Prof. Milne with Morgan).

### Infra-Red Technology

Our academic Center for Infrared Technology consisting of Profs Cooper, Crittenden, Rodeback, and Milne has continued its work on FLIR-System performance assessment. It is involved in developing a data base for IR search and target designation in sea, land and air background and it is giving technical support to the NATO SEA GNAT program for off-board countermeasures.

### Non Equilibrium Statistical Mechanics Application to Complex System Dynamics and Theory of $C^3$

The department has begun a new initiative with this research. It has been known for some time that large complex non-linear systems have some common features that can be theoretically captured by the most general language of Statistical Mechanics which has rather universal applicability. The application of modern formulations of this theory in terms of path integrals to such systems like a complex  $C^3$  system promises to lead to useful measures of effectiveness and give methodologies for planning of  $C^3$  and SDI systems. This initiative is led by Prof. Ingber.

### Surface Physics

This long-standing effort by Prof. Harrison of investigating the interaction of high energy particles with crystal surfaces appears more at the fundamental level of interface physics compared to some of the other research in the department. The understanding of the complex physics of such interactions however, is at the basis of the ultimate ability of developing hard materials that must function at the interface with hostile environments.

Title: Development of a New Method for Measuring the Characteristic Impedance and Complex Propagation Constant of Porous Acoustic Material

Investigator: S. R. Baker, Adjunct Professor of Physics

Sponsor: NPS Foundation Research Program

Objective: The objective of this work is to investigate the feasibility of obtaining the characteristic impedance and the complex propagation constant of a fluid-filled porous solid by measuring the resonance frequencies and the half-power widths of the standing waves in a fluid-filled cavity which is partially occupied by the porous solid. The advantages of this technique over traditional impedance tube methods are that it does not require probing of the sound field either within or in front of the porous solid as does the traditional probe-tube technique, nor does it require a pair of phase-matched microphones as does a two-point correlation technique. Extracting the desired quantities is computationally a more difficult problem, however, with the resonance technique. In this phase of the program the porous solid is fiberglass, the fluid is air, and the cavity is made of plexiglass.

Summary: Funds to purchase equipment and supplies were received in January 1986. Equipment orders were placed by the end of March. Most of the equipment was received by the end of June.

An underwater acoustics student is working on this project for his Master's thesis and it is expected to be completed by the end of June 1987. The fiberglass has been characterized by the conventional impedance tube technique. Measurements have been made of the complex pressure field (inphase and quadrature components) of the lowest frequency mode of a plane-wave resonator which has been partially filled with fiberglass. The mass density and DC flow resistance of the fiberglass have also been measured.

Before going on to measure the pressure fields of higher modes we must develop the theory and compare it to our data for the lowest mode. Our measurements show that the introduction of a modest amount of fiberglass (20% by volume) into an otherwise empty resonator increases the viscous point so that a description of the pressure field in terms of standing waves is questionable (the measured  $Q$  of the lowest mode is approximately 5). A proper description of the field is likely in terms of suitable collection of image sources. Most of my present effort on this project is directed toward solving this theoretical problem.

Title: Directed Energy Test Detection

Investigators: F. R. Buskirk, Professor of Physics  
J. R. Neighbours, Professor of Physics

Sponsor: Defense Advanced Research Projects Agency

Objective: To investigate the electromagnetic radiation from a charged particle beam in air.

Summary: Calculations have been done for electron beams propagating in air. The radiated fields have been calculated in both the frequency and time domains, and the mechanisms include Cerenkov and transition radiation.

Publication: F. R. Buskirk, J. R. Neighbours, and X. K. Maruyama, "Radiation Produced by the Modulated Electron Beam of a Free Electron Laser," NPS-61-86-013, June 1986.

Conference Presentation: F. R. Buskirk, J. R. Neighbours, and X. K. Maruyama, "Radiation Produced by the Modulated Beam of a Free Radiation Produced by a Free Electron Laser," International Conference on Free Electron Lasers, Glasgow, Scotland, September 1986.

Title: Measurement of E. M. Radiation from High Current  
Electron Beams

Investigators: F. R. Buskirk, Professor of Physics  
J. R. Neighbours, Professor of Physics

Sponsor: Naval Sea Systems Command PMS405, now called Naval  
Space and Warfare Command PMW145

Objective: Radio frequency radiation from intense electron  
beams are to be measured. The beams include ATA  
(Livermore), Phermex (Los Alamos) and Rad Lac  
II (Sandia). Cerenkov and other electromagnetic  
pulse mechanisms are considered.

Summary: Measurements of R. F. and microwave radiation from  
the electron beams of the NPS electron Linac,  
Phermex at Los Alamos and Rad Lac II, Sandia Labs  
have been made. Some of the results are in the  
report below, results for Phermex and Rad Lac II  
appear in Los Alamos reports. Preparations are  
underway for the Livermore experiments.

Publications: F. R. Buskirk and J. R. Neighbours, "Cerenkov  
Radiation and Electromagnetic Pulse Produced by  
Electron Beams Traversing a Finite Path in Air,"  
Physical Review, A, Vol. 34, October 1986, pp.  
3470-3473.

F. R. Buskirk and J. R. Neighbours, "Cerenkov  
Radiation and Electromagnetic Pulse Produced by  
Electron Beams Traversing a Finite Path in Air,"  
NPS-61-86-011, March 1986.

Thesis Directed: A. J. O'Grady, LCDR, USN, "Cerenkov Radiation,  
Transition Radiation and Diffraction Transition  
Radiation from Periodic Electron Bunches," Master's  
Thesis, June 1986.



Title: FLIR Performance Model Assessment

Investigators: A. W. Cooper, Professor of Physics  
E. A. Milne, Associate Professor of Physics  
D. R. Mensh, Adjunct Professor of Physics  
E. C. Crittenden, Jr., Distinguished Professor of Physics Emeritus

Sponsor: Naval Environmental Prediction Research Facility,  
Weapons Effects Division

Objective: To gather, implement and evaluate available FLIR performance models; to determine general parameter sensitivity; to participate in design and performance of experiments for model validation; to evaluate test results.

Summary: Three codes selected from the five available computer models of FLIR performance were evaluated. The NOSC model for the Navy Shipboard Tactical Environmental Support System (TESS) was adapted to the IBM PC and tested for sensitivity to the input parameters. An experiment to compare model predictions with operational FLIR performance was carried out off the Monterey coast in May 1986. For this test the R/V Point Sur was fitted with a temperature sensor, and Radiometric infrared signature measurements made using the AGEMA system. Other necessary environmental data were available on the Point Sur. Code predictions were compared with observations from an overflying A-6. A preliminary analysis with suggested interpretation of discrepancies was prepared for the sponsor. This project plan extends through FY88.

Publications: A. W. Cooper, E. C. Crittenden, D. R. Mensh, E. A. Milne, E. N. Ward, "FLIR Performance Model Assessment," Naval Postgraduate School Technical Report, NPS61-86-016, July 1986, Forthcoming.

Theses Directed: G. Dimitriadis, LT, Hellenic Navy, "Thermal Image Measurements of Infrared Signatures," Master's Thesis, December 1986.  
D. L. DeBroux, LT, USN, "FLIR Performance Model Assessment," Master's Thesis, December 1986.

Title: FLIR Performance Model Assessment and Evaluation

Investigators: A. W. Cooper, Professor of Physics  
A. Milne, Associate Professor of Physics

Sponsor: Naval Environmental Prediction Research Facility

Objective: To test and evaluate computer-based models for the prediction of FLIR performance.

Summary: The NOSC model for the Navy's shipboard Tactical Environmental Support System (TESS) was adapted for for the IBM PC then tested for the sensitivity of the model to the many input parameters. An experiment to compare the predictions of the model with the actual performance of the FLIR was carried out off the Monterey coast in May 1986 using the research vessel Point Sur.

Theses Directed: G. Dimitriadis, LT, Hellenic Navy, "Thermal Image Measurements of Infrared Signatures," Master's Thesis, December 1986.

D. L. DeBroux, LT, USN, "FLIR Performance Model Assessment," Master's Thesis, December 1986.

Title: Infra-Red Search and Target Designator Research

Investigators: A. W. Cooper, Professor of Physics  
E. C. Crittenden, Jr., Distinguished Professor of  
Physics Emeritus  
W. J. Lentz, Research Associate

Sponsor: Space and Warfare Systems Command, PDW107-3

Objective: To modernize and mount for operation the Advance Development Model of the AN/SAR-8 Infrared Search and Target Designation system; to develop a data recording system; and to initiate a program of measurement of sea, land and air backgrounds, target signatures, and cloud radiance, and of evaluation of processing algorithms.

Summary: The SAR-8 ADM scanner has been modified, using liquid nitrogen cooling with a solid insulating vessel to replace the Sterling cooler and dewar, and necessary repairs to the system carried out. The required optical design modification has been determined analytically. Laboratory evaluation of the detector array has shown deficiencies in 6 detectors. A roof-top scanner platform and base and an equipment hoist were installed together with cable channels to the control/digitizing system on the 7th floor, with fiber-optic data link to the 2nd floor recording/processing system. An 8-bit, 5.4 Megabyte/sec data recording system was assembled in the Naval Academic Center for Infrared Technology (NACIT) with interfaces to the Masscomp Unix computer system, a 1 Gigabyte Optical disk, a 9-track tape drive. The system was upgraded to 12 bit words during the year, and upgrades for the ADC system to 12 bits were ordered. A 500 Megabyte memory unit has also been ordered. Software was written to display and read the data from the Ampex tape recorder. An analytical evaluation of passive range estimation indicates possible applicability at short range only.

Publications: Quarterly progress reports have been provided to the sponsor.

- Theses Directed:
- A. Manalopoulos, LT, Hellenic Navy, "Infrared Background and Target Measurement", Master's Thesis, December 1985.
- C. E. Lewis, LT, USN, "The Infrared Search and Target Designation System AN/SAR-8 ADM at the Naval Postgraduate School," Master's Thesis, December 1985.
- H. Mor, LTC, Israeli Army, "Analysis of Roof Location for Mounting the AN/SAR-8 IRSTD ADM System," Master's Thesis, March 1986.
- G. Parker, CPT, USA, "Optical Performance Implications of Naval Postgraduate School Modifications to the AN/SAR-8, Infrared Search and Target Designation System," Master's Thesis, September 1986.
- S. Smith, LT, USN, "Evaluation of Techniques for Passive Range Estimation," Master's Thesis, September 1986.

Title: Technical Support to Off-Board Countermeasure Programs

This project comprises the work performed under the three proposals:

- 1) Off-Board Countermeasures Program Support
- 2) Counter ARM Decoy Development Program Support
- 3) Ship Launched Electronic Decoy Development Program Support

Investigators: A. W. Cooper, Professor of Physics  
E. C. Crittenden, Jr., Distinguished Professor of Physics Emeritus  
G. W. Rodeback, Associate Professor of Physics Emeritus  
E. A. Milne, Associate Professor of Physics  
E. N. Ward, Programmer/Analyst

Sponsor: Space and Warfare Systems Command PDW107-5

Objective: To provide support to the NATO SEA GNAT program, the Counter ARM Decoy Program, and the Ship Launched Electronic Decoy Program by continuing development of a low cost laser altimeter, through modelling studies addressing employment tactics for off-board decoys in single and multiple ship missions, and the influence of environmental conditions on the performance of the systems.

Summary: Development of small cheap avalanche photodiode detectors has led to the design of a new prototype laser altimeter for possible use in disposable off-board decoys. The new system incorporates a small glass lens in place of the fresnel lens previously used. A working model has been built and tested over a reservoir. The new design shows about a factor of ten improvement in sensitivity over previous designs, consistent with theoretical analysis. Further studies of sea surface reflection are being pursued, to improve confidence in predictions of system performance under operational conditions. The NPS version of NRL's SIREM infrared decoy engagement model has been improved by the addition of the DISSPLA plotting package. A

documentation report on use of SIREM at NPS is in preparation. A study has been carried out to develop a tactics plan for IR decoy deployment based on threat bearing for an ASCM against a DD-963 class destroyer. Further improvements have been made to the interactive LOWTRAN6 code, and the FASCODE2C high resolution code has been installed on the IMB 3033. The Ship Combat System Simulation Code is now operational at NPS, and results of SIREM studies have been incorporated into SCSS.

Theses Directed:

M. A. Kuharik, "Ship Launched Infra-Red Countermeasures Modelling," Master's Thesis, December 1985.

A. Curry, LT, USN, "IRCM Inclusion Ship Combat System Simulation," Master's Thesis, September 1986 (Mensch/Cooper)

D. MacDougall, LT, USN, "Application of the Stochastic Infrared Engagement Model Computer Code to Tactical Analysis," Master's Thesis, December 1986, Forthcoming.

C. Bourne, LCDR, USN, "Improved Laser Altimeter," Master's Thesis, December 1986 (Crittenden), Forthcoming.

Title: Fiber Optic Gradient Hydrophone

Investigator: S. L. Garrett, Associate Professor of Physics

Sponsor: Space and Naval Warfare System Command

Objective: To design, fabricate, and test an entirely fiber optic acoustic sensor system which is directional and compact as part of a continuing research program in fiber optic sensor systems.

Summary: During this period significant progress was made with the development of a new interferometric bi-directional hydrophone which utilizes a sensitive interferometric seismic instrument contained within a neutrally buoyant case. The seismic sensor consists of a mass supported by two rubber mandrels (springs) wrapped with single mode optical fiber. The sensitivity of the sensor above resonance was measured to be in excess of 10,000 radians/micron. This corresponds to a sensitivity improvement over the previous best existing sensor of this type of  $\approx 35$  dB. Progress was also made in the area of interferometric sensor demodulation with the demonstration of an optical fringe rate demodulator. Development of the fiber optic heading sensor (compass) continued with the design of both a "split analog/digital" four-channel polarization angular encoder and a two-channel digital encoder.

Publications: D. L. Gardner, R. K. Yarber, E. F. Carome, and S. L. Garrett, "A Fiber-Optic Interferometric Geophone," J. Acoust. Soc. Am., 80, S7, 1986.

C. M. Crooker and S. L. Garrett, "Fringe Counting Demodulator for Fiber Optic Interferometric Sensors," J. Acoust. Soc. Am., 80, S27, 1986.

Thesis Directed: P. A. Feldmann, LT, USN, "Construction of a Fiber Optic Gradient Hydrophone using a Michelson Configuration," Master's Thesis, March 1986.

Patent Issued: A. Migliori, G. W. Swift, and S. L. Garrett, "Remotely Readable Fiber Optic Compass," U. S. Patent #5,577,414, March 25, 1986.

Title: Optical Fiber Fusion Splicer

Investigator: S. L. Garrett, Associate Professor of Physics  
J. P. Powers, Professor of Electrical and Computer Engineering

Sponsor: NPS Foundation Research Program (Capital Equipment)

Objective: To purchase an optical fiber fusion splicer and associated accessories to improve our capabilities for research in the area of single mode optical fiber sensor systems and optical fiber data communications systems.

Summary: An extensive product search was conducted and various fusion splicers were tested. The Sumitomo TYPE-11X was chosen and purchased at the end of the fiscal year. It was used extensively in construction of several single mode fiber optic interferometric seismic and acoustic sensors.



Title: Reciprocity Calibration in Unconventional Geometrics

Investigator: S. L. Garrett, Associate Professor of Physics

Sponsor: Office of Naval Research (Physics Division)

Objective: To test extensions of the reciprocity method for absolute calibration of electroacoustic transducers beyond the traditional applications and to initiate studies of the physics of thermoacoustic heat engines and their Navy related applications. This is Phase V of a continuing program in physical acoustics research.

Summary: During this period we completed an experiment to test an extension of the reciprocity calibration technique to ultracompliant transducers. The new technique was applied to a magnetohydrodynamic (MHD) transducer in a pressure released trough filled with either salted water or mercury which acted as the wave propagation medium. The agreement between the reciprocity calibration and a calibration based on a primary standard was excellent. This result demonstrated that the sensitivity of the MHD transducer is just that given by the simple application of Faraday's Law, in contrast to recent measurements indicating otherwise.

Instrumentation for further reciprocity studies in compliant-walled, water-filled waveguides was developed and a laboratory for thermoacoustics studies was begun.

Publications: M. E. Johnson and S. L. Garrett, "Reciprocity Calibration in a Compliant Cylindrical Tube," J. Acoust. Soc. Am, 78, S54, 1985.

S. L. Garrett and G. W. Swift, "Resonant Reciprocity Calibration of an Ultracompliant Transducer," J. Acoust. Soc. Am, 80, S25, 1986.

S. L. Garrett, "Resonant Reciprocity Calibration of Conventional, Magneto hydrodynamic, and Quantumfluidic Transducers," J. Acoust. Soc. Am, 80, S46, 1986.

Thesis Directed: C. L. Burmaster, LCDR, USN, "Reciprocity Calibration in a Plane Wave Resonator," Ph.D Thesis, December 1985.

Title: The Interaction of Electromagnetic Waves with Rough Surfaces

Investigator: N. E. Glass, Adjunct (Teaching) Professor of Physics

Sponsor: NPS Foundation Research Program

Objective: To implement and test a perturbation theory for the reflectances of the diffracted beams and the field enhancements in EM scattering from conducting surfaces, with surface-plasmon-polariton resonances, on bigrating. To start a theory on resonant scattering from random arrays of surface bosses, and to continue work on Smith-Purcell radiation from bigratings.

Summary: A coupled-mode perturbation theory (which retains all non-resonant terms and uses them to renormalize the surface-wave frequencies) was implemented numerically, to calculate the reflectances and surface field-enhancements, due to EM wave diffraction with surface-polariton resonant excitation, from a bigrating. The results, for a variety surface profiles, were compared to those of the exact theory, in order to demonstrate the validity of the perturbative approach. A perturbative matrix, as the sum of single bump perturbations, for developing a T-matrix formalism, was calculated, but it appears that the long range nature of the perturbation precludes the planned use of the "Coherent Potential Approximation" to deal with the random array of bumps. The analytic development of a theory for resonant Smith-Purcell radiation from a bigrating was brought to near-completion.

Publications: N. E. Glass, A. A. Maradudin, "Polariton Resonant Absorption in a Bigrating: Exact Theory Compared to Recent Experiments and to Perturbation Theory," Optics Communications, Vol. 56, No. 5, January 1986, pp. 339-344.

N. E. Glass, "A Perturbation Theory for Optical Reflectance with Surface-Polariton Excitation on a Bigrating," (Abstract) Bulletin of the American Physical Society, Vol. 31, No. 3, March 1986, p. 632

N. E. Glass, "Perturbation Theory for Light Diffraction with Surface-Polariton Resonances on a Bigrating," Physical Review B, Forthcoming.

N. E. Glass, A. A. Maradudin, and A. Wirgin, "Diffraction of Light from a Classical Grating and a Bigrating," Proceedings of the International Laser Science Conference, (IEEE Press, New York), Forthcoming.

Conference Presentations:

N. E. Glass, A. A. Maradudin, and A. Wirgin, "Diffraction of Light from a Classical Grating and Bigrating," International Laser Science Conference, Dallas, November 1985.

N. E. Glass, "A Perturbation Theory for Optical Reflectance with Surface-Polariton Excitation on a Bigrating," American Physical Society General Meeting, Las Vegas, 31 March - 04 April 1986.

Theses Directed:

Three students have or are beginning thesis work on this project, but none has yet reached completion.

Title: Classical Trajectory Simulation Studies of High and Low Energy Particle-Beam Interactions

Investigator: D. E. Harrison, Jr., Professor of Physics

Sponsor: Office of Naval Research (Special Research Opportunity Grant: High and Low Energy Particle-Beam Interactions with Solids)

Objective: Continue study of the effects produced when ions bombard clean and chemically reacted single crystal metal surfaces, to understand mechanisms and to coordinate with experimental investigations. Study damage produced in target surface by bombarding ions. Study fundamental properties of ion bombardment induced cascades in solids.

Summary: Classical trajectory simulations are used to study the cascade of atoms produced when an ion strikes a target surface. Calculations have been done for combinations of systems using  $\text{Ar}^+$ ,  $\text{O}^+$ ,  $\text{O}_2^+$  and various metal ions in combination with Cu, Ni, W, Mo, Ti, V and Nb targets. Effort this year has been concentrated on fundamental problems and computer program improvement. The program can now be used to study atom ejection by low energy ( $\approx 100$  eV) ions. Sputtering of copper by very low energy oxygen ions has been investigated, ejected molecules which involve the incident ion have been recorded.

Publications: M. M. Jakas and D. E. Harrison, Jr., "Dependence of Atom Ejection on Electronic Energy Loss," Physics Review 32 B1, 1985, p. 2752.

M. M. Jakas and D. E. Harrison, Jr., "Many-Body Effects in Atomic-Collision Cascades," Physical Review Letters, Vol. 55, No. 17, 1985, pp. 1782-85.

M. H. Shapiro, P. K. Haff, T. A. Tombrello and D. E. Harrison, Jr., "Simulation of Isotope Effects in Sputtering," Nuclear Instrument and Methods, Vol. B12, 1985, pp. 137-145.

D. E. Harrison, Jr., and M. M. Jakas, "Inelastic Energy Losses in Cascades and Atom Ejection," Nuclear Instrument and Methods, Vol. B15, 1986, p. 25.

M. M. Jakas and D. E. Harrison, Jr., "A Comparison between Multiple Interaction Computer Simulations and the Linear Theory of Sputtering," Nuclear Instrument and Methods, Vol. B14, 1986, p. 535.

A. D. Jenner, R. P. Saxon, K. T. Gillen, D. E. Harrison, T. C. M. Horn. and A. W. Kleyn, "Computer Simulations and Rainbow Patterns of Alkali Ion Scattering from Metal Surfaces," Surface Science, Vol. 172, 1986, pp. 121-150.

R. Walkup, P. Avouris and D. E. Harrison, Jr., "Model for Direct Ejection of Diatomic Molecules by Collisional Sputtering," Nuclear Instruments and Methods, Vol. B15, 1986, p. 461.

R. P. Webb, D. E. Harrison, Jr., and M. M. Jakas, "The Computer Simulation of Ion Induced Atomic Collision Cascades," Nuclear Instruments and Methods, Vol. B15, 1986, p. 1

Theses Directed:

S. M. Webb, LT, USN, "Study of Computer Simulation of Sputtering from Nitrogen Reacted Molybdenum and Tungsten Targets," Master's Thesis, June 1986.

M. R. Polnaszek, LT, USN, "Aspects of Simulating Interstitial Diffusion in a Face-Centered-Cubic Lattice," Master's Thesis, June 1986.

S. R. Miller, LT, USN, and Philip Mattson, CAPT, USA, December 1986, Master's Thesis, Forthcoming

Title: C<sup>3</sup> Measures of Effectiveness

Investigators: M. Sovereign, Chairman, C<sup>3</sup> Group,  
L. Ingber, Professor of Physics

Sponsor: Naval Ocean Systems Center

Objective: To execute tasks of Joint Directors of  
Laboratories (JDL) Program Plan of the Basic  
Review Group (BRG) of the Technical Panel for C<sup>3</sup>  
(TPC<sup>3</sup>).

Summary: There was continued development of theory and  
supporting experiments in the measurement of the  
effectiveness of command and control.

Publications: L. Ingber, "Applications of Biological  
Intelligence to Command, Control and  
Communications", in Proceedings of Computer  
Simulation in Brain Science, Copenhagen, 1986.

Conference  
Presentations: L. Ingber, "Applications of Biological  
Intelligence to Command, Control and  
Communications," Computer Simulation in Brain  
Science, Copenhagen, August 1986.

Title: Statistical Mechanics to Options Planning

Investigator: L. Ingber, National Research Council Senior  
Research Associate, Operations Research  
Department

Sponsor: National Research Council of the National  
Academies of Science and Engineering, and the  
Institute of Medicine

Objective: To apply modern methods of nonlinear  
nonequilibrium statistical mechanics to options  
planning algorithms of governmental concern.

Summary: Several collaborations are established to  
organize an effective approach to describe  
spatial-temporal patterned properties of  $C^3$   
systems. Code development was begun at UC  
Livermore Laboratory, by Dr. Mike Weher, and at  
Sandia Laboratory, Livermore, by Professor  
Wilhelm Wolfer, to integrate long-time probability  
distributions of several variables using their 1983  
one-dimensional algorithm as a basis. Working  
with a graduate student, CAPT Stephen Upton, USMC,  
several combat simulations were analyzed as  
prospective candidates for this modeling approach.

Publications: L. Ingber, "Towards Clinical Applications of  
Statistical Mechanics of Neocortical  
Interactions," Innovation et Technologie en  
Biologie et Medicine 6, 1986, pp. 753-758.

L. Ingber, "Noise-Induced Extrema in  
Time-Dependent Ginsburg-Landau Systems,"  
Mathematical Modelling 7, 1986, pp. 525-528.

L. Ingber, "Nonlinear Nonequilibrium Statistical  
Mechanics Approach to  $C^3$  Systems," Proceedings  
of 9th MIT/ONR Workshop on  $C^3$  Systems, (MIT  
Press, MIT), Forthcoming.



L. Ingber, "Riemannian Contributions to Short-Ranged Velocity-Dependent Nucleon-Nucleon Interactions," Physical Review D 33, 1986, pp. 3781-3784.

L. Ingber, "Riemannian Contributions to Velocity-Dependent Nucleon-Nucleon Interaction," Bulletin of American Physical Society, 1986 p. 869.

L. Ingber, "Statistical Mechanics Algorithm for Response to Targets (SMART)," Proceedings of Workshop on Uncertainty and Probability in Artificial Intelligence, (AAAI-RCA, Los Angeles), pp. 258-264, 1986.

L. Ingber, "Statistical Mechanics of Neocortical Interactions," Bulletin of American Physical Society, (American Institute of Physics, New York), p. 868, 1986.

Conference  
Presentations:

L. Ingber, "Statistical Mechanics Algorithm for Response to Targets (SMART)," Workshop on Uncertainty and Probability in Artificial Intelligence, Los Angeles, August 1985.

L. Ingber, "Riemannian Contributions to Velocity-Dependent Nucleon-Nucleon Interaction," Spring Meeting of the American Physical Society, Washington, D.C., April - May 1986.

L. Ingber, "Statistical Mechanics of Neocortical Interactions," Spring Meeting of the American Physical Society, Washington, D.C., April - May 1986.

L. Ingber, "Nonlinear Nonequilibrium Statistical Mechanics Approach to  $C^3$  Systems," 9th MIT/ONR Workshop on  $C^3$  Systems, Monterey, June 1986.

Title: Technical Monitoring of Alphatech SDI-BM  
Methodology

Investigators: M. Sovereign, Chairman, C<sup>3</sup> Group,  
L. Ingber, Professor of Physics

Sponsor: Naval Air Development Center

Objective: To assist in the technical direction of  
Alphatech's BM/C<sup>3</sup> effectiveness model  
development.

Summary: We examined specific areas such as optimization  
techniques and operational realism, i.e., is  
model simulating the SDI environment as  
envisioned?

Title: Synthesis of Minimal Scattering Profiles in Inhomogeneous Anisotropic Material

Investigators: E. A. Milne, Associate Professor of Physics  
M. A. Morgan, Associate Professor of Electrical and Computer Engineering

Sponsor: Office of Naval Research

Objective: To develop a computer-based model for the reflection of electromagnetic radiation from stratified layers of anisotropic materials on conducting and non-conducting substrates.

Summary: A series of programs have been written and extensively tested for accuracy. The first program, ISO, calculates the reflection coefficients for electromagnetic radiation reflected from stratified layers of isotropic media. The second program, NONISO, calculates the reflection coefficients from layers of anisotropic materials. The other programs are used for creating input files for these two programs and plotting the output of the two programs. A third program is being developed to include absorption and scattering from particles imbedded in the layers.

Conference Presentation: M. Morgan, D. Fisher, E. Milne, "Microcomputer Computation of Electromagnetic Scattering by Stratified Anisotropic Materials," ACES Annual Meeting, Naval Postgraduate School, Monterey, March 1986.

Title: Investigation of Roles of Environmental Factors in  
Generating Infrasonic Ambient Ocean Noise

Investigator: R. H. Nichols, Adjunct Professor, ONR Research Chair  
of Underwater Acoustics

Sponsor: Office of Naval Research

Objectives: To determine the relative roles of wind and ocean  
surface waves in generating very-low-frequency  
ambient ocean noise.

Summary: A 40-day series of concurrent data on ambient ocean  
noise at frequencies of 2.5-20 Hz, wind speeds and  
wave heights was taken at each of three  
widely-separated sites in the eastern North Pacific.  
Analysis of the data show that, above a background  
level of noise due to other sources, the noise  
spectrum level rises linearly with the log of the  
wind speed. While wave height is broadly  
correlated with wind speed, short periods in which  
the one did not correlate with the other showed that  
the wind was the driving factor associated with the  
noise spectrum level.

Publications: R. H. Nichols, "VLF Ambient Ocean Noise vs Wind and  
Waves," Proceedings of the 12th International  
Congress on Acoustics, Vol. III, Paper H3-1,  
Toronto, July 1986.

R. H. Nichols, "Infrasonic Ambient Ocean Noise vs  
Wind and Waves," Jour. Acoust. Soc. Am.,  
Forthcoming.

Title: Development and Validation of a Navy Chemical Threat Assessment Model for Burst Releases

Investigator: G. E. Schacher, Professor of Physics

Sponsor: Naval Environmental Prediction Research Facility

Objective: Develop a threat assessment model for overwater chemical warfare agents that is applicable to burst releases.

Summary: Current chemical warfare threat assessment models were developed from overland data and we are not necessarily applicable to the overwater regime. Last year an overwater plume model was parameterized and validated using NPS data. These data have been separated into meander and relative diffusion components and the relative diffusion portion used to develop a burst model. The model and subsequent new displays have been delivered to the Navy.

Publications: C. E. Skupniewicz and G. T. Vaucher, "Parameterization of Overwater Diffusion: Separation of Relative Diffusion and Meander", NEPRF CR-86-02, February 1986.

Title: Parameterization of Overwater Diffusion

Investigators: G. E. Schacher, Professor of Physics  
K. L. Davidson, Professor of Meteorology

Sponsor: Naval Surface Weapons Center, Dahlgren

Objective: To develop a parameterization for overwater atmospheric turbulence.

Summary: Data from four overwater operations were used to parameterize the overwater horizontal wind variability. It was found that three parameters were needed to account for shear, buoyancy, and mesoscale forcing. The later two mechanisms are inverse functions of the wind speed. The mesoscale mechanism is dominant for all but high wind speeds and must be taken into account in diffusion modeling. Current models have not done this and underestimate dispersion to a considerable degree.

Publications: G. E. Schacher, "Overwater Horizontal Wind Variability Parameterization", submitted to Journ. Climate and Applied Meteorology

C. E. Skupniewicz and G. E. Schacher, "Parameterization of Plume Dispersion Overwater", Atmos. Environment, 20, 1333, 1986.

Title: Space Shuttle Rocket Exhaust Hazard

Investigators: G. E. Schacher, Professor of Physics  
K. L. Davidson, Professor of Meteorology

Sponsor: Air Force Space Division

Objective: To parameterize the flow and turbulence at Vandenberg Air Force Base and develop a hazard estimates handbook for the Space Shuttle Exhaust.

Summary: Detailed analyses of the mean winds and wind fluctuations at 11 meteorological towers on Vandenberg AFB have been completed. The mean winds have been divided into generic flow scenarios and specific scenarios that can lead to a significant hazard identified. It has been found that the area must be considered as having separate upper and lower fluids for many circumstances. Turbulence data have been reduced to baseline 15 sec turbulence intensity averages and formalisms developed for converting to other time averages. Wind direction, stability, and location dependences have been identified. A coupled puff/flow model has been developed by a contractor and is producing hazard estimates.

Publications: G. E. Schacher, S. Larsen, and T. Mikkelsen, "Diffusion Estimates Handbook (Applications to the Space Shuttle HCL Exhaust Cloud)", NPS-61-86-009, February 1986.

I. Toren, "Flow Models Applied to Vandenberg", Proceedings of the DoD Flow Modeling Workshop, CPIA, 1986.

G. E. Schacher, "Mean Flow in Vandenberg Terrain, Experimental Results", Proceedings of the DoD Flow Modeling Workshop, CPIA, 1986.

E. S. Takle and J. D. Griffin, "Analysis of Wind Speeds at the Space Shuttle Launch Site", BLMRP86-01, Iowa State University, 1986.

G. E. Schacher, C. Skupniewicz, S. Larsen, E. S. Takle, and M. Buell, "Characterizing Turbulence for Complex Terrain Diffusion Modeling", Proceedings 7th Symposium on Turbulence and Diffusion, Amer. Meteorological Society, November 1985.



Title: Atmospheric Isoplanatic Angle Sensor

Investigator: D. L. Walters, Associate Professor of Physics

Sponsor: Massachusetts Institute of Technology, Lincoln  
Laboratory

Objective: The refinement, development and delivery of a fourth  
generation atmospheric isoplanatic angle sensor  
system.

Summary: NPS has been developing remote atmospheric sensors  
that are being used in many Strategic Defense  
Initiative Programs. In support of their SDIO  
programs, Lincoln Laboratory requested that a sensor  
be developed for their use. This task was accepted  
and has been accomplished.

Title: Evaluation of Atmospheric Isoplanatic Angle Measurements

Investigator: D. L. Walters, Associate Professor of Physics

Sponsor: Naval Sea Systems Command (PMS-405)

Objective: To evaluate a one year data base of atmospheric isoplanatic data collected over maritime (Hawaii) conditions.

Summary: An isoplanatic angle probability density curve has been developed for a set of data collected by NPS at Maui, Hawaii. A cross correlation of this data set with the local and synoptic atmospheric patterns has identified the atmospheric features that occur during the median and both wing regions of the probability density curve. The maritime isoplanatic angle appears to be about 30% larger than observed over the continental United States.

Title: Remote Atmospheric Optical Turbulence Sensors

Investigator: D. L. Walters, Associate Professor of Physics

Sponsor: Defense Advanced Research Projects Agency, Rome Air Developments Command

Objective: To investigate the refinement of fourth and fifth generation atmospheric isoplanatic angle sensors. To collect Pacific Coast atmospheric turbulence relevant to Strategic Defense Initiative programs.

Summary: Two major field programs were held during August, 1986. A one week set of atmospheric modulation transfer function and isoplanatic angle measurements were collected during 6-9 August at Mt. Wilson, CA. These measurements showed that the quality of the atmosphere, parameterized by the coherence length  $r_0$  became 2-3 times higher around sunset and sunrise than has ever been measured before. Using these measurements as a guide, a second set of measurements was collected at Anderson Peak during 22-24 August. This mountain is on the Big Sur coast line. Essentially identical results were found at this site. This indicates that the Pacific Coast mountain region has a substantially superior optical quality compared to other continental sites. These measurements may have substantial impact on Strategic Defense Initiative test programs.

Title: Remote Atmospheric Remote Sensor Development

Investigator: D. L. Walters, Associate Professor of Physics

Sponsor: Air Force Weapons Laboratory

Objective: To develop a semi-automated atmospheric modulation transfer function system, a high resolution, long range acoustic sounder for profiling atmospheric turbulence, and to provide atmospheric modulation transfer function measurements at field tests at McDonald Observatory, Texas.

Summary: This is a multi-year program initiated last year. During FY87 we initiated integration of a two dimensional charged coupled detector array to the existing NPS optical system. Additionally, we initiated the development of a computer controlled telescope drive and participated in four field measurement programs at McDonald Observatory, Texas, that quantified the total wavefront distortion across a large aperture. A bids were solicited for a phased array acoustic sounder and an award was granted to the Radian Corporation.

Conference Presentation: D. L. Walters, "Fourth Generation Isoplanatic-angle Sensor," Optical Society of America Annual Meeting, Seattle, October 1986.

Thesis Directed: K. B. Stevens, CAPT, USAF, "Remote Measurement of the Atmospheric Isoplanatic Angle and Determination of Refractive Turbulence Profiles by Direct Inversion of the Scintillation Amplitude Covariance Function with Tikhonov Regularization," Doctor of Philosophy Thesis, December 1985.

Title: Acoustic Multipath Measurements and Analysis

Investigator: O. B. Wilson, Professor of Physics

Associate Investigator: LT Louis Prudhomme, Underwater Acoustics Curriculum

Sponsor: Naval Undersea Warfare Engineering Station

Objective: This is an extension of thesis work done earlier by CDR Bjoern Brekke, and now by LT Prudhomme, under the guidance of Professor Wilson. The objective is to develop a technique for resolving and measuring the transmission loss along the multiple acoustic paths between a source, such as a torpedo, and a receiving hydrophone on the underwater ranges at Keyport and to verify the technique and processing methods using selected experimental data. Although the currently used models for short range acoustic propagation loss appear to work satisfactorily, it is possible that for unusually rough surface conditions or when a directional acoustic array is used, errors of unknown amount could appear.

Summary: The approach here makes use of the time delay spectrometry (TDS) technique. In this method, the frequency of the sound generated at the source is changed fairly rapidly with time, usually with a linear sweep. The received signal at a hydrophone may consist of sounds arriving by multiple paths, each having a different frequency because of the differences in the propagation delay times. The spectrum of the received signal is analyzed and the multipaths resolved using a Hewlett Packard Model 3461A Dynamic Signal Analyzer that performs a rapid sequence of spectra, records and displays them as a function of time. CDR Brekke developed programs which permit an HP 9836 computer to control the analyzer, make analysis of the output data and to construct graphical presentations.

LT Prudhomme has continued this work by analyzing more recent experimental data collected on NUWES' test ranges by Mr. John Burwell, his coworkers, and LT Prudhomme, which cover a wider variety of environmental conditions and regions (Dabob Bay and Nanoose). LT Prudhomme's thesis will be completed in December 1986.

Title: In-Service Performance Monitoring of Submarine  
Sonar Hydrophones

Investigators: O. B. Wilson, Professor of Physics  
S. R. Baker, Adjunct Professor of Physics  
S. L. Garrett, Associate Professor of Physics

Sponsor: Naval Sea Systems Command

Objective: The primary objective has been to develop more operationally relevant performance criteria and measurement techniques for sonar hydrophones by taking advantage of recent developments in the technology of computer controlled instrumentation. With significant contributions from our students, we have developed an automated measuring system using commercially available desk-top computer controlled instruments that have the potential for replacing and/or augmenting some of the instruments currently used in the fleet for monitoring the in-service performance of transducers and for providing the person evaluating the system better information for making maintenance and design improvement decisions. Some specific objectives are:

\*Complete the evaluation of a portable hydrophone test and evaluation system which will provide conventional parameters as well as data from the complex immittance method (CIM)

\*Relate measured parameters to the complex sensitivity.

\*Continue development of a well documented computer program which can calculate changes in the performance of the Sonar array, i. e., sensitivity, beam pattern, steering error, etc., due to degraded hydrophone performance.

\*Develop direct in-situ measurement methods to determine hydrophone sensitivity and wiring polarity using only the apparatus currently employed in CIM measurements.

Summary:

COMPLEX IMMITTANCE MEASUREMENT (CIM) SYSTEM: A CIM system has been delivered to fleet personnel at the Submarine Maintenance and Monitoring Support Office (SMMSO) team in Charleston where it has been used during this past year as a supplement to the standard measurement procedures. Reports indicate that it has been successful and has resulted in significant savings in maintenance work. A CIM User Manual for application to the DT-276 hydrophone in the AN/BQR sonar system has been written and is now being "field-tested".

CHANGES IN ARRAY PERFORMANCE DUE TO DEGRADED HYDROPHONES: A computer program was developed for the Hewlett Packard 200 series computer used with the CIM procedures that calculates changes in beam patterns of the AN/BQR-7 sonar system due to degraded hydrophone performance. This program was augmented in several ways. A simple equivalent circuit model of the DT-276 hydrophone and preamplifier combination has been used in an algorithm which determines the change in complex sensitivity arising from shunt leakage resistance in the stave wiring, hydrophone disconnects, and improper replacement of disconnected hydrophones by a "dummy" capacitor. An algorithm which computes the beam-former time delays for all look-bearing angles, or maximum response angles (MRA) has been developed. (Fleurant had available only the data for three MRAs). Algorithms which compute and display bearing errors and change in the Figure of Merit as a function of MRA have been added.

IN-SITU CALIBRATION AND IN-BOARD POLARITY TESTS: Submarine personnel, to date, have no way of measuring or calculating hydrophone sensitivity after the initial installation of the sonar system. Information about the degradation of the individual hydrophones or staves, if it could be accounted for, would be extremely valuable to the optimum operation of the array. An in-situ relative sensitivity test based on a method due to Van Buren has been developed, and the software for this test has been written. The test involves current and voltage measurements made on sets of three adjacent hydrophone staves during stave to stave transmissions. The software has been tested on a



simulated stave for instrument-controlling capability, and has successfully controlled the switching requirements for 15 stave measurements at a time. A computer program has been written which uses the in-situ calibration system to analyze the phase and amplitude of signals received from a hydrophone stave when an adjacent stave is used as a sound source. An estimate of correctness of the polarity of the hydrophone wiring for each stave is made using a logic table based on measurements taken on a submarine in which correct phasing had already been verified using the outboard phase test currently used by the fleet. It has been found that this stave polarity test will identify incorrectly wired staves, which will then require further testing using the same type of analysis on individual hydrophones in the stave to determine the miswired hydrophone. The test will eliminate the need to go outside the hull, and reduce the number of junction box terminals that are handled.

DEGRADATION OF HYDROPHONE PREAMPLIFIER PERFORMANCE: Changes in the internal impedance of the hydrophone due to sea water leakage into the hydrophone and cable affects the gain and phase of the hydrophone-preamplifier system in the BQR-7 sonar. Studies were made to determine the sensitivity of the system to this form of degradation, using both equivalent circuit modeling and measurement. The results have been useful in computations of beam pattern degradation.

This is a continuing program.

Publication:

E. Kuntsal and O. B. Wilson, "Effects of Changes in Impedance on Performance of the Hydrophone Preamplifier Assembly in the BQR-7 Sonar System," NPS-61-002, Naval Postgraduate School, October 1985.

Theses Directed:

R. E. Self, LT, USN, "Automated Test and Evaluation of Passive Submarine Sonar Transducers," Master's Thesis, December 1985.

S. J. Fleurant, CAPT, Canadian Forces  
"Micro-Computer Modeling and Simulation of Conformal Acoustic Array Performance and Array Element Degradation Effects," Master's Thesis, December 1985.

C. J. Warner, LCDR, USN, and K. M. Ward, LT, USN,  
"Micro-Computer Modeling of Array Performance in the  
AN/BQR-7 Sonar System, Master's Thesis, September  
1986.

Title: Purchase of Impedance/Gain-Phase Analyzer

Investigators: O. B. Wilson, Professor of Physics  
S. L. Garrett, Associate Professor of Physics

Sponsor: NPS Foundation Research Program

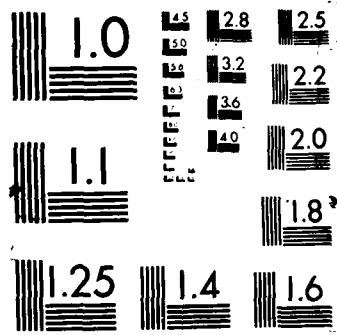
Objective: To improve our capabilities for research in the area of SONAR system transducer, preamplifier, and beam forming modeling, analysis and in situ evaluation.

Summary: Primarily because a Hewlett-Packard Low Frequency Impedance Analyzer came on the instrumentation market three years ago, we and our students have developed procedures for in-service performance monitoring of sonar hydrophones that have been at the technical forefront of this area of work and have proved to be very cost-effective in the Navy's work of maintenance and monitoring of the AN/BQR-7 submarine passive sonar system. The HP4192A continues to be a useful measurement tool. It has also been found to be very versatile instrument. Originally purchased for its capability for transducer admittance and impedance analysis, it has also been effective in measurement of the transfer functions of many other parts of a sonar system.

The HP4149A is the next generation of impedance analyzer, containing both a video graphics display, which presents the results of its measurements, and an ability to do an equivalent circuit analysis and compute circuit parameters for the device under test. It also has the capability to dump these results to a hard copy plotter or printer. We have been getting these results using a computer to control the 4192 and to do the data analysis and graphics. The 4194 will still be computer controllable. However, its forte and the important reason for having one in our laboratory is that the instrument will be more versatile and will be adaptable to a variety of measurement tasks without the necessity of writing a program for the controlling computer. It also may reduce the number of items of equipment needed in a field test.

This instrument, ordered in FY86, had not been received by 31 September 1986. Therefore no results have been obtained.





Title: Application of the Parametric Acoustic Array as a Sub-Bottom Sonar

Investigators: S. W. Yoon, Adjunct Research Professor of Physics  
A. B. Coppens, Associate Professor of Physics  
O. B. Wilson, Professor of Physics  
LCDR K. Ku, ROKN

Sponsor: Naval Undersea Warfare Engineering Station

Objective: This is a continuation of a task first begun in FY85. Its objectives are to investigate the feasibility of using a parametric acoustic array as a sub-bottom sonar to project an acoustic signal from the water column into the bottom and to develop techniques for receiving echoes from the sub-bottom and detecting objects buried in the sub-bottom with the parametric array.

Summary: During the past year the procurement phase was completed. A round redwood tank of 12 feet diameter and 4 feet height was purchased and a fan-shaped sediment tray was constructed from wood. The tray is lined on the sides and bottom with redwood wedges to reduce interior reflections. The narrow end of the tray has an acoustically transparent window to pass the sound beam of the parametric array from the redwood tank into the sediment. Ball clay was chosen as a material suitable for simulating the Keyport sediments. A line-in-cone transducer for use as both a conventional source and a parametric array was procured. It is a line array of eight ceramic cylindrical elements nested within a conical reflector with a mouth diameter of 18 inches. For projection of the parametric beam with a difference frequency ( $f_d$ ) of 20 kHz, a resonance of the wall thickness of the ceramic will be excited at the primary frequencies of 190 and 210 kHz, each component being applied to a subarray of four ceramic elements using separate 500 watt amplifiers. For conventional projection of a 20 kHz sound, the circumferential resonance mode of the ceramics is excited. Hydrophones have been constructed using small (one-quarter inch diameter) piezoelectric ceramic cylinders, to be used in a receiving array.

Work has been progressing on the fabrication and premeasurement phase. A mounting stand for the line-in-cone transducer was designed and constructed. In the sunken anechoic tanks, the transducer was tested for course levels and beam patterns at the primary frequencies (near 200 kHz), at the parametric difference frequency (20 kHz), and at the driving frequency of 20 kHz for conventional projection of sound. The receiving response of each of the piezoelectric ceramic hydrophones has been obtained. Techniques have been developed for the mixing of the ball clay with water to obtain a homogeneous, bubble-free sediment.

These experiments are still in progress. We anticipate concluding our preliminary measurements on the tank and tray, the hydrophone array, and the rod-in-cone transducer and then to compare the properties of the 20 kHz beam projected into the sediment by the source driven conventionally with those of the parametrically formed 20 kHz beam. LCDR Kim graduates in June 1987.



**DEPARTMENT  
OF  
ELECTRICAL AND  
COMPUTER ENGINEERING**

## DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

### Introduction

The research program of the Department of Electrical and Computer Engineering involves projects in the following areas: signal processing, electromagnetics, radar and electronic warfare, communications, and computer engineering. Most projects involve thesis student efforts as indicated by the number of theses published in support of the project.

### SIGNAL PROCESSING

Professor Sydney Parker continued his work on multi-dimensional, nonlinear signal processing. The effort is to develop and implement algorithms to be used in the modeling, identification, and digital filtering of multidimensional, non-linear discrete-time systems.

An investigation has been conducted by Professor John Powers to develop techniques for obtaining quantitative data that can be used to relate rocket propellant combustion and operating environment to the behavior of solid particulates within the grain port and exhaust nozzle.

Preliminary computer simulation results have been obtained by Professor Ziomek in two major areas of study, underwater acoustic model-based signal and frequency domain adaptive beamforming.

### ELECTROMAGNETICS

Professor Hung-Mou Lee continued his work on calculating the electromagnetic fields back-scattered from a cylindrical object. This project extends scattering calculations from wire loops to the cylinder and investigates wall thickness effects. Efforts to improve computer codes were initiated.

Professor Powers continued work on a linear systems approach to the modeling of propagation of short ultrasonic pulses.

### RADAR and ELECTRONIC WARFARE

Professor Titus obtained a very large scale simulation from NRL and converted it for use in the C Lab Computer. Simulations were undertaken regarding the optimum chaff deployment against these missiles.

Professor Titus conducted missile radar simulations in an ECM environment. The Soviet SA10, SA11 and SA12 were simulated. The latest developments in Soviet missilery were studied.

Professor Titus studied a new system coming into the fleet which provides a real time locating and tracking technique for emitters.

#### COMMUNICATIONS

Analytical work was carried out by Professor Bukofzer in order to evaluate digital communication systems' performance in terms of receiver probability of error when jamming signals were present in the channel. Computer programs were written to evaluate receiver performance and optimum jamming schemes.

An underwater battery monitoring system that transmits the data over a fiber optic cable was designed, built and tested by Professor Powers. The link was successfully tested in the laboratory and in the ocean.

Professors Stephen Jauregui and Glen Myers compared compressive and digital receivers. Included in the study were the effects on performance due to noise and inherent ambiguities of the digital receiver.

#### COMPUTER ENGINEERING

Professor C. H. Lee concentrated on building a knowledge based Expert System for Image Understanding. A PROLOG interpreter system allows experimentation of expert rules.

Professor Chin-Hwa Lee continued his work investigating algorithm development and architectural issues for computer-aided mapping applications. The application of VLSI technology and systolic array computers to mapping applications were the areas of interest in this investigation.

Professors Donald Kirk and C. H. Lee developed a signal processing tutorial that emphasizes VHSIC application and held a workshop to present it.

Professors Larry Abbott and Harriett Rigas continue a study of the implication of high speed optical communications on strategic computing where limited data flow has proven to be a bottleneck. The increased data rate offered by laser transmission offers the hope for improved computer performance.

Professor Larry Abbott continues work at NPS on the design of a fault-tolerant computer. Both the computer hardware architecture and the operating system are being designed to reduce failure. The ultimate goal of the project is to reduce the design to a VLSI design.

Professor Harriett Rigas studied a software system that would allow analysis and fabrication of digital circuits for implementation in VLSI.

#### SYSTEMS and CONTROLS

Professors Harold Titus and Alex Gerba worked on developing a Kalman tracking algorithm for a CIE-680 computer to be used in torpedo tracking on test ranges in the presence of multiple sources.

Professor Alex Gerba developed a CSMP program to represent the Brushless DC Motor and its mechanical load that operates on the IBM 370 computer. Refinements to the program are presently being added with a FORTRAN code useful for the IBM PC.

Professor Roberto Cristi formulated an adaptive control strategy and proved its stability mathematically. Further results on persistency of excitation have also been obtained. In particular it has been shown that persistently exciting conditions (sufficient for the convergence of the estimated plant parameters to their values) can be guaranteed by random perturbations of the parameters in the feedback compensator.

Professor Titus conducted studies to determine the interplay of chaff and active decoys used in consort with the Aegis System.

Professor Titus worked on a project to develop microcomputer programs that would calculate optimum drop locations to achieve precision parachute delivery to desired locations for known wind conditions.

Title: Analysis and Experimental Verification of Performance of Coherent and Non-Coherent Binary and M-ary Digital Communication Receivers

Investigator: Daniel C. Bukofzer, Assistant Professor ECE

Sponsor: Space and Naval Warfare Systems Command

Objective: To analyze and evaluate jamming techniques that are effective against digital communication transmissions and to correlate analytical and computer aided results with physical systems measurements.

Summary: Analytical work was carried out in order to evaluate digital communication systems' performance in terms of receiver probability of error, when jamming signals were present in the channel. Computer programs were written in order to evaluate receiver performance, and optimum jamming schemes that are power constrained were derived and evaluated in order to determine their effectiveness. Efforts to correlate results with physical measurements were not successful due to inavailability of the prototype hardware caused by funding cutbacks.

Conference

Presentations: Daniel Bukofzer, "Performance of Digital Communication Receivers in Additive Noise and Intentional Interference", Siam Conference on Linear Algebra in Signals, Systems and Control. Boston, Aug. 1986.

Daniel Bukofzer, "Performance of Receivers in Digital Radio Applications Operating in the Presence of Noise and Jamming", Military Communications Conference. Monterey, Oct. 1986.

Thesis Directed: Fikret Gunes, "Performance Analysis of Modified M-ary PSK and QAM Signaling Schemes in the Presence of Noise and Jamming", June 1986, M.S. Thesis

Barry Shoop, "An Analysis of Coherent and Differentially Coherent Digital Receivers in the Presence of Colored Noise Interference", Sep 1986, M.S. Thesis

Title: Digital Adaptive Control with Finite Time  
Persistency of Excitation

Investigator(s): Roberto Cristi, Assistant Professor of  
Electrical and Computer Engineering

Sponsor: ONR Foundation Research Program

Objective: To provide on-line identification only when  
the plant dynamics change with operating  
conditions;

Summary: An adaptive control strategy has been  
formulated, its stability has been proved  
mathematically, and tested by computer  
simulations. Its major feature is the  
capability of "Turning itself off" when  
satisfactory compensation is achieved,  
by stopping adaptation of the compensator  
parameters. Further results on persistency  
of excitation have also been obtained. In  
particular it has been shown that persis-  
tently exciting conditions (sufficient for  
the convergence of the estimated plant para-  
meters to their values) can be guaranteed by  
random perturbations of the parameters in  
the feedback compensator. The result is  
significant in the indirect adaptive control  
context, since it can be used to avoid con-  
vergence of the estimated plant to unstabi-  
lizable models.

Publications: R. Cristi, "Adaptive Control with Finite  
Time Persistency of Excitation", IEEE  
Transactions on Automatic Control, October  
1986;

R. Cristi, "Hybrid Adaptive Regulation for  
Continuous Time Systems", NPS Technical  
report, inprogress. To be submitted for  
publication;

R. Cristi, "A Parallel Structure for Adaptive  
Pole Placement Algorithms", NPS Technical  
report, submitted to Automatica, in progress.

R. Cristi, "Note on Indirect Adaptive Control  
with Stabilizable Plant Estimates", NPS Technical  
report, submitted to the IEEE Transactions on  
Automatic Control, in progress.

Title: Simulation and Performance of Brushless DC Motor Actuator

Investigator: A. Gerba Jr., Associate Professor of Electrical & Computer Engineering

Sponsor: Naval Weapons Center, China Lake, CA

Objective: To develop a CAD computer program for use in evaluation of the Brushless DC Motor as a replacement device for pneumatic/hydraulic fin control actuators on cruise missiles.

Summary A CSMP program has been developed to represent the Brushless DC Motor and its mechanical load that operates on the IBM 370 computer. Refinements to the program are presently being added with a FORTRAN code useful for IBMPC application in place. Design of a PWM position controller is now underway with completion set for Dec. 1987.

Publication: Alex Gerba, Jr., Simulation and Performance of Brushless DC Motor Actuators  
NPS Tech. report #NPS69-85-028, Dec. 1985.

Title: SIGINT, SIGSEC, C<sup>3</sup>CM Research and Support

Investigators: Professors S. Jauregui and G. Myers, Department of Electrical and Computer Engineering

Sponsor: Space and Naval Warfare Systems Command

Objective: This is an ongoing program to evaluate systems and techniques as they relate to:  
SIGINT, SIGSEC, AND C<sup>3</sup>CM

Summary: The research consisted of a comparison of compressive receivers and digital receivers as energy detectors. Parameters of interest are frequency detection and effects of noise. Also considered were the effects of averaging on and inherent ambiguities of the digital receiver.



**Title:** VHSIC Design Methodology and System Applications, VHSIC Integration in Tactical Image Processing

**Investigator:** D.E. Kirk and Chin-Hwa Lee  
Dept. of Electrical and Computer Engineering

**Sponsor:** Naval Ocean System Center

**Objective:** To develop new design methodology to use VHSIC chips in Naval systems applications.

**Summary:** The application of VHSIC technology to Navy/DoD problems will be continued in the area of image processing. The development of a signal processing tutorial with VHSIC applications were completed and presented at the VHSIC application workshop. During FY86 the investigation was concerned primarily with the preliminary bit-slice micro computer design of a controller for a real-time image processing system.

**Publications:** Lee, C. H. "A parallel Image Registration for object Defection" NPS report NPS-62-86-007. June 1986.

C. H. Lee and A. Keiyu, "Image Compression Using Non-Uniform Samples with Controlled Compression Ratio" proceeding of the 19th Asilomar Conference of Circuit, System and Computers.

Title: Advance Algorithm and Architecture for Digital Mapping

Investigator: C. H. Lee, Dept. of Electrical & Computer Engineering

Sponsor: Defense Mapping Agency

Objective: To explore the advance algorithms and architecture to support the demands of the digital mapping in the Defense Mapping Agency.

Summary: FY86's efforts are concentrated in building the knowledge based Expert System for Image Understanding. A PROLOG interpreter systems allows experimentation of expert rules. This prototype systems invoke the FORTRAN and PASCAL image processing operator for tedious operations. Preliminary results include video tape of the prototype system which will be evaluated by DMA in Washington, D.C.

Thesis directed: LT. M. B. Steward II, "The Application of Bit-Slice Design to Digital Image Processing," M.S. Thesis September 1986.

LT. A. Ledesure, "Image Interpreter Using Expert System," M.S. Thesis, June 1986.

Title: Image Registration Using Similarity Counting Method

Investigator: C. H. Lee Dept. of Electrical and Computer Engineering

Sponsor: NPS Foundation Research Program

Objective: To study the characteristics of a fast image registration algorithm and compare the results with these of the traditional two dimensional correlation algorithm.

Summary: This is a study on the characteristics of a new sequential similarity counting method for the image registration problem. The new algorithm is implemented on the computer. Imagery test data are tried to reveal the ability of the new algorithm in order to confirm its superior processing efficiency and registration accuracy.

Publications: C. H. Lee "Similarity Counting Architecture, Architecture Using CAM memory," proceeding of the 19th Asilomar Conference on Circuit, Systems and Computer, 1985.

**Title:** Finite Cylinder Scattering

**Investigator:** Hung-Mou Lee, Associate Professor of Electrical and Computer Engineering

**Sponsors:** Office of Naval Research

**Objectives:** To investigate theoretically and experimentally the back scattered field from a tubular cylinder and to explore possible applications of the research findings to more complicated targets.

**Summary:** This is a continuation of prior studies into the problem of finite cylinder scattering. In view of the importance of the interior resonant modes, it is desirable that the inside and outside surface current distributions be separated from the radiation current. The inside current is directly related to the internal resonances. The efficiency of the computer codes will be improved and time domain scattering will be investigated.

**Publication:**

"H<sub>11</sub> Circular Waveguide Mode and Back Scattering Cross Section Along the Axis of a Thin Walled Tubular Cylinder of Finite Length." H.-M. Lee, G.P. Chung, D. Geller and B. Haklay, IEE Proceedings, 133, pt.H.(1), 77-78, Feb. 1986.

"Fields from a Uniform Current Source - Instantaneous Switch-on." H.-M. Lee, Journal of Applied Physics, 60(2), 514-517, July 1986.

"Electromagnetic Scattering of Tubular Cylindrical Structure - Double Series Formulation and Some Results." H.-M. Lee, to appear in the IEEE Transactions on Antennas and Propagation.

"Transient Front and Initial Conditions in Maxwell's Theory." S.-C. Lee and H.-M. Lee, to appear in the Journal of Applied Physics.

"Rise and Fall of Directed Transient - Use of Mellin Transformation in Time Domain Problems." H.-M. Lee, submitted to the IEEE Transactions on Antennas and Propagation.

Conference Presentation: "Time-Domain Radiation from an Aperture." H.-M. Lee, Symposium Digest, IEEE/AP-S International Symposium at Boston, (II), 1019-1021, June 1986.

"On Wu's Electromagnetic Missile." H.-M. Lee, Proceedings of the IEEE Symposium on Antenna Technology and Applied Electromagnetics at Winnipeg, Canada, 1, (8), 1-8, August 1986.

"A Class of Pulses Whose Strengths Decrease More Slowly Than  $1/r$ ." H.-M. Lee, accepted for formal presentation at the Fifth International Conference on Antennas and Propagation, York University, UK, 29 March-2 April, 1987.

"Time Domain Studies of Slowly Decaying Pulses." H.-M. Lee, submitted to URSI International Radio Science Meeting, Blacksburg, VA, June 1987.

Title: Aegis System Research

Investigator: Harold A. Titus, Rudolph Panholzer, M. Cotton, Professors of Electrical and Computer Engineering and Uno Kodres, Professor of Computer Science

Sponsor: Navy Sea Systems Command

Objective: To conduct studies in adaptive tracking in an ECM environment.

Summary: Studies were involved in investigating the interplay of chaff and active decoys used in consort with the Aegis System. In this regard the interplay via microcomputers with the Aegis system for aiding and point defense was investigated.

Title: Common filtering for real time torpedo tracking

Investigator: Harold A. Titus and Alex Gerba, Professors of Electrical and Computer Engineering

Sponsor: Navy Undersea Warfare Engineering Station (NUWES)

Objective: To develop a real time common filter tracking algorithm for the torpedo range.

Summary: An extended Kalman filter program was developed and designed to track torpedos via the four hydrophone array that exist on one mile centers in the torpedo ranges associated with the Keyport facility. The program was developed to run on the range computers which are a CIE-680 system utilizing sea language.

Publications: One thesis was involved in this project. Computer programs and computer on loan from Keyport are being returned to them for installation on the range.

**Title:** EA6B Update

**Investigator:** Harold A. Titus, Professor of Electrical and Computer Engineering

**Sponsor:** Pacific Missile Test Center

**Objective:** To apply extended Kalman filter tracking techniques to the bearing only observations for an update to the EA6B ESM system.

**Summary:** Previously the EA6B systems had very marginal capability in giving good angle information on emanations from enemy radar. The new system coming into the fleet will provide great improvements in this area, making it possible to provide a real time locating and tracking technique for emitters.

**Publications:** One thesis is presently working on this project. One thesis was involved in developing and applying the extended Kalman filter to the specific nature of this problem.



Title: Evaluation Simulation and Analysis for the  
Crossbow Committee

Investigator: Harold A. Titus, Professor of Electrical and  
Computer Engineering

Sponsor: Navy Weapons Center, China Lake

Objective: Evaluation, simulation and analysis of Soviet  
missiles/radars.

Summary: Missile radar sumulations in an ECM environ-  
ment are under way. The Soviet SA10, SA11  
and SA12 were simulated. The latest devel-  
opment in Soviet missilery were studied.

Title: Gaters-RPV-AROD

Investigator: Harold A. Titus, Professor of Electrical and  
Computer Engineering

Sponsor: NOSC-HAWAII

Objective: Simulation and Design AROD Control System

Summary: Simulating Fiber Optic Linked RPV with RF  
back up.

Title: NATO SEA GNAT Development Program

Investigator: Harold A. Titus, Professor of Electrical and Computer Engineering and Professor A. W. Cooper, Professor of Physics

Sponsor: Space and Naval Warfare System Command

Objective: To develop optimum strategies for the development of the NATO SEA GNAT chaff against Soviet Antiship cruise missiles.

Summary: Very large scale simulation was obtained from NRL and converted for use in the CQ Lab Computer. Simulations were undertaken regarding the optimum chaff deployment against these missiles. Several other students worked independently in developing cruise missiles simulation programs and radar and electronic warfare programs to aid in this research.

Publications: There have been five thesis students who have worked in support of this research. A composite paper is being prepared for submission to the Tri-Service involved in this project. The software package that was developed is now being used by NOSC.

**Title:** Study and Evaluation of a Miniaturized GPS System with a Guidance Package for Use by Parachutists to Guide them to a Landing Area

**Investigator:** Harold A. Titus, Professor of Electrical and Computer Engineering

**Sponsor:** Naval Ocean Systems Center

**Objective:** To develop a optimum control procedure for a parachutist to drop from 30,000 feet altitude to a precise location given varying wind conditions at different altitudes.

**Summary:** Computer programs were written on the mainframe computer and on the microcomputer to determine optimum launch points for parachutists given an objective drop point and the local wind conditions from the Fleet Numerical Weather Facility. In addition a control point was given to optimally steer the parachutist at various altitudes from his drop point.

**Title:** Underwater Acoustic Propagation and Scattering in a Random Ocean-A Linear Systems Theory Approach

**Investigator:** L. J. Ziomek, Associate Professor of Electrical and Computer Engineering

**Sponsor:** DARPA

**Objective:** To use previously developed computer simulation models (based on derived mathematical models) to study problems in underwater acoustic communication, multiple source localization, and target detection.

**Summary:** Preliminary computer simulation results have been obtained in two major areas of study, underwater acoustic model-based signal processing and frequency domain adaptive beamforming. Model-based phase weights (which correct for deterministic ray bending effects) were derived and were shown (via computer simulation) to significantly increase the ability of a noncoherent correlator receiver to detect pulses propagating in the inhomogeneous ocean medium. A new frequency domain adaptive beamforming algorithm for planar arrays was derived and demonstrated its ability (via computer simulations) to estimate simultaneously, both the depression and azimuthal angles of incoming general plane wave fields. The algorithm is a modified version of the complex LMS adaptive algorithm.

**Publications:** L. J. Ziomek and R. J. Blount, Jr., "Underwater Acoustic Model-Based Signal Processing," IEEE Trans. Acoust., Speech, Signal Processing, in review. L. J. Ziomek and F. Chan, "Frequency Domain Adaptive Beamforming for Planar Arrays," Proc. Twentieth Annual Asilomar Conference on Signals Systems, and Computers, November 10-12,

**Thesis Students:** Francis Chan, Two-Dimensional Beamforming using a Frequency Domain Complex Least Mean-Squares (LMS) Adaptive Filter, Master of Science in Electrical Engineering and Electrical Engineer, June 1986.

**DEPARTMENT  
OF  
METEOROLOGY**

## DEPARTMENT OF METEOROLOGY

The research program in the Department of Meteorology continues in several areas: (1) numerical air/ocean modeling and prediction, (2) dynamics of fronts and flow over and around mountains, (3) analysis and dynamics of tropical weather systems, (4) atmospheric boundary layers over the sea and ice, (5) forecasting marine air/ocean parameters using model output statistics, (6) regional weather studies and (7) satellite remote sensing. A number of related investigations have been pursued by various faculty members under each of these headings.

### NUMERICAL MODELING AND PREDICTION

R. T. Williams is developing and testing numerical procedures for global and regional weather prediction. He is investigating various finite element formulations with respect to treatment of small-scale flow fields. He is applying the techniques to the prediction of air flow near mountains and to tropical cyclones. R. T. Williams and M. A. Rennick are studying topographic effects and the behavior of planetary waves with a spectral baroclinic model and with the normal mode technique. R. T. Williams, C.-P. Chang, M. Peng and C.-S. Liou, are investigating the "Mei-Yu" front over eastern Asia with a regional model.

M. A. Rennick and R. L. Haney are investigating mechanisms of large-scale air-sea interaction in the tropics using coupled numerical models. The work concentrates on ocean temperature and atmospheric circulation anomalies associated with El Nino.

R. L. Elsberry and L. K. Shay are using a three-dimensional ocean model to simulate the response to passage of a hurricane. The present focus is on comparing the predicted response to recent observations of currents and temperature in the ocean after hurricane passage.

Numerical-observational studies of rapid maritime cyclogenesis events are being pursued by R. L. Elsberry, C.-S. Liou, W. A. Nuss and C. H. Wash. Diagnostic studies of analyses and predictions by the Naval Operational Regional Atmospheric Prediction System are used to evaluate physical processes that occur during rapid cyclogenesis.

Other modeling efforts include (1) a dynamical-statistical model for predicting the movement of tropical cyclones, led by R. L. Elsberry, (2) a marine atmospheric boundary layer model for predicting (6-12 hours) properties which affect radar and optical propagation within the boundary layer and those factors (radiation and boundary fluxes) which affect the upper part of the ocean, directed by K. L. Davidson, and (3) a numerical investigation of the dynamics of synoptic-scale variability in the California Current, led by R. L. Haney.

## DYNAMICS OF FLOW OVER AND AROUND MOUNTAINS

R. T. Williams and M. A. Rennick are studying the conditions which determine whether or not the air will flow over or around a long mountain range. The formation of cyclones in the lee of mountain complexes is being investigated. Also, R. T. Williams and M. S. Peng are studying the interaction of fronts with topography.

## ANALYSIS AND DYNAMICS OF TROPICAL WEATHER SYSTEMS

C.-P. Chang, R. L. Elsberry, R. T. Williams and M. S. Peng continue to investigate various aspects of the dynamics of tropical weather systems, including the development of hurricanes and typhoons by R. L. Elsberry, typhoon motion by R. T. Williams, the dynamics of tropical synoptic and planetary motions, and lateral interactions by C.-P. Chang, R. T. Williams and M. S. Peng, and the diagnostic analysis of east Asian monsoon circulations by C.-P. Chang and M. S. Peng. C.-P. Chang and J. S. Boyle also studied the interactions of time-mean and transient flows using a ten-year global data base.

## MARINE ATMOSPHERIC BOUNDARY LAYERS OVER THE SEA AND ICE

Research in the area includes several interdisciplinary shipboard and land-based observational and theoretical projects involving K. L. Davidson and W. J. Shaw. Recent observational projects have occurred in the Marginal Ice Zone of the East Greenland Sea off the coast of Newfoundland and across an ocean front in the northwest North Atlantic Ocean. Objectives of the individual projects are: (1) to evaluate and formulate models which relate changes in the depth and structure of the atmospheric boundary layer to surface fluxes and sky conditions, (2) to evaluate and formulate models for equilibrium marine aerosol distribution, (3) to establish synoptic-scale descriptions of the magnitude and height variations of optical turbulence, and (4) to evaluate synoptic-scale forcing on the boundary layer processes and evolutions in the marginal ice zone.

W. J. Shaw continued investigations of mesoscale variability in the coastal and marine atmospheric boundary layers. Aircraft data collected aboard the NCAR Electra research aircraft in the Sargasso Sea are being analyzed to determine the mechanisms involved in the response of the atmosphere to an open-ocean front. Acoustic sounder and rawinsonde measurements in the Santa Barbara Channel are being used to describe diurnal and topographic influences on coastal boundary layers.

## FORECASTING MARINE AIR/OCEAN PARAMETERS USING MODEL OUTPUT STATISTICS

A multiple-year project directed toward applying the methods of model output statistics (MOS) to forecasting operationally important air and ocean parameters to 48 hours, for all oceans of the world, continued in FY86. The research, involving R. J. Renard, is presently concerned with forecasting near surface horizontal visibility and fog over the North Atlantic Ocean area. Forecast strategies include three conditional probability approaches; linear regression with minimum probable error and maximum-likelihood-of-detection threshold models, and the principal discriminant method. R. J. Renard is applying the methods of Model Output Statistics to develop an objective scheme to forecast horizontal visibility at the Naval Support Force Antarctica base at McMurdo/Williams Field.



## REGIONAL WEATHER STUDIES

F. R. Williams and R. J. Renard (with collaborative efforts from G. H. Jung, Oceanography Department) are in the initial stages of developing a Forecaster's Handbook for the Central American land and adjacent ocean areas which will include sections on climatology, and air/ocean circulations and thermal features that are important to naval air/sea operations.

## SATELLITE REMOTE SENSING

K. L. Davidson is involved in experimental verification on mechanisms responsible for scatterometer and synthetic aperture radar (SAR) images of the ocean surfaces. Measurements of surface stress are being made on a tower off the California Coast, near San Diego, in conjunction with aircraft and Space Shuttle (Shuttle Imaging Radar) overflights. P. A. Durkee is examining the relationship between satellite-detected visible and infrared radiance and extinction by aerosols. C. H. Wash and P. A. Durkee are applying interactive computer techniques to GOES and NOAA visual, infrared and other radiometric data to specify cloud and precipitation patterns using the NEPRF Satellite Processing and Acquisition System and the NPS Interactive Digital Environmental Analysis Laboratory. P. A. Durkee is also examining the relationship between aerosols and cloud development, and the radiative characteristics of clouds. C. H. Wash is using high resolution Space Shuttle photography to better understand mesoscale cloud structure in NASA and DMSP imagery.

Title: Evaluation of NOGAPS Tropical and Medium Range Forecasts

Investigators: J. S. Boyle, Adjunct Professor of Meteorology  
C. H. Wash, Associate Professor of Meteorology  
C.-P. Chang, Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To evaluate the numerical weather prediction products of NOGAPS with special emphasis on the medium-range (3-5 day) and the tropical forecasts.

Summary: Systematic errors of wind, heights and temperature have been computed for the winter of 1983/84, summer 1984 and winter 1984/85. The case study of Asian cold surges in NOGAPS 24 h forecast done last year has been extended to 72 h which shows that the underestimate of jet acceleration due to inadequate divergence representation becomes progressively worse. The summer data indicate that NOGAPS underestimates the monsoon circulation around the Indian Ocean and in southern Asia. The Somali jet and other circulation features are too weak in the model. Comparison with CAC OLR fields indicate that the model forecast convective precipitation fields become less realistic with time. These discrepancies in the convective fields partly explain the wind errors. The continents are too cold at low levels in the summer. In the winter the continents are too cold and the oceans are too warm. This creates spuriously strong sea level baroclinic zones off the east coast of continents. The winter Asian monsoon is also underestimated. The height fields over the Northern Hemisphere oceans reflect the fact that the model cyclones develop too slowly in the western oceans and deepen too much as they pass to the east. A comparison of the systematic error of the 36 hour forecasts of NOGAPS and the Japan Meteorological Agency's Fine Mesh Limited Area Model (JFLM) was carried out over East Asia and the western North Pacific. The study is carried out for the 1983 Mei-Yu season (May-July) which is the wettest season over Eastern Asia based on non-typhoon produced rainfall. Both NOGAPS and JFLM models are more likely to underforecast than to overforecast the existence and/or genesis of cyclones. They also forecast both cyclones and anticyclones too slow and too far to the north. Diurnal variations in central pressure errors suggest that the error source is the lack of

radiation processes in NOGAPS. Also, the failure to treat adequately the bulk effects of cumulus convection seems to be primarily responsible for the poor forecasts of oceanic cyclone development.

Medium-range five-day forecasts were investigated to study high and low predictability periods from two winter seasons. Northern hemisphere 500 mb height fields are scored using the anomaly correlation coefficient. Results show that it is possible to objectively determine why some high and low periods occurred. Flow characteristics leading to high scoring five-day forecasts include: long wave amplitude decay, transition from meridional to zonal flow, and more meridionally extensive flow patterns. This study revealed that persistence is not a good indicator of model performance, and no appreciable skill difference exists between good and poor five-day forecasts at the 48 hour point.

Publication:

Chen, A. T. J., Y. J. Wang, and C.-P. Chang:  
"Evaluation of the surface prognoses of cyclones and anticyclones of the JMA and FNOC Models over East Asia and the Western Pacific during the 1983 Mei-Yu Season". Monthly Weather Review, December 1986.

Conference  
Presentation:

Wash, C. H., J. S. Boyle and J. E. Curtis,  
"Investigation of high and low predictability periods in medium range forecasts". WMO/IUGG International Symposium of Short and Long Range Numerical Weather Prediction, Tokyo, Japan, 4-8 August 1986.

Thesis Directed:

J. Curtis, "An investigation of high and low predictability periods of NOGAPS 2.1 medium range forecasts", Master's Thesis, December 1985.

Title: Analysis of Surface Winds over Tropical Oceans during TOGA

Investigator: C.-P. Chang, Professor of Meteorology

Sponsor: National Oceanic and Atmospheric Administration

Summary: This project is to study the feasibility of enhancing the objective analysis of the surface wind and wind stress fields over the tropical Pacific Ocean during the Tropical Global Atmosphere Experiment. The enhancement is to be based on the incorporation of low-level cloud drift winds from satellite observations using objective methods. The project started in August 1986. In this two-month spin-up phase the marine wind and satellite data are collected and processing has started. A preliminary study has also been carried out to examine some ideas using numerical weather prediction models to accomplish the data incorporation.

Thesis directed: H. H. Chen, "An experiment to improve tropical Pacific marine wind analysis using low-level cloud drift winds", Master's Thesis, December 1986.

Title: Interannual and Spatial Variations of Large-Scale Motions

Investigator(s): C.-P. Chang, Professor of Meteorology  
James S. Boyle, Adjunct Professor of Meteorology

Sponsor: National Oceanic and Atmospheric Administration

Summary: The time mean and transient interactions in the tropical global band from 40S-60N were studied using a 9-year (1974/75-1982/83) data set. We used the concept of an extended Eliassen-Palm flux (E-vector) introduced by Hoskins (1983) and the related calculations to elucidate the dynamics of the time-mean subtropical jet streaks over Eastern Asia (EAJ), North America (NAJ) and North Africa (NAFJ). Similarities and differences between the three jets were discussed in terms of transient momentum and vorticity forcings at both the synoptic and low-frequency time scales. The forcings of both time scales are basically barotropic. The exit regions of the EAJ and the NAJ are quite similar in structure with respect to many of the transient features, and are very similar to the schematic model presented by Hoskins (1983), but the distribution near the NAFJ is different. On the other hand, the entrance region of the NAFJ resembles that of the NAJ, but not the EAJ. In this regard the NAFJ may be considered the entrance region of the combined NAFJ-EAJ system. For low frequency eddies, both the subtropical E-vector and the tropical transient kinetic energy indicate an equatorward energy propagation and a tropical response at 200 mb over the mid-Pacific where the zonal wind is westerly. This seems to agree with the "westerly duct" theories. However, the maxima of these two fields, which are longitudinally aligned, do not coincide with the maximum tropical westerlies. An analogous situation was not observed over the Atlantic. The low frequency calculations also revealed barotropic instability regions in the exit regions of the EAJ and NAJ, and poleward of the NAFJ maximum. This instability distribution agrees with Simmons et al. (1983)'s modeling result near the EAJ, but differs from their results considerably elsewhere. A comparison of the transient kinetic energy fields at the surface indicated the expected transition of a synoptic scale maximum on the western side of the

ocean basins to a low frequency maximum on the eastern side and further north. This is consistent with the history of baroclinic waves as they move east-northeastward while deepening and slowing down. The low frequency fields also tend to have an equivalent barotropic structure apparently due to the vertical development accompanied by deepening (Hoskins, 1983). The transients have little effect on the acceleration of the jet maximum and appear in some regions to have a decelerating effect.

Publications:

Boyle, J. S. and C.-P. Chang, 1986a: Monthly and seasonal winter climatology over the global tropics and subtropics for the decade 1973-1983: Vol. III. Surface winds. Tech Report NPS 63-86-002, 114 pp.

Boyle, J. S. and C.-P. Chang, 1986b: Monthly and seasonal winter climatology over the global tropics and subtropics for the decade 1973-1983: Vol. IV. 700 mb winds. Tech Report NPS 63-86-003, 140 pp.

Boyle J. S. and C.-P. Chang, 1987: An observational study of the time mean-transient interactions during the northern winters of 1973/74-1982/83. Submitted to J. Atmos. Sci.

Lau, K. M. and C.-P. Chang, 1987: Planetary scale features of the winter monsoon and atmospheric teleconnections. Monsoon Meteorology, Oxford University Press (in press).

Title: Tropical and Monsoon Studies

Investigators: C.-P. Chang, Professor of Meteorology  
R. T. Williams, Professor of Meteorology

Sponsor: National Science Foundation

Summary:

A two-level model was used to investigate the effects of vertical shear, differential damping and the planetary boundary layer on the responses to internal heating. It was found that all three effects can allow a transfer of energy from the internal-mode motions, which are directly forced by the internal heating, to external-mode motions. To generate external-mode divergent motions, it is necessary to have a planetary boundary layer or other equivalent effects that force vertical motion at the bottom of the atmosphere. The efficiency of generation increases with the horizontal scale. In addition, this efficiency depends strongly on the relative vertical shear (vertical shear divided by vertical mean wind). The investigation of stability properties of zonally varying mean flow has been continued with a two-scale expansion. It was found that the waves possessed properties which are different from those calculated from local parallel flow theory. This higher order correction shifts the spatial growth rate profile for the nonparallel flow downstream relative to that for the parallel flow. This correction is due to two effects: the lag effect as revealed by previous numerical modeling studies, and an additional effect due to the phase speed difference between the parallel and non-parallel flows. If the disturbance propagates faster than predicted by parallel flow theory, the local spatial growth rate will be smaller than that calculated by the parallel flow and vice-versa. The accuracy of various formulae which relate the spatial and temporal growth rates for barotropic instability was also studied. Several numerical experiments were carried out to simulate the quasi-steady structure of the Mei-Yu front in different environments. The results show that the Low-Level Jet (LLJ) is most conspicuous in the subtropical simulation when high humidity and surface fluxes are included. It is developed and maintained through the Coriolis torque exerted by the low-level poleward branch of a "reversed Hadley cell" equatorward of the front. This thermally direct cell is different from the normal cross-frontal secondary circulation and its development depends on the occurrence of intense convection.

- Publications: Boyle, J., 1986a: Comparison of the synoptic conditions in midlatitudes accompanying cold surges over Eastern Asia for the months of December 1974 and 1978. Part I: Monthly mean fields, individual events and composites. Mon. Wea. Rev., 114, 903-918.
- Boyle, J., 1986b: Comparison of the synoptic conditions in midlatitudes accompanying cold surges over Eastern Asia for the months of December 1974 and 1978. Part II: Time evolution and relations to the general circulation. Mon. Wea. Rev., 114, 918-930.
- Boyle, J. and G. T. Chen, 1987: Synoptic aspects of the Asian winter monsoon. Monsoon Meteorology, Oxford University Press (in press).
- Boyle, J. S. and C.-P. Chang, 1987: An observational study of the time mean-transient interactions during the northern winters of 1973/74- 1982/83. Submitted to J. Atmos. Sci.
- Chan J. C.-L. and R. T. Williams, 1986: Analytical and numerical studies of the beta-effect in tropical cyclone motion. Part I: Zero mean flow. J. Atmos. Sci. (in press).
- Chang, C.-P. and H. Lim, 1986: Kelvin wave CISK: A possible mechanism for the 30-day oscillations. Preprints, Int. Conf. Monsoon and Mesoscale Meteorology, November 1986, Taipei.
- Chang, C.-P. and K. G. Lim, 1987: Kelvin wave-CISK: A probable mechanism for the 30-50 day oscillations. Submitted to J. Atmos. Sci.
- Lau, K. M. and C.-P. Chang, 1987: Planetary scale of the winter monsoon and atmospheric teleconnections. Monsoon Meteorology, Oxford University Press, (in press).
- Lim, H. and C.-P. Chang, 1986: Generation of internal- and external- mode motions from internal heating: Effects of vertical shear and damping. J. Atmos. Sci., 43, 948-957.
- Lim, H. and C.-P. Chang, 1987: On the dynamics of midlatitude-tropical interactions and the winter monsoon. Monsoon Meteorology, Oxford University Press, (in press).
- Peng, M. S., and R. T. Williams, 1986: Spatial instability of the barotropic jet with slow streamwise variation. J. Atmos. Sci., 43, 2430-2442.



Peng, M. S. and R. T. Williams, 1987a: A note on the relation between temporal and spatial growth rates. Submitted to J. Atmos. Sci.

Peng, M. S. and R. T. Williams, 1987b: Spatial instability of a baroclinic current with slow streamwise variation. Submitted to J Atmos. Sci.

Theses Directed: Chou, L. C., 1986: A numerical simulation of a Mei-Yu front and the associated low-level jet. Ph.D. Thesis, Naval Postgraduate School, 153 pp.

Title: Analyses of Atmospheric Measurements (MIZEX)

Investigators: K. L. Davidson, Professor of Meteorology  
G. E. Schacher, Professor of Physics

Sponsor: Office of Naval Research (ONR-1125AR)

Objective: To complete the analyses of shipboard obtained data describing properties of the atmospheric surface layer over open water near the marginal ice zone of the East Greenland Sea. The properties include both the mean and fluctuating wind and the mean temperature and humidity. The data were obtained in MIZEX-84, June-July 1984. Coordination with other groups is required in analyses.

Summary: Analyses and interpretation were performed on surface layer wind, temperature and humidity data. These data were used to obtain estimates of the surface fluxes. The surface layer results were being matched in time and space to atmospheric meso- and synoptic scale features obtained from analyses of data from several locations and from meteorological satellites. Emphasis was placed on how sea surface temperature fronts, separating the Atlantic and Polar water, affected surface stress values. Further emphasis was placed on the variation of the mixed layer depth across the ice edge during different flow conditions. This analysis involved examination of rawinsondes from all ships in MIZEX-84. Papers were prepared, in cooperation with other investigators, on MOZ ocean eddy features and remotely sensed phenomena.

Publications: O. M. Johannessen, J. A. Johannessen, S. Sandven and K. L. Davidson, "Preliminary Results of the Marginal Ice Zone Experiment (MIZEX) Summary Operations", in the Environment of the Nordic Seas, Editor, B. H. Hardle, Springer Verlag, New York, (pp. 665-679), Feb. 1986.

P. S. Guest, and K. L. Davidson, "The effect of observed ice conditions on the drag coefficient in the Summer East Greenland Sea," Journal of Geophysical Research, (forthcoming).

J. A. Johannessen, J. A., O. M. Johannessen, E. Svendsen, P. Shuchman, T. Manley, W. Campbell, E. Josberger, S. Sandven, J. Gascard, T. Olausson, K. Davidson and J. Van Leer, "Mesoscale Eddies in the Fram Strait Marginal Ice Zone during MIZEX 1983 and 1984," Journal of Geophysical Research, (forthcoming).

W. J. Campbell, P. Gloersen, E. G. Josberger, O. M. Johannessen, P. S. Guest, N. Lannelongue and K. L. Davidson, "Mesoscale and large-scale sea ice morphology in MIZEX-84," Journal of Geophysical Research, (forthcoming).

R. W. Lindsay, K. L. Davidson, M. Gueb-Lenhardt, P. S. Guest, R. Picard and C. Wamser, "Synoptic weather events of MIZEX-84," Journal of Geophysical Research, (in progress).

K. L. Davidson, and P. S. Guest, "Naval Postgraduate School Meteorology Studies in the Marginal Ice Zone", Naval Research Reviews (ONR), (forthcoming).

Conference  
Presentations:

K. L. Davidson, "Meteorological studies in the Summer and Winter Marginal Ice Zone (MIZ)," International Conference on Polar Lows, Oslo, Norway, 20-23 May 1986.

K. L. Davidson, "Atmospheric Boundary Layers in the Marginal Ice Zone," Seminar Series Nansen Center, Nansen Ocean and Remote Sensing Center, Bergen, Norway, 26 May 1986.

Thesis Directed:

R. M. Runge, "Variation of Friction Velocity Across the Surface Marginal Ice Zone in the East Greenland Sea," Master's Thesis, December 1985.

Title: Analysis of Atmospheric Measurements Collected on the NOSC Mast

Investigators: K. L. Davidson, Professor of Meteorology  
T. Mikkelsen, Adjunct Professor of Meteorology

Sponsor: Office of Naval Research (Code 1122Cs)

Objective: To perform measurements of mean and turbulent wind, temperature and humidity from the Naval Ocean Systems Center (NOSC) tower off shore at San Diego, California during Shuttle Imaging Radar (SAR) and aircraft overflights and in conjunction with tower based radar measurements. To analyze and interpret the atmospheric stress on surface relative to remotely sensed wave features.

Summary: Eddy flux and variance dissipation rate measurements were made from the Naval Ocean Systems Center (NOSC) tower, located off the coast near San Diego, California during October 1984 (4 weeks) and February 1985 (3 weeks). Eddy flux measurements were made with a sonic anemometer and dissipation rate measurements were made with hot film sensors. Data from the hot film sensors were continuous and from the sonic were for selected periods. Values of the neutral drag coefficient were mostly found to be near constant (0.00094) over the windspeed range of 4 to 10  $\text{ms}^{-1}$ . However, systematic increases of the drag coefficient occurred with the time evolution of the coastal sea-breeze and during the passage of atmospheric cold fronts. A paper describing these results has been submitted for publication (Geernaert, et al.).

Publications: G. L. Geernaert, B. J. Byars, K. L. Davidson, S. E. Larsen and T. Mikkelsen, "Measurements of the Drag Coefficient During the Tower Ocean Wave and Radar Dependence Experiment," Boundary Layer Meteorology, (forthcoming).

Conference  
Presentation: G. L. Geernaert and K. L. Davidson, 1985: "TOWARD Meteorology Measurements" First TOWARD Workshop, Naval Research Laboratory, Washington, DC, 30 Sep -1 Oct 1985.

G. L. Geernaert, 1986: "Systematic Patterns in the Drag Coefficient Observed During the Tower Ocean Wave and Radar Dependence Experiment," Sixth Conference on Ocean-Atmosphere Interaction, Miami, FL, 13-17 Jan 1986.

Title: Analysis/Interpretation of MIZ Atmospheric Mesoscale Features

Investigator: K. L. Davidson, Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To facilitate combined analysis/interpretation of atmospheric features occurring in MIZEX-84 between investigators at NEPRF, NPS, the Polar Science Center (PSC), the University of Washington, Seattle, Washington, and the Alfred Wegner Institute for Polar Research, Bremerhaven, Federal Republic of Germany.

Summary: Polar Science Center and Alfred Wegner Institute investigators performed analysis/interpretation tasks at NPS and NEPRF. The interaction yielded a quite comprehensive description of atmospheric events occurring during MIZEX-84. A paper was prepared for publication (Lindsay, et al.) and a Master's Thesis (Phegley) resulted from the interaction facilitated by the travel funds provided.

Publications: R. W. Lindsay, K. L. Davidson, M. Gube-Lenardt, P. S. Guest, R. Picard and C. Wamser, "Synoptic weather events of MIZEX-84," Journal of Geophysical Research, (submitted).

Thesis Directed: L. D. Phegley, "Synoptic/Mesoscale Meteorological Features in the Marginal Ice Zone," Master's Thesis, December 1 985.

Title: Atmospheric Forcing on Ocean-Atmosphere Mixed-Layer Processes

Investigators: K. L. Davidson, Professor of Meteorology  
G. E. Schacher, Professor of Physics  
W. J. Shaw, Professor of Meteorology

Sponsor: Office of Naval Research (ONR 1122P0)

Objective: The long range objective is to understand and to parameterize the dynamic and thermodynamic processes responsible for coupled changes of adjacent oceanic (OBL) and atmospheric (ABL) boundary layers. Near term objectives are to analyze a Gulf of Alaska (STREX) and a Eastern Pacific data set (MILDEX) for evaluation of an existing coupled OBL-ABL model and to conduct an observational experiment for the Western Atlantic (FASINEX).

Summary: Interpretations were completed and a paper prepared on surface stress results obtained during the Storm Transfer and Response Experiment (STREX) conducted in the Gulf of Alaska. These results show enhancement of wind stress due to wind-wave interaction in advance of fronts, troughs and ridges. Interpretations of surface stress and mixed-layer profiles were performed on data obtained during the Mixed-Layer Dynamics Experiment (MILDEX) conducted off the West Coast. Surface layer and mixed layer (rawinsonde) measurements were made from two ships (R/V Endeavor and R/V Oceanis) during the Frontal Air Sea Interaction Experiment (FASINEX) conducted in the North-West Atlantic (27N, 70W). Preliminary data summaries of surface layer, mixed layer and synoptic scale data were distributed to other investigators.

Publications: P. J. Boyle, K. L. Davidson and D. E. Spiel, "Characteristics of the Overwater Surface Stress during STREX," Dynamics of Oceans and Atmospheres, (forthcoming).

C. Gautier, R. Fourin, J. J. Moncrette and K. L. Davidson, "A method to Estimate Downward Longwave irradiance at the Ocean Surface based on Satellite Data," Journal of Geophysical Research, (in progress).

G. L. Geernaert and K. L. Davidson, "Variation of the Drag Coefficient and Wind Wave Coupling in the Vicinity of a Storm Front," (in progress).

K. L. Davidson and W. G. Large, "Meteorology Measurement Program (Ship Operations)," in FASINEX (Frontal Air-Sea Interaction Experiment), Volume Two: Field Plan", pp. 5.A-1 to 5.A-11, December 1985.

K. L. Davidson, and R. Payne, "FASINEX Phase Two: Shipboard Meteorological Data," FASINEX (WHOI) Data Report, June 1986.

Presentations:

K. L. Davidson, C. Gautier and K. Katsaros, "Radiation with Respect to Atmospheric Boundary Layer (ABL) Cloud Conditions in MILDEX," AGU Ocean Sciences Meeting (MILDEX Session) New Orleans, LA, 13-17 January 1986.

S. R. Fellbaum, K. L. Davidson, P. J. Boyle, and W. Shaw, "Marine Atmospheric Boundary Layer Response to Sea Surface Temperature", AGU Ocean Sciences Meeting (MILDEX Session) New Orleans, LA, 13-17 January 1986.

K. L. Davidson, "Mesoscale Variations of Surface Stress Associated with Wind-wave Coupling," Ocean Wave Dynamics Workshop, Woods Hole, MA, 5-7 August 1986.

K. L. Davidson, "Surface wind stress variations in the vicinity of storm fronts: in situ measurements strategies, Air-Sea Interaction in the ERS-1 pre-launch experiment", Nansen Ocean and Remote Sensing Center, Bergen, Norway, 15 Sept. 1986.

Title: Droplet Contributions to Humidity Exchanges over the Sea

Investigators: K. L. Davidson, Professor of Meteorology  
G. E. Schacher, Professor of Physics

Sponsor: Office of Naval Research (Code 1122MM)

Objective: The long term objective is to determine the humidity exchange from sea to air due to surface prediction of sea salt aerosol. The near term objective is to determine aerosol production per unit white cap coverage from laboratory measurements and to relate observed open ocean aerosol data to white cap coverage.

Summary: Aerosol data obtained in the University College Galway (UCG) whitecap simulation facility and in the Mixed Layer Dynamics Experiment (MILDEX) have been analyzed. Aerosol spectral results from UCG data analyses have been incorporated into a marine aerosol production model (Monahan et al., 1986). Analyses are being performed on data obtained in the University of Marseille wind-wave tunnel during June 1985. A data workshop, held at RISO National Laboratories, Roskilde, Denmark, was attended by D. Spiel. Equipment preparation and calibration was performed for use on board the Research Vessel Frederick Russell off the coast of the Netherlands from 3 October to 19 November 1986. This shipboard measurement effort was part of HEXMAX, a tower and ship based set of measurements to establish humidity exchange properties under high wind conditions.

Publications: C. W. Fairall and K. L. Davidson, "Dynamics and Modeling of Aerosol in the Marine Atmospheric Boundary Layer," in Oceanic Whitecaps and Their Role in Air-Sea Exchange Processes, pp. 195-208, edited by E. C. Monahan and Gearoid MacNiocail, D. Reidel Publishing, 1986.

E. C. Monahan, D. E. Spiel and K. L. Davidson, "Model for Aerosol Production via Whitecaps and Wave Disruption," in Oceanic Whitecaps and Their Role in Air-Sea Exchange Processes, pp. 167-174, edited by E. C. Monahan and Gearoid MacNiocail, D. Reidel Publishing, 1986.

K. L. Davidson and C. W. Fairall, "Optical Properties of the Marine Atmospheric Boundary Layer: Aerosol Profiles," Proceedings, SPIE, Ocean Optics VIII, pp. 18-24, 1986.



Conference  
Presentation:

K. L. Davidson and C. W. Fairall, "Optical Properties of the Marine Atmospheric Boundary Layer: Aerosol Profiles," SPIE, Ocean Optics VIII, Orlando, FL, 31 Mar - 3 April, 1986.

Title: FASINEX Shipboard Meteorology

Investigator: K. L. Davidson, Professor of Meteorology

Sponsor: Space and Naval Warfare Systems Command (Code 00Y)

Objective: To purchase and prepare rawinsonde components and travel to Woods Hole Oceanographic Institution for data transfer in support of measurements of vertical profiles of temperature, humidity and vector wind during FASINEX.

Summary: Rawinsondes and system calibrations were acquired fro profile measurements from the R/V Endeavor during FASINEX (27N, 70W). Data transfer to support these measurements were preformed by Woods Hole Oceanographic Institution.

Title: Marine Boundary Layer Aerosol Optical Extinction

Investigators: K. L. Davidson, Professor of Meteorology  
G. E. Schacher, Professor of Physics

Sponsor: Naval Ocean Systems Center (Code 54)

Objective: The long term objective is to characterize atmospheric aerosol within the atmospheric boundary layer (ABL) in terms of the number, density and size. These characterizations will incorporate meteorological descriptions of the ABL including the vertical profiles of temperature and humidity, the turbulent fluxes at the surface and the inversion. This is a continuing project. Near term objectives are to perform the aerosol characterization for both compact ice and open water regions of the East Greenland Sea Marginal Ice Zone and to develop an oceanic vertical aerosol model.

Summary: Efforts were directed toward three separate areas during the period. These were 1) interpretation of aerosol measured in the East Greenland Sea Marginal Ice Zone (MIZ) during MIZEX-83 and MIZEX-84, 2) formulation of a model for vertical distributions of marine boundary layer aerosol and 3) perform aerosol measurements in East Atlantic (FASINEX) during February and March 1986. Aerosol results from MIZEX-83 were presented at the American Association for Aerosol Research Annual Meeting, Albuquerque, NM, November 1985 and were used in a presentation submitted to the Journal of Geophysical Research in July, 1986 (Borrmann, et al.). Entrainment criteria for the vertical aerosol model were established in meetings between NRL, MOSC and NPS investigators. The basic model for mixed-layer gradients of aerosol was presented at the SPIE, Ocean Optics VIII Conference, 1 April, 1986, Orlando, FL. The model description appears in a full paper in the proceedings (Davidson and Fairall, 1986). Aerosol collection during FASINEX was not successful due to equipment malfunctions.

Publications: C. W. Fairall and K. L. Davidson, "Dynamics and Modeling of Aerosol in the Marine Atmospheric Boundary Layer," in Oceanic Whitecaps and their Role in Air-Sea Exchange Processes, pp. 195-208, edited by E. C. Monahan and Gearoid MacNiocail, D. Reidel Publishing, 1986.

K. L. Davidson and C. W. Fairall, "Optical Properties of the Marine Atmospheric Boundary Layer: Aerosol Profiles," in Proceedings of SPIE Vol. 637, Ocean Optics VIII, pp. 18-24, 1986.

S. H. Borrmann, K. L. Davidson and M. E. Miller, "Surface Measurements of Aerosol Size Distributions in the Marginal Ice Zone during MIZEX 83," Journal of Geophysical Research, (forthcoming).

Conference  
Presentation:

K. L. Davidson and S. H. Borrmann, "Aerosol Measurements During the Marginal Ice Zone Experiments", American Association for Aerosol Research, 1985 Annual Meeting, Albuquerque, NM, 18-22 Nov. 1985.

K. L. Davidson and C. W. Fairall, "Optical Properties of the Marine Atmospheric Boundary Layer: Aerosol Profiles", Ocean Optics VIII, Orlando, FL, 31 March - 2 April 1986.

**Title:** Observational Studies of Marine Boundary Layer Processes

**Investigators:** K. L. Davidson, Professor of Meteorology  
G. L. Schacher, Professor of Physics

**Sponsor:** Naval Air Systems Command (AIR-330)

**Objective:** The long term objective is to understand through observations and modeling the turbulent and radiative processes in the Atmospheric Boundary Layer (ABL) over ocean, ice and mixed surfaces. Near term objectives are to perform analyses and interpretation on ABL properties observed in the Fram Strait Marginal Ice Zone Experiments in the summers of 1983 (MIZEX-83) and 1984 (MIZEX-84) and to prepare for measurements in winter MIZ during March and April 1987.

**Summary:** Analyses and interpretations were performed on the R/V Polar Queen in the East Greenland Sea Marginal Ice Zone (MIZ) during the period 1 June to 20 July 1984. The MIZED-84 results obtained pertain to surface stress and drag coefficients and heat flux derived from a profile mast situated on an ice flow. They also pertain to evaluations of the mixed layer as observed by a flow mounted SODAR. The surface stress and heat flux results indicate that bulk formulae can be derived for the marginal ice zone. Papers describing drag coefficients for various ice conditions, the influence of the atmospheric forcing on ice edge morphology and the mean wind regimes occurring with oceanic eddies have been completed and submitted. Plans are being made and procedures started to instrument three ships for surface layer and rawinsonde measurements during MIZEX-87 to be conducted during March and April 1987.

**Publications:** MIZEX Group (Johannessen, et al.), "MIZEX East 83/84: The Summer Marginal Ice Zone Program in the Fram Strait/Greenland Sea", EOS, Transaction, American Geophysical Union, Vol 27, 33, 10 June 1986.

J. A. Johannessen, O. M. Johannessen, E. Svendsen, R. Shuchman, I. Manley, W. Campbell, E. Josberger, S. Sandven, J. Gascard, T. Olaussen, K. Davidson, and J. Van Leer, "Mesoscale Eddies in the Fram Strait Marginal Ice Zone during MIZEX 1983 and 1984," Journal of Geophysical Research, (forthcoming).

W. J. Campbell, P. Gloersen, E. G. Josberger, O. M. Johannessen, P. S. Guest, N. Lannelongue and K. L. Davidson, "Mesoscale and large-scale sea ice morphology in MIZEX-84," Journal of Geophysical Research (forthcoming).

P. S. Guest and K. L. Davidson, "The effect of observed ice conditions on the drag coefficient in the Summer East Greenland Sea," Journal of Geophysical Research (forthcoming).

K. L. Davidson, and P. S. Guest, "Naval Postgraduate School Meteorology Studies in the Marginal Ice Zone", Naval Research Reviews (ONR)(forthcoming).

Conference  
Presentation:

K. L. Davidson, "Meteorological Studies in the Summer and Winter Marginal Ice Zone (MIZ)," International conference on Polar Lows, Oslo, Norway, 20-23 May 1986.

K. L. Davidson, "Atmospheric Boundary Layers in the Marginal Ice Zone," Seminar Series Nansen Center, Nansen Ocean and Remote Sensing Center, Bergen, Norway, 26 May 1986.

Theses Directed:

E. O. de Rouge, "An Investigation of the Atmospheric Boundary Layer over the Marginal Ice Zone using SODAR," Master's Thesis, December 1985.

L. D. Phegley, "Synoptic/Mesoscale Meteorological Features in the Marginal Ice Zone," Master's Thesis, December 1985.

Title: Electronic Weapon System Satellite Support

Investigator: Philip A. Durkee Assistant Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To develop a method to estimate visibility from satellite measurements of upwelling radiance. Also to evaluate the Defense Meteorological Satellite Program Operational Linescan System (DMSP OLS) and the NOAA Advanced Very High Resolution Radiometer (AVHRR) for their ability to provide input to the visibility estimation scheme.

Summary: The DMSP and AVHRR sensors were evaluated for their potential for visibility estimations. The DMSP system was found to have severe limitations due to a low signal to noise ratio and to ambiguities in the upwelling radiance from the ocean surface. The AVHRR system has considerably higher signal to noise and the spectral response limits the ocean surface contribution to upwelling radiance. The AVHRR system also is able to measure radiance at multiple wavelengths which provides indications of the vertical distribution of aerosol particles. Four radiative transfer approximations were tested for their suitability in a visibility estimation scheme. Fortunately the simplest and most easily inverted approach provides accuracy within our current ability to measure aerosol optical depth from satellites. Therefore the first version of a visibility estimation technique will be simple and easy to evaluate. The project is continuing and is expected to begin producing visibility climatologies of various ocean basins.

Publications: P. A. Durkee and D. E. Burks, "A Method for Estimations of Boundary Layer Visibility from Satellite Measurements." In preparation.

Thesis Directed: Frederick R. Pfeil, "Developing a Physical Basis for an Aerosol Climatology of the Pacific Ocean," Master's Thesis, September 1986.

Title: Radiometric Detection of Marine Atmospheric Boundary Layer (MABL) Characteristics

Investigator: Philip A. Durkee, Professor of Meteorology

Sponsor: Office of Naval Research

Objective: To investigate new techniques for detecting characteristics of the marine atmospheric boundary layer. The program of study was to include participation in field experiments and theoretical radiative transfer calculations to provide physical basis for the observations.

Summary: This project was designed as a three year effort and grew out of an NPS Research Foundation Project. The major accomplishment so far has been the quantization of the effect of aerosol particles above the marine boundary layer on the various techniques for boundary layer characterization. Also, development was begun of a technique designed to estimate boundary layer thickness and relative humidity from satellite measurements of optical depth and total water vapor. The technique uses data from only one satellite sensor but at various wavelengths. The technique is computationally efficient and will provide estimates over wide areas of cloud-free ocean.

Publications: "Aerosol Characteristics Inferred from Dual-Wavelength Radiance Measurements." Submitted to Journal of Geophysical Research.

Conference Presentation: P. A. Durkee, "Aerosol Characterization with Dual-Wavelength Radiance Measurements." Presented at Second Conference on Satellite Meteorology/Remote Sensing and Applications, American Meteorological Society, Williamsburg, VA, 13-16 May 1986.

Thesis Directed: Scott P. Bullfinch, "Determination of the Atmospheric Aerosol Distribution by Multi-Channel Remote Sensing Techniques." Master's Thesis, March 1986.



Title: Satellite Applications for TESS

Co-Investigators: Philip A. Durkee, Assistant Professor of Meteorology  
Carlyle H. Wash, Associate Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To provide NEPRF with satellite applications for the TESS 3.0 system. The philosophy was to prepare applications which best fit within the constraints of available data sources, available computer resources and fleet operational importance.

Summary: A cloud and precipitation classification program, designed for geostationary satellite data, was applied to various cases of polar orbiting satellite data. To improve polar orbiter applications, a navigation routine was developed which will provide accurate location of the image data. Also, study was begun on the application of AVHRR multichannel data to the cloud classification algorithms. Variations in marine status cloud systems was emphasized in this study.

Title: Satellite Detection of Marine Atmospheric Boundary Layer (MABL) Characteristics

Investigator: Philip A. Durkee, Assistant Professor of Meteorology

Sponsor: NPS Foundation Research Program

Objective: This two-year study was designed to investigate the uses of various satellite-borne remote sensing systems to characterize the MABL. The study was to proceed on two tracks. First, a set of observations was to be collected including conventional meteorological observations and satellite data from various sensors. Second, theoretical radiative transfer calculations were to be made to provide physical bases for the observations. The study was to emphasize the use of multiple data-types in order to eliminate as many of the inherent ambiguities in the procedures as possible.

Summary: In the first year of the effort, emphasis was placed on the collection of data sets. Two data sets were obtained for the coastal California region. Early in the study it was realized that a very important error source needed to be analyzed. The technique pursued in this study relies on the detection of aerosol particles in the MABL. Since satellite-borne systems necessarily view the entire atmosphere, aerosol particles above the MABL proved to be a severe hinderance to the technique and their presence must be at least detected. Therefore, the main accomplishment of the first year was the development of a technique to detect the presence of aerosols above the MABL. The second year's effort was devoted to theoretical varification of the upper-level aerosol detection scheme. Also in the second year, work was begun on combining MABL aerosol techniques with water vapor retrieval to develop a MABL depth estimation scheme.

Publications: P. A. Durkee, D. R. Jensen, F. E. Hindman and T. H. Vonder Haar, "The relationship between marine aerosol particles and satellite-detected radiance." J. Geophys. Res., 91, 4093.

Theses Directed: Susan K. Runco, "The Relationship Between Marine Aerosol Optical Depth and Satellite-Sensed Sea Surface Temperature," Master's Thesis, June 1986.

**Title:** Observational-Numerical Study of Maritime Extratropical Cyclones Using FGGE Data

**Investigators:** R. L. Elsberry, Professor of Meteorology  
C. H. Wash, Associate Professor of Meteorology

**Sponsor:** National Aeronautics and Space Administration

**Objective:** To better understand the development, maturation and decay of maritime extratropical cyclones using a combined observational and numerical modeling approach.

**Summary:** Diagnostic studies of a collection of rapid and slow developing cyclones were completed with FGGE data. Additional model simulations of rapid developing systems were studied using GSFC and UCLA models.

**Publications:** Wash, C. H., J. Peak, W. Calland, and W. Cook, 1986: Diagnostic study of explosive cyclogenesis during FGGE", Mon. Wea. Rev., Revised manuscript submitted.

Elsberry, R. L., and M. Sinclair, "A Diagnostic Study of Baroclinic Disturbances in a Polar Air System", Mon. Wea. Rev., Nov. 1986.

**Theses**

**Directed:** D. Smith, "Diagnostic Investigation of Explosive Maritime Cyclogenesis during FGGE," Master's Thesis, March 1986.

P. Kirchoffer, "Study of potential vorticity in FGGE cyclogenesis cases," Master's Thesis, June 1986.

Title: Oceanic Response to Atmospheric Forcing

Investigator: R. L. Elsberry, Professor of Meteorology

Sponsor: Office of Naval Research (Code 422P0)

Objective: To understand and predict the response of the upper ocean to atmospheric forcing.

Summary: The thrust of this continuing research is on the near-inertial current response to hurricane forcing using observations and numerical simulations. A greatly expanded observational study (addition of the other three NAVOCEANO arrays and another current meter array from an Ocean Thermal Energy Conversion (OTEC) site) of the near-inertial response to hurricane Frederic has been completed. The near-inertial response was detected at 950 m at the OTEC site, which was even deeper than the response measured at the NAVOCEANO moorings. The inclusion of the first two baroclinic slope modes in the normal mode decomposition explained 10 and 4% more variance than the first two flat bottom baroclinic modes. A summation of the vertically-averaged flow and the first two baroclinic modes accounted for 52-59% and 67% of the variance in the flat and sloping bottom models. The time-evolution of the first two baroclinic modes agrees with linear theory which predicts that these baroclinic modes will develop a  $\pi/2$  phase difference and separate from the solution in 25 h and 7.2 Inertial Periods.

A 10-level ocean circulation model has been initialized with a geostrophically balanced current field in either the along-track or the cross-track direction using AXBT profiles acquired in the wake of hurricane Frederic. Although a deeper near-inertial response has been simulated, the predicted currents are still considerably less than the observed currents during the passage of Frederic. The numerical simulations with the cross-track initial flow regime demonstrate that the near-inertial wavelength scales with the width of the imposed baroclinic zone.

Publication: L. K. Shay and R. L. Elsberry, "Effect of an initial current regime on the oceanic response to hurricanes," Sixth Annual Gulf of Mexico Information Transfer Meeting, U. S. Dept. of Interior, Minerals Management Service, New Orleans, LA, October 1985.

Conference Presentation: L. K. Shay and R. L. Elsberry, "Simulations of ocean response to hurricanes in a region of initial currents," American Geophysical Union, Fall Meeting, San Francisco, CA, December 1985.

**Title:** Rapid Maritime Cyclogenesis Studies

**Investigators:** R. L. Elsberry, Professor of Meteorology  
 C. H. Wash, Associate Professor of Meteorology  
 C.-S. Liou, Adjunct Professor of Meteorology  
 W. A. Nuss, Adjunct Professor of Meteorology

**Sponsor:** Office of Naval Research (Marine Meteorology)

**Objective:** To understand the physical processes that lead to rapid cyclogenesis at sea by use of Genesis of Atlantic Lows Experiment (GALE) data.

**Summary:** The major thrust of our pre-GALE studies has been the investigation of an east-coast cyclogenesis event on 28-29 March 1984. Application of a linear stability analysis indicates that the rapid growth of this system can be explained as a combined baroclinic and barotropic instability (Toll, 1986; Toll, et al., 1986). Mass, vorticity, heat and moisture budgets based on operational analyses and a NORAPS prediction have been prepared (Rau, 1986). Further studies of the impact of cumulus parameterization have been made by Liou, Elsberry and Hodur (1986). Our active participation in the field experiment has provided many opportunities to test hypotheses related to rapid cyclogenesis.

**Publications:** W. A. Nuss, R. A. Anthes, "A numerical investigation of low-level processes in rapid cyclogenesis," Monthly Weather Review (forthcoming).

W. A. Nuss, "Air-sea interaction influence on the structure and intensification of marine cyclones," (In preparation).

R. F. Toll, Jr., J. C.-L. Chan, R. L. Gall, C. H. Wash, "Baroclinic and barotropic instabilities in the rapid development of the Carolinas storm of March Of 1985," (In preparation).

**Conference Presentation:** C.-S. Liou, R. L. Elsberry, M. Hodur, "Impact of cumulus convection on meso-alpha scale prediction," World Meteorological Organization, Conference on Numerical Weather Prediction, Tokyo, Japan, August 1986.

**Theses Directed:** R. F. Toll, Jr., "A linear stability analysis of the rapid development of an extratropical cyclone". Master's Thesis, March 1986.

R. E. Rau, Jr., "Heat and moisture budgets of an extratropical cyclone based on Navy Operational Regional Atmospheric Prediction System (NORAPS) analyses and forecasts," Master's Thesis, June 1986.

Title: Tropical Cyclone Motion Studies

Investigator: R. L. Elsberry, Professor of Meteorology

Sponsor: Office of Naval Research (Marine Meteorology)

Objective: This new project involves administrative activities and research studies in support of the ONR Accelerated Research Initiative on Tropical Cyclone Motion.

Summary: In addition to serving as Chief Editor of a book emanating from the International Workshop on Tropical Cyclones in Bangkok, I am the author of a chapter on Analysis and another chapter on tropical cyclone motion (Elsberry, 1987). A summary of the results of a planning meeting on the theory of tropical cyclone motion was prepared (Elsberry, 1986).

Publications: R. L. Elsberry, "Some issues related to the theory of tropical cyclone motion," NPS Technical Report NPS 63-86-005, 24 pp., September 1986.

R. L. Elsberry, "Analysis of tropical cyclones" and "Tropical cyclone motion", Chapters 1 and 4, A Global View of Tropical Cyclones, University of Chicago Press, (forthcoming).

Title: Tropical Cyclone Prediction

Investigator: R. L. Elsberry, Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: A continuing effort to improve tropical cyclone prediction by incorporating storm-related factors and synoptic environmental effects in a decision tree approach.

Summary: An evaluation of tropical cyclone forecast aids based on cross-track and along-track components has been published (Elsberry and Peak, 1986). A statistical regression technique for predicting turning motion and acceleration of tropical cyclones has been published (Peak and Elsberry, 1986a). Recent tropical cyclone research at the Naval Postgraduate School has been described at the Pacific Tropical Cyclone Conference (Elsberry, Chan and Peak, 1986). A technique for estimating objectively the location of a tropical cyclone from a variety of fixes has been developed and tested (Curry, Elsberry and Chan, 1986). Based on an independent sample of 22 storms with 610 warning positions, the accuracy of the objective technique is not significantly different from the official Joint Typhoon Warning Center Positions. A detailed analysis has been made of the performance of the U. S. Navy Nested Tropical Cyclone Model (NTCM) in terms of five storm-related factors (Chan, Williams and Elsberry, 1986; Williams, 1986). This study can serve as a prototype for evaluating an objective track forecast aid based on storm-related factors, and thus should be useful to forecasters and to those improving the aids. Empirical orthogonal function analysis has been shown to be useful in depicting efficiently the synoptic flow surrounding tropical cyclones (Peak, Wilson, Elsberry and Chan, 1986). Regression equations for track prediction that are stratified by prior 12-h motion have 72-h forecast errors of only 481 km for the dependent sample. Similarly small errors are found for regression equations derived within synoptic subgroups based on only two eigenvectors. Significant differences in the environmental flow associated with cyclones having different initial directions and speeds can be reconstructed with only a small number of EOF coefficients (Schott, Chan and Elsberry, 1986; Schott, 1985). A post-processing scheme for the One-way Tropical Cyclone Model based on the EOF coefficients achieved a 30% reduction in forecast error at 72 h in the dependent sample. Storm related variables and synopticity factors

represented by EOF coefficients have been objectively combined into classification trees to select the best of eight objective aids (Peak and Elsberry, 1986b). This objective approach reduces the 72-h forecast errors by at least 5% relative to always selecting any one of the eight aids, and is also more accurate than the corresponding JTWC forecasts.

Publications:

J. C.-L. Chan, B. J. Williams, R. L. Elsberry, "Performance of the Nested Tropical Cyclone Model as a function of five storm-related parameters," Monthly Weather Review, (forthcoming).

W. T. Curry, R. L. Elsberry, J. C.-L. Chan, "An objective technique for estimating tropical cyclone warning positions," Monthly Weather Review, (forthcoming).

R. L. Elsberry, J. E. Peak, "An evaluation of tropical cyclone forecast aids based on cross-track and along-track components," Monthly Weather Review, 114, (January 1986), pp. 147-155.

J. E. Peak, R. L. Elsberry, "Prediction of tropical cyclone turning and acceleration using empirical orthogonal function representations," Monthly Weather Review, 114, (January 1986), pp. 156-164.

J. E. Peak, R. L. Elsberry, "Objective selection of optimum tropical cyclone guidance using classification trees," Monthly Weather Review, (forthcoming).

J. E. Peak, W. E. Wilson, R. L. Elsberry, J. C.-L. Chan, "Forecasting tropical cyclone motion using empirical orthogonal function representations of the environmental wind fields," Monthly Weather Review, (forthcoming).

T. B. Schott, J. C.-L. Chan, R. L. Elsberry, "Further applications of empirical orthogonal functions of wind fields for tropical cyclone motion studies," Monthly Weather Review, (forthcoming).

Conference  
Presentation:

R. L. Elsberry, J. C.-L. Chan, J. E. Peak, "Recent tropical cyclone research at the Naval Postgraduate School." Proceedings, 1986 Tropical Cyclone Conference, Environmental Group, U.S. Pacific Command, 154-163.



Theses Directed:

T. B. Schott, "Applications of wind empirical orthogonal functions in tropical cyclone motion studies," Master's Thesis, December 1985.

B. J. Williams, "Effects of storm-related parameters on the accuracy of the Nested Tropical Cyclone Model," Master's Thesis, March 1986.

**Title:** Eddy Generation Mechanisms in Eastern Boundary Current Regions

**Investigator:** Robert L. Haney, Professor of Meteorology

**Objective:** This project is to investigate processes responsible for the generation, evolution and decay of intense synoptic scale variability observed in eastern boundary current regimes, with particular application to the California Current region. It's ultimate goal is to enhance our understanding of eddy generating processes in such regimes, and to thereby provide a basis for high resolution numerical analysis and prediction in these ocean regions.

**Summary:** A 15-level primitive equation ocean model with surface layer physics has been adapted to include an idealized Mendocino Escarpment and continental slope along a straight meridional coastline. The model is in sigma coordinates (non-dimensional depth) and has open boundaries (radiation condition) on all but the eastern coastal boundary. I am studying two types of geophysical problems. The first type is the evolution of an idealized baroclinic coastal jet over an escarpment. The second type of problem is the response of the model ocean to a variety of steady and unsteady wind forcings in the California Current region. The ultimate goal is to understand and predict the generation of synoptic scale eddies which have been observed south of Cape Mendocino in the OPTOMA program.

**Publications:** R. L. Haney, "Some SST anomalies I have known, thanks to Jerome Namias" in Namias Symposium, John O. Rhodes, Ed., Scripps Institution of Oceanography Reference Series 86-17, August 1986, p. 148-159.

T. R. Mettlach, R. L. Haney, R. W. Garwood, Jr., and S. J. Ghan, "The response of the upper ocean to a large summertime injection of smoke in the atmosphere", J. Geophys. Res., 91, (in press), 1987.

Conference  
Presentations:

M. L. Batteen, R. L. Haney and C. N. K. Mooers, The influences of the Mendocino Escarpment, mean flow instabilities and wind forcing on eddy and jet formations in a model of the California Current System. A.G.U. Ocean Sciences Meeting, 13-17 January 1986, New Orleans, LA (EOS, 66 (51), p. 1259).

R. L. Haney, Some SST anomalies I have known, thanks to Jerome Namias. Invited talk, Namias Symposium, Scripps Institution of Oceanography, La Jolla, CA, 22 Oct 1985.

Thesis directed:

Hergert, A., "Eddy energy in the California Current --A model study," Master's Thesis, extension granted until September 1987.

Title: G. J. Haltiner Research Chair in Meteorology

Investigators: R. J. Renard, Professor of Meteorology  
D. W. Thomson, Professor of Meteorology, Pennsylvania State University

Sponsor: Naval Air Systems Command

Objective: The Chair has been established to provide a strong interaction between NAVAIR and NPS with regard to meteorological research of particular relevance to the Navy and to stimulate the professional development of students and faculty in the area of expertise of the incumbent of the chair.

Summary. Several new techniques for measuring the structure of and dynamical processes in the atmosphere's boundary layer, "free" troposphere and stratosphere are being studied: remote sensing systems such as the VHF and UHF Doppler radars and Doppler sodars (for wind and turbulence profiling) and the mm wave radiometers (for temperature and humidity profiling). In the three-radar Pennsylvania State University network, the only one of its type in the world, the various systems are deployed about 160 km apart, a separation corresponding to "fleet" scale. Although installation of such equipment on many ships in a naval task force is clearly impractical, the current measurement and analysis program will define for many naval applications the limitations, if any, of deploying only one or a few rather than many systems for measurements of fleet-scale weather phenomena.

Specific analyses based on the data derived from the remote sensing systems include: developing single station forecasting techniques for estimating temperature and stability advection, calculating mesoscale convergence, estimating vertical heat and momentum fluxes, predicting the spatially inhomogeneous and temporally intermittent evolution of patches of turbulence associated with "CAT" and degraded astronomical "seeing", and finally for defining the fine scale structure of fronts, internal waves and convective systems.

Theses Directed: F. R. Pfeil, "Developing an Aerosol Climatology in the Pacific," Master's Thesis, September 1986.

M. C. Dotson, "Relations of Data Base to the Quality and Reliability of the Integrated Refractive Effects Prediction System's (IREPS) Products," Master's Thesis, March 1987.

Title: Model Output Statistics for Forecasting Air/Ocean Parameters Important to the U. S. Navy

Investigators: R. J. Renard, Professor of Meteorology  
R. A. Hale, Meteorologist, Department of Meteorology  
R. W. Preisendorfer, Scientist, NOAA, Pacific Marine Environmental Laboratory, Seattle, WA

Sponsor: Naval Environmental Prediction Research Facility

Objective: Using methods of model output statistics, develop prediction schemes to forecast (out to 48 hr) air/ocean parameters of operational importance to U.S. Navy activities over the open ocean and coastal waters.

Summary: A multiple-year project directed toward further developing and applying the methods of model output statistics (MOS) to forecasting operationally important air and ocean parameters to 48 h, for all the oceans of the world, continued in FY86. In the past two years the research has been principally concerned with forecasting horizontal visibility near the surface, over the North Atlantic Ocean area, as stratified into physically homogeneous sections. Predictor information has been derived from the Fleet Numerical Oceanography Center's Navy Operational Global Atmospheric Prediction System (NOGAPS). Prediction strategies included three conditional probability approaches (two maximum probability schemes and natural regression); linear regression with minimum probable error (i.e., equal variance and quadratic) and maximum-likelihood-of-detection threshold models; and the principal discriminant method. This year, the research was split between two major efforts, in one case testing four MOS prediction methods on simulated data fields for the purpose of determining their relative skills in forecasting a generic weather parameter. A second major effort involved the effect of the statistical distributional character of six MOS NOGAPS parameters on the skill of forecasting summer fog for the North Atlantic Ocean area, using Beta, Normal and Gamma distributions, and several measures of forecast accuracy.

Publications: R. W. Preisendorfer, "Simulation Data Sets for Testing MOS (Model Output Statistics) Prediction Methods", NOAA Technical Memorandum ERL PMEL-65, Pacific Marine Environmental Laboratory, Seattle, WA, Oct 85, 53 pp.

R. J. Renard "Postgraduate School in Forefront of MOS Research", Naval Environmental Prediction Research Facility METEOREPORT NO. 26, February 1986.

Theses Directed: S. J. Fatjo, "A Study to Determine the Relative Skill of Four Model Output Statistics Prediction Methods Using Simulated Data Fields," Master's Thesis, March 1986.

O. J. Muldoon, "Relating the Distributional Character of Numerical Model Output Parameters to the Occurrence of Fog over the North Atlantic Ocean," Master's Thesis, June 1986.

Title: Operational Weather Forecasting--Antarctica

Investigators: R. J. Renard, Professor of Meteorology  
R. A. Hale, Meteorologist

Sponsor: Naval Support Force Antarctica

Objective: To improve the operational weather forecasting capability in Antarctica, with emphasis on the area surrounding the Naval Support Force Antarctica base at McMurdo/Williams Field.

Summary: The McMurdo/Williams Field Antarctica surface and automatic weather station data base (February 1980 - December 1983) was established. Multiple linear discriminant, persistence and conditional climatology schemes were developed and applied to visibility forecasts (< 3, < 2, < 0.5 mi.) at McMurdo for 3-, 6- and 12-h forecasts. Using skill indicators of percentage correct, power of detection, false alarm rate, threat score and Brier probability score, the dependent data evaluation indicates that the discriminant approach generally excels in power of detection and threat score.

Publications: R. A. Hale and R. J. Renard, "Statistical Visibility Forecasting at McMurdo/Williams Field, Antarctica using Local/Regional Observations", (pp. 256-60) in Proceedings of Second International Conference on Southern Hemisphere Meteorology, Wellington, New Zealand, 1-5 December 1986, 482 pp.

Title: Regional Synoptic Forecasting Central America and  
Adjacent Caribbean Sea/North Pacific Ocean Areas

Investigators: R. J. Renard, Professor of Meteorology  
F. R. Williams, Adjunct Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To produce a handbook describing the analysis and  
forecasting of atmospheric and ocean conditions  
important to air/sea operations over and near Central  
America.

Summary: Climatological, analytical and forecast information on  
air/ocean parameters of operational importance in the  
Central American area were assembled from literature  
searches, personal contacts and site visits to the  
National Hurricane Center, Coral Gables, FL;  
Oceanography Command Detachment, Key West, FL; Air  
Force Global Weather Center, Offutt Air Force Base,  
NE; Fleet Numerical Oceanography Center, Monterey, CA;  
Air Force Twenty-fifth Weather Detachment, Fifth  
Weather Wing, Howard Air Force Base and Panama Canal  
Commission, Panama Canal Zone; Air Force Environmental  
Technical Applications Center, Scott Air Force Base,  
IL; and the National Center for Atmospheric Research,  
Boulder, CO. In FY87 a Forecaster's Handbook will be  
developed from the assembled materials.



**Title:** Air Flow over Large Scale Topography

**Investigators:** M. A. Rennick, Adjunct Professor of Meteorology  
R. T. Williams, Professor of Meteorology  
M. S. Peng, Adjunct Professor of Meteorology

**Sponsor:** National Science Foundation

**Objective:** To utilize observational results from ALPEX with theoretical and numerical studies to investigate the interaction between air flow and large scale topography.

**Summary:** The formation of cyclones in the lee of a long mountain range was studied with analytic and numerical models and the principal mechanism was isolated. The interaction of deformation forced fronts with topography was investigated. The two scale method was applied to baroclinic instability in a zonally varying basic current, which could have been forced by topography.

**Publications:** R. L. Gall, R. T. Williams, and T. L. Clark, "On the minimum scale in fronts". Submitted to Journal of the Atmospheric Sciences.

R. L. Gall, R. T. Williams and T. L. Clark, "Gravity waves generated during frontogenesis". Submitted to Journal of the Atmospheric Sciences.

J. L. Hayes, R. T. Williams and M. A. Rennick, "Lee cyclogenesis, Part I: Analytic studies." Journal of the Atmospheric Sciences, January 1987.

M. S. Peng and R. T. Williams, "Spatial instability of a baroclinic current with slow streamwise variation." Submitted to Journal of the Atmospheric Sciences.

M. S. Peng and R. T. Williams, "A Note on the relation between temporal and spatial growth rates". Submitted to Journal of the Atmospheric Sciences.

**Conference Presentations:** D. A. Zankofsky, R. T. Williams and M. S. Peng, "Interaction of fronts with topography". American Geophysical Union, Fall Meeting, San Francisco, CA, December 8-13, 1985.

D. A. Zankofsky, R. T. Williams and M. S. Peng, "Interaction of fronts with topography." WMO/IUGG International Symposium on Short and Medium Range Weather Prediction, Tokyo, Japan, August 4-8, 1986.

Title: Large-Scale Atmosphere-Ocean Coupling

Investigators: Mary Alice Rennick, Adjunct Professor of Meteorology  
Robert L. Haney, Professor of Meteorology

Sponsor: National Science Foundation

Objective: To investigate and identify processes responsible for large scale air-sea interaction in the equatorial region associated with the El Nino-Southern Oscillation (ENSO) phenomenon.

Summary: An analytic investigation of unstable air-sea interactions in a coupled reduced-gravity ocean-atmosphere model of the equatorial region has been completed (Rennick and Haney, 1987). The results demonstrate the extreme sensitivity of the coupled air-ocean system to processes that affect the ocean surface temperature. A comment was made on a previous model study by Anderson and McCreary which was based on an improper formulation of upper ocean physics (Haney and Rennick, 1986). We are presently investigating, analytically and numerically, the processes that influence the equatorial SST variability on ENSO time scales.

Publications: M. A. Rennick, and R. L. Haney, "Stable and unstable air-sea interaction in the equatorial region", J. Atmos. Sci., (1987, in press).

R. L. Haney, and M. A. Rennick, "Comments on 'Slowly propagating disturbances in a coupled ocean-atmosphere model'", J. Atmos. Sci., 43, 749-750 (April, 1986).

Title: Aircraft Measurements in the Frontal Air-Sea Interaction Experiment (FASINEX)

Investigator: W. J. Shaw, Assistant Professor of Meteorology

Sponsor: The National Science Foundation

Objective: To collect data during FASINEX using NCAR Electra aircraft and to use it to deduce the atmospheric boundary layer's response to an ocean front.

Summary: The NCAR Electra flew six missions near 70W and 28N in February 1986. Meteorological data were received from NCAR in July 1986. Work is currently in progress to execute inter-platform data comparisons, map the surface mean and flux fields, remove INS drifts from the winds, establish averaging criteria for statistics and produce momentum and energy budgets for the flight days. Early results indicate that there is a clear reflection of the ocean front in the surface stress fields. Further, there appears to be very good agreement between airborne scatterometer measurements and eddy-correlation estimates of surface stresses.

Title: Investigation of Atmospheric Boundary Layer Processes in the Santa Barbara Channel

Investigators: W. J. Shaw, Assistant Professor of Meteorology

Sponsor: Western Oil and Gas Association

Objective. To collect data using surface meteorological instrumentation and rawinsondes on the R/V Acania and using an instrumented tower and a sodar at a shore station in the Santa Barbara Channel for the purpose of investigating mesoscale circulation patterns in the Channel.

Summary: The project was a continuation from FY 1985. The data collection was completed in the first week of October, 1985. The remaining time was spent in dismantling equipment, returning it to NPS, and reducing the data. Data tapes containing rawinsonde profiles, Acania and tower surface fluxes at hourly intervals, and sodar wind and backscatter profiles have been produced. The data reveal very large amplitude sea breeze circulations in the area with significant modulations by the local topography. These circulations occur in conjunction with stable boundary layers which at times are only a very few tens of meters deep.

Publications: W. J. Shaw, S. Borrmann, C. Fellbaum, C. E. Skupniewicz, C. A. Vaucher, and G. T. Vaucher, "Sodar, rawinsonde, and surface layer measurements at a coastal site: SCCAMP data report, Part II", Naval Postgraduate School Technical Report, NPS-63-86-001, April 1986.

C. E. Skupniewicz, S. Borrmann, C. Fellbaum, W. J. Shaw, C. A. Vaucher, G. T. Vaucher, "Shipboard observations of mean and turbulent atmospheric surface layer quantities: SCCAMP data report, Part I." Naval Postgraduate School Technical Report, NPS-61-86-012, May 1986.

Theses directed: D. Scovil, "An analysis of mesoscale variability in the Santa Barbara Channel using Sodar data," Master's Thesis, December 1986.

Title: Atmospheric Profiles of Optical Turbulence

Investigators: D. L. Walters, Associate Professor of Physics  
W. J. Shaw, Assistant Professor of Meteorology

Associate Investigators:

K. L. Davidson, Profesor of Meteorology  
P. J. Boyle, Meteorologist

Sponsor: Naval Environmental Prediction Research Facility

Objective: Interpretation of recent data on vertical profiles of  $C_N^2$  and comparison of data with recent models which are based on mean properties of the troposphere and stratosphere.

Summary: Sodar data collected aboard the R/V Acania during the 1983 Mixed Layer Deepening Experiment (MILDEX) were analyzed to yield the vertical structure of small-scale index of refraction variations in the marine atmospheric boundary layer (ABL). A recently-derived calibration of the acoustic sounder was employed to yield quantitative values of the refractive index structure parameter  $C_N^2$ . Time-height cross-sections of this variable were generated in an analysis of the nature and extent of the evolution of refractive structure in the marine ABL.

Above the boundary layer, measurements of  $C_N^2$  were made a several sites using the isoplanatic angle for optical wavelengths. This metho<sup>d</sup> was complementary to the ABL information, and together they provided a comprehensive picture of refractive index fluctuations throughout the entire atmosphere.

Title: GOES Satellite Data Analysis for Weather Analysis and Forecasting

Investigators: C. H. Wash, Associate Professor of Meteorology  
P. A. Durkee, Assistant Professor of Meteorology

Sponsor: Naval Air Systems Command

Objective: Implement algorithms to analyze GOES visual, infrared and other channel data to produce specification of hazardous surface weather for naval operations (presence of precipitation intensity, low visibilities and ceilings) in silent areas between conventional observations using the SPADS system.

Summary: Satellite cloud and precipitation estimation program evaluation was modified for winter, spring and fall seasons. Collected GOES and surface data sets are being used to further develop cloud mapping techniques.

Publications: Wash, C. H., L. Spray and L. Chou, 1986: "Geostationary Satellite ANALyses of Cloud and Precipitation Parameters", Weather and Forecasting, Accepted with revisions.

Theses  
Directed: Spray, L., "Geostationary Satellite Analyses of Precipitation and Cloud Parameters", Master's Thesis, December 1985.

Crosby, Robert F., "Three-Dimensional Display of synoptic Scale Weather Data," Master's Thesis, June 1986.

Title: Development of Finite Element Prediction Model

Investigators: R. T. Williams, Professor of Meteorology  
A. L. Schoenstadt, Professor of Mathematics  
R. E. Newton, Professor of Mechanical Engineering

Sponsor: Naval Air Systems Command

Objective: To develop and test a finite element atmospheric prediction model.

Summary: The Canadian finite element program was modified to allow for time dependent boundary conditions. Also a more efficient solver was developed for the Helmholtz equation. A study of the effects of different finite element formulations on Rossby waves was carried out.

Publications: B. Neta and R. T. Williams, "Stability and Phase Speed for Various Finite Element Formulations of the Advection Equation." Computers and Fluids, 14, 393-410 (1986).

B. Neta, D. Hinsman and R. T. Williams, "Studies in a Shallow Water Fluid Model with Topography," Numerical Mathematics and Applications, Elsevier Science Publishers, 1986, 347-354.

R. E. Newton, Improvements to the Staniforth-Mitchell Barotropic Numerical Weather Prediction Code. NPS Report NPS 69-86-008, 1986, 22 pp.

Title: Numerical Modeling of Unique Atmospheric Phenomena

Investigators: R. T. Williams, Professor of Meteorology  
M. S. Peng, Adjunct Professor of Meteorology  
M. A. Rennick Adjunct Professor of Meteorology

Sponsor: Naval Air Systems Command

Objective: Develop and test better numerical techniques for use in Navy weather forecasting models.

Summary: Numerical solutions from the UCLA potential enstrophy model and the NEPRF spectral model were compared with respect to synoptic pattern, energy and potential enstrophy. A study of the interaction of planetary waves with synoptic waves was begun. The NOGAPS model was used with the technique developed by Errico and selective Fourier smoothing was employed. The interaction of fronts with topography was simulated for a variety of mountain scales.

Publications: J. L. Hayes, R. T. Williams and M. A. Rennick, "Lee cyclogenesis Part I: Analytic Studies". Journal of the Atmospheric Sciences, January 1987.

Conference Presentations: D. A. Zankofsky, R. T. Williams, and M. S. Peng, "Interaction of Fronts with Topography," American Geophysical Union, Fall Meeting, San Francisco, CA, December 8-13, 1985.

D. A. Zankofsky, R. T. Williams and M. S. Peng, "Interaction of Fronts with Topography." WMO/IUGG International Symposium on Short and Medium Range Numerical Weather Prediction, Tokyo, Japan, August 4-8, 1986.



**DEFENSE**

**RESOURCES MANAGEMENT**

**EDUCATION CENTER**

### Defense Resources Management Education Center

The Defense Resources Management Education Center (DRMEC) is a DoD sponsored tenant activity located at the Naval Postgraduate School. The mission of the Center is to conduct resources management short courses for mid to senior level officers and civilians from the U.S. and allied nations. Since 1965 over 16,000 U.S. and 5,000 international participants have attended DRMEC courses.

The faculty of the Center are faculty of NPS and as such engage in a wide variety of research programs in support of the DoD mission. Recent areas of faculty research include: Soviet Public Expenditure (Professor Earl Brubaker); The Impact of Defense Expenditures on Economic Growth (Associate Professor Peter Frederiksen and C. J. LaCivita); The Structure of the Defense Industry (Assistant Professor Robert Pirog); Systemic and Demographic Approach to Federal Budgeting (Professor John Dawson); Behaviorally Based Models of Defense Planning and Decision Making (Associate Professor Kent Wall); JCS Sponsored Global Simulation Modelling (Professor Robert Von Pagenhardt); U.S.A.F. Air Logistic Center Effectiveness Indicators (Associate Professor Robert Boynton and LCDR Larry Vaughan); Performance and Absenteeism in Public Organizations (Associate Professor James Morris); DoD Manpower Issues (Professor James Blandin).

Title: Foundations for Functional Manpower Standards

Investigators: Robert E. Boynton, Associate Professor of Management, DRMEC; LCDR Larry E. Vaughan, Instructor, DRMEC

Sponsor: U.S. Air Force, Air Logistics Command

Objective: To assist the Air Force Logistics Command in clarifying the functions, activities, and indication of effectiveness for the material management organizations of the five Air Logistics Centers. The analysis will lay the ground work for developing the ability to identify, defend, and project manpower requirements for the material management organization.

Summary: Information on the perceived functions of the material management (MM) organizations was gathered through (1) systems analytic discussions with groups of managers within each MM organization and (2) an open-ended functional survey of related organization and users/customers. These revealed a lack of agreement on the organization's basic function, requiring the development of a comprehensive list of functions. This list was used in a structured survey of related organizations and users/customers. It was also used in a computer-based preference modeling program to establish importance weights for each function by executives in the MM organization and Commanders or Vice Commanders of the ALC's.

Title: Design of Procedures for Public Expenditure Decisions

Investigator: Earl R. Brubaker

Objective: To design a procedure for collective economic decisions that will facilitate near unanimous approval of an efficient allocation without requiring complete disclosures of demands.

Summary: A novel hypothesis about behavior in collective economic decisions was proposed, namely, it was suggested that participants in such decisions will disclose latent demands provided that doing so results in no appreciable loss of opportunity for material gain. A procedure for collective decision based on the hypothesized behavior was proposed.

Publication: E. R. Brubaker, "Efficient Allocation and Unanimous Consent with Incomplete Demand Disclosures?" Public Choice, 48-3 (1986) pp. 217-227.

Title: Soviet Public Expenditure Decisions

Investigator: Earl R. Brubaker

Objective: To study Soviet public expenditure decision procedures to learn: (1) who participates (2) how objectives are defined, (3) what criteria are used, (4) how the process might be modeled and (5) how understanding the process can facilitate explanation and/or prediction of Soviet public expenditure changes in response to changing circumstances.

Summary: Collection and analysis of pertinent materials continued.

**Title:** FORECASTS System

**Investigator:** Robert von Pagenhardt, Professor of Political Science, John E. Dawson, Professor of Management; LtCol Linwood E. Blackburn, Jr., Military Instructor; Donald Bonsper, Adjunct Professor of Management; Robert L. Pirog, Assistant Professor of Economics; Kent D. Wall, Associate Professor of Systems Engineering; and LCDR Larry Vaughan, Military Instructor, Defense Resources Management Education Center

**Sponsor:** Office of Joint Chiefs of Staff; JDSSC/DCA

**Objective:** To update, enhance, and make more useful the FORECASTS System of the Joint Staff in order that J-5 and others may (1) wisely anticipate trends, developments and challenges affecting the U.S. and the world twenty years hence, and (2) better consider alternative long-range strategies to deal with dangers and/or opportunities.

**Summary:** The needed work will transform the present main-frame FORECASTS onto a micro-computer based FORECASTS II by updating a validated database through 1985, developing PC DOS compatible software for JCS desktop computers, creating an informational relations forecasting module, and providing documentation meeting high standards of science and exposition.

**Publication:** This project calls for a book covering the use of the FORECASTS System in anticipating global challenges and evaluating alternative national policy.

**Conference Presentation:** Binary Conference at Dartmouth, July 20-23, 1986.

DEPARTMENT  
OF  
AERONAUTICS

## DEPARTMENT OF AERONAUTICS

During the reporting period, Aeronautics faculty have been active in the following major research areas:

### AIRCRAFT COMBAT VULNERABILITY

Professor Hall conducted studies on six different projects the past year. These included two missile description projects, survivability assessment in conceptual design, survivability guidelines for aircraft designers, anti-aircraft gun effectiveness, and a case study of the vulnerability of a fixed-wing aircraft.

### SPACECRAFT AND AIRCRAFT IN IONOSPHERIC PLASMAS

Professor Ruppel is studying applications of electrode theory and plasma flow theory to electromagnetic propulsion devices. Many devices considered require high current currents traversing plasma flows. The electrodes are a potential source of problems which may give rise to a variety of undesirable effects. The work is aimed at the basic understanding of these phenomena.

### MEASUREMENTS OF THE DYNAMIC STALL OF OSCILLATING AIRFOILS

Professors Ruppel and Platzer are performing an investigation to qualitatively and quantitatively determine the effects of unsteady separation, flow reattachment, separation, reattachment, type of stall and the development over an oscillating airfoil as the Mach number is increased from 0.2 to 0.8.

### COMBAT VULNERABILITY TO HIGH ENERGY LASERS

Professor Ruppel and Professor Fuhs has continued work in his area of Satellite vulnerability to high energy lasers (HEL) by completing several studies during the year. The primary problem of tracking satellites in LEO was investigated. Experiments were conducted using an optical simulation. The effects of wavelength, and the effects of wavelength were scaled.

### NUMERICAL SOLUTIONS OF FREE EXHAUST

Professor Fuhs is extending previously used methods for obtaining solutions for the flow of a gas through transitional to free-molecular flow. This work was done in collaboration with Professor Fuhs and Dr. J. Falcovit during the year. The work was done using a "down-surface" model and an integral method. Solutions were obtained using



### UNDERWATER SHAPED CHARGES

In a continuation of the effort to predict the behavior of metal jets from shaped charges fired underwater, the warheads designed by Distinguished Professor Fuhs' Underwater Shaped Charge team were fabricated and tested at NSWC/WOL. Temperature, velocity, burning times, particle size, and particle dynamics were measured for a series of metals.

### SOLAR CELL RADIATION DAMAGE EFFECTS

The components for a Solar Cell Test Facility were procured and assembled by Distinguished Professor Fuhs. The test facility is operational except for special measurement of the test lamp and for calibration of the irradiance from the test lamp. Gas cells were purchased for tests in FY86; a series of tests were conducted using 20 MeV radiation from the NPS Linac. Tests were performed so as to permit drawing curves of performance degradation versus fluence.

### HELICOPTER-SHIP INTERFACE

A study of the feasibility of simulating the land of an arbitrary helicopter on an arbitrary non-aviation ship in poor weather conditions is being performed by Professor Healey. The objective of this study is to develop a realistic ship-helicopter-weather simulation that will permit determination of the 'corners-of-the-envelope' for certifying helicopter landings on 'small boys'.

### COMPUTER MODEL FOR WINDSTREAM TEST FACILITY

Professors Miller and Biblarz are studying the fluid dynamics of a Windstream Test Facility and propose improvements in flow characteristics and controllability.

### SOLID FUEL RAM JET COMBUSTION

An experimental investigation was conducted by Professor Netzer to examine the effects of inlet air swirl and secondary gas injection on the combustion properties in a solid fuel ramjet. Also, an experimental investigation was conducted of highly metallized (approximately 70% by weight) solid fuels burned in a two-dimensional solid fuel ramjet (SFRJ).

### FUEL EFFECTS ON COMBUSTOR AND AUGMENTOR TUBE EMISSIONS

Professor Netzer experimentally investigated the combustion mechanisms of smoke suppressant fuel additives and the effects of JP fuel composition by evaluating their effects on the distribution of temperature, carbon particle concentration and  $\text{NO}_x$  concentrations within a gas turbine engine combustor and the exhaust augmentor tube.

### SOLID PROPELLANT COMBUSTION/AUTOMATED DATA RETRIEVAL FROM HOLOGRAMS

Professor Netzer is developing techniques for obtaining quantitative data that can be used to relate rocket propellant composition and operating environment to the behavior of solid particulates within the grain port and exhaust nozzle. The techniques employed are high speed motion pictures, SEM analysis of collected products, light scattering measurements at the entrance and exit of the exhaust nozzle and holograms within the grain port.

### RELIABILITY CHARACTERISTICS OF COMPOSITE MATERIALS

Professor Wu is using mechanics of materials techniques to quantitatively model composite material behavior to gain an understanding of the parametric roles of fiber and matrixes on the strength and durability of composites. Experimental measurements have been made on graphite/fiber, graphite/aluminum and graphite/epoxy composites. A laser diffraction instrument for measuring fiber diameter was developed. Design and construction for stress rupture measurement of single filament life was initiated.

### AGING CHARACTERIZATION FACILITIES FOR COMPOSITES

Uniaxial and combined-stress probabilistic strength and life determinations are being made by Professor Wu in order to develop test methods, data and theories that will contribute to the rational development of certification methodologies for fiber reinforced composite structures.

### COMPOSITES STRESS RUPTURE EQUIPMENT

Professor Wu is establishing stress rupture equipment for long term tests. The facilities will consist of portable stress-rupture testing machines which are capable of recording the elapse time of stress life and immune to external disturbances. Data generated by these facilities, when interpreted by kinetic process relations together with the chain-of-bundles model will provide an estimation of long term aging effect and a quantitative basis for reliability design.

### TURBOPROPULSION

Professor Shreeve, the Director of the NPS Turbopropulsion Laboratory, and his collaborators are studying propulsion problems ranging from the numerical simulation of internal flows, the development of a transonic compressor model, the development of a centrifugal diffuser test device and the investigation of compressor tip clearance effects to the study of wave rotors, wave engines and detonation pulse engines.

## INVESTIGATION OF UNSTEADY FLOW PROBLEMS IN AIRCRAFT PROPULSION SYSTEMS

Professor Platzer and collaborators completed the following tasks:

A computer code, incorporating a panel method to calculate the inviscid cascade flow and a finite difference boundary layer procedure, was developed to analyze incompressible cascade flows. The code was tested on a NASA 65 series cascade geometry for which experimental data were available.

Experiments were performed to investigate the mixing mechanism by organized turbulence structures in a plane jet excited by a novel method. Three distinct phases in the flow could be observed during excitation, namely, flapping motion near the exit region, formation of vortices at a critical Strouhal number and their amplification, and breakdown of the large vortices into smaller components with the flow becoming fully turbulent. The jet when operated with a simple straight duct-diffuser ejector system increased the thrust augmentation ratio by a factor of 1.2.

Volume I of the AGARD Manual on Aeroelastically in Axial-Flow Turbomachines was completed and submitted for publication in November 1986. It contains the contributions of eleven experts in the field of unsteady turbomachinery aerodynamics.

## HEAT TRANSFER IN THE STAGNATION REGION OF TURBINE BLADES

A method for computing the heat transfer in the stagnation region of turbine blades was developed by Professor Platzer and collaborators for incompressible flows and evaluated for two model problems involving laminar flows. This method is general and, with minor changes, can also be used for turbulent flows as well as for compressible flows.

Title: Aircraft Combat Survivability

Investigator(s): R.E. Ball, Professor, Dept. of Aeronautics

Sponsor: Naval Weapons Center

Objective: To conduct studies in aircraft combat survivability.

Summary: Studies were conducted on six different projects the past year. These included two missile description projects, survivability assessment in conceptual design, survivability guidelines for aircraft designers, anti-aircraft gun effectiveness, and a case study of the vulnerability of a fixed wing aircraft.

Title: Electrode Regions in Dense Plasmas

Investigator(s): O. Biblarz, Associate Professor of Aeronautics

Sponsor: Air Force Office of Scientific Research (AFOSR)

Objective: Study applications of electrode theory and plasma flow theory to electromagnetic propulsion devices of interest in the Air Force.

Summary: Many devices considered under SDI depend on currents traversing plasma flows. The electrodes are a necessary interface which may give rise to a variety of undesirable effects. Our work adds to the basic understanding of these phenomena.

Publications: 1986 AFOSR (AFRPL), Chemical Rocket Research Meeting, 9-11 Sept 1986 - Abstracts.

Conference Presentation: Sixth International Symposium on Gas Flows and Chemical Lasers, Jerusalem, Israel, 8-12 Sept 1986.

Title: Compressibility Effects on the Dyanmic Stall of Oscillating Airfoils.

Investigator(s): Satya Bodapati, Adjunct Professor of Aeronautics  
Max F. Platzer, Professor of Aeronautics

Sponsor: NASA AMES Research Center and Army Aeroflight-  
dynamics Directorate

Objective: To design a dynamic stall rig consisting of a wind tunnel test section, oscillating mechanism and models to investigate the effects of compressibility on dynamic stall.

Summary: A long term research proposal to investigate "the compressibility effects on the dynamic stall of oscillting airfoils" was submitted to the Army Research Office. These investigations are proposed to be carried out cooperatively with NASA Ames Research Center. While the proposal is being evaluated by ARD this project was continued with the support of NASA Ames and Army Aero-flightdynamics Directorate. The design of the test section, oscillating mechanism and models was completed and detailed drawings are being prepared to issue for fabrication. It was decided to test the quality of Schlieren windows under simulated static loading conditions, as the flow visualization is going to be the major aspect of the investigation. For this purpose a simple test rig was designed and fabricated. Effective from April 1987, this project is being continued with the support of the Army Research Office-Durham, Durham, North Carolina.

Title: Compressibility Effects on the Dynamic Stall of Oscillating Airfoils

Investigator(s): Satya Bodapati, Adjunct Professor of Aeronautics  
Max F. Platzer, Professor Aeronautics

Sponsor: U.S. Army Research Office

Objective: The objective of this investigation is to qualitatively and quantitatively determine the effects of unsteady compressible flow on transition, separation, reattachment, type of stall and stall development over an oscillating airfoil as the mach number is increased progressively from 0.2 to 0.5.

Summary: Dynamic stall effects have been the subject of many studies during the past few years. However, most of the tests were performed at relatively low Mach numbers  $M < 0.3$ , while most of the flight conditions are for conditions of significantly higher Mach numbers. A better understanding of the effects of compressibility is mandatory. A unique dynamic stall rig was designed to test a series of airfoils. The model is attached between a pair of Schlieren quality glass windows and the windows are rotated; the view of the flow near the surface of the airfoil will be completely unobstructed. The glass windows were tested in a special test rig under simulated loading for Schlieren quality. The loading did not effect the quality of the Schlieren pictures. The detailed drawings for the oscillating mechanism, wind tunnel test section, and model were finalized. The drawings will be released for fabrication after carrying out the modifications suggested during the design review. Methods for data acquisition and analysis using CCD and stroboscopic Schlieren under simulated conditions are being explored and the instrumentation and computer software are ready. This project is a continuation of the investigation initiated with the support of AFOSR and Army Research Office. The results are available.

Thesis Abstract: M. F. Platzer, "Flow Field Measurements of Airfoil with Oscillating Airfoil in a Low Speed Wind Tunnel," Master's Thesis, September 1989.

**Title:** Satellite Vulnerability to High Energy Lasers

**Investigator:** A. E. Fuhs, Distinguished Professor of Aeronautics

**Sponsor:** Space and Naval Warfare Systems Command

**Objective:** The project has two objectives. First, a specific USN satellite will be studied for vulnerability to a Soviet laser. Second, a range of lasers, basing modes, and satellites will be investigated.

**Summary:** The research was initiated in FY83. During FY86 several studies were completed. The optical problem of tracking satellites in IR was investigated. Experiments were conducted using an optical simulation. The simulation used a HeNe laser, and the effects of wavelength were scaled.

**Theses Directed:**

Gary L. Leaman, "Laser Optical Studies," Master's Thesis, March 1986.

Joseph M. Delpino, "Satellite Survivability," Master's Thesis, September 1986.

Anthony Bailey, "Diffraction Patterns of Retroreflectors," Master's Thesis, June 1986.

Jonathan E. Lathrop, "Theoretical and Experimental Investigation of Countermeasures to Optical Resolution of Satellites," Aeronautical Engineer Degree, March 1986.



Title: Solar Cell Radiation Damage Effects

Investigator: A. E. Fuhs, Distinguished Professor of Aeronautics

Sponsor: Space and Naval Warfare Systems Command

Objective: To determine the performance degradation of Gallium Arsenide photovoltaic cells when exposed to a high energy electron flux.

Summary The project was initiated in FY84 by funding from NPS to create a Solar Cell Test Facility. In FY85 components for the test facility were purchased and assembled. The test facility is operational except for special measurement of the test lamp and for calibration of the irradiance from the test lamp. GaAs cells were purchased for tests in FY86; a series of tests were conducted using 20 MeV radiation from the NPS Linac. Tests were performed so as to permit drawing curves of performance degradation versus fluence.

Thesis Technical Report: Donald Gold, "Radiation Damage Effects to Gallium Arsenide Solar Cells", Master's Thesis, March, 1986.

**Title:** Spacecraft Contamination from Laser Exhaust

**Investigator:** A. E. Fuhs, Distinguished Professor of Aeronautics

**Sponsor:** Strategic Defense Initiative Office/Directed Energy Office, SDIO/DEO

**Objective:** To determine the flux of backscattered molecules when an open cycle laser is fired from a spacecraft.

**Summary:** The project was initiated late in FY82 with several man-days effort for a literature survey. In FY83 computer codes for solving the span of flow from continuum through transitional to free-molecular flow were examined. The Monte Carlo technique was selected as the best approach for a numerical solution. During FY84, a Monte Carlo computer Program was written by Dr. Shaul Abramovich who was at the Naval Postgraduate on sabbatical from Israel. A submodule of the program was an axisymmetric method of characteristics (MOC) program. The Monte Carlo program required extensive computer time. In FY85 and FY86 alternate approaches for obtaining solutions were examined including a "breakdown-surface" model and an integral approach sometimes known as BKG-Method. Solutions were obtained using both methods.

**Contract Support for Research:** Contractor, J. Falcovitz; Contract Number N62271-84-M-3345.

**Contract Report:** J. Falcovitz, Spacecraft Contamination from a Chemical Laser Ring Jet, August 1986.

**Publications:** J. Falcovitz and A. E. Fuhs. "An Integral Method for Thermal Backscattering from the Exhaust Plume of a Space-Based HF Laser," AIAA Paper 86-1320, June 2-4, 1986, Boston, Massachusetts.

J. Falcovitz and A. A. Fuhs, "Contaminating Sideflow from Supersonic Exhaust Jets in Space," 37th Congress of the International Astronautical Federation, Innsbruck, Austria, October 4-11, 1986, IAF-86-29.

Title: Underwater Shaped Charges

Investigator: A. E. Lohs, Project Director, Test Cell, Aerodynamics

Spans to: Naval Surface Warfare Center, White Oak  
Laboratory

Objectives: The project has two objectives as follows: First, an understanding of metal jet formation is needed, and, second, a capability to predict behavior of metal jets from shaped charges underwater is to be developed.

Penetration of the metal jet from an underwater shaped charge generates a vapor cavity and a bow shock wave. The metal jet penetrates supersonically relative to the water causing intense shock waves (10000 atmospheres). Under certain circumstances, the metal jet reacts vigorously with the water releasing considerable chemical energy. The project was initiated in FY82. A summary of activity is given to provide background information:

Year	Activity
FY82	A series of tests were conducted at NSWC/WOL involving shaped charges of NPS design. The warheads were conceived, designed, and tested by NPS project personnel. NSWC/WOL fabricated the shaped charges.
FY83	Apparatus for exploding wires in a steam or other atmosphere was designed, built, and calibrated. A new laboratory was created in the Control Room of the Jet Engine Test Cells. Tests were conducted of aluminum burning in steam and air. A computer program was initiated for supersonic flow in water.
FY84	Work was initiated on a new series of warheads to be tested at NSWC/WOL. NPS project personnel designed the shaped charges. The warhead tests were scheduled for FY85. In the Torpedo Warhead Laboratory, the temperature of burning metal particles was measured.
FY85	The warheads designed and fabricated were tested at NSWC/WOL. Temperature, velocity, burning times, particle sizes, and particle dynamics were measured for a series of metals.

Free

A computer model was developed which simulates the interaction of a combustion particle with a gas stream under various conditions.

Publications:

J. Kol, A. E. Fahs, and Y. Ch. Zev, "Experimental Investigation of Aluminum Combustion in a High Velocity Oxide Atmosphere," AIAA Paper 86-1494, AIAA-ASME 4th Joint Thermophysics and Heat Transfer Conference, June 1-4, Boston, Massachusetts, 1986.

Y. Ch. Zev, A. E. Fahs, and J. Kol, "Burnout Time and Size of Aluminum, Magnesium, Titanium, Tantalum, and Pyrolore Particles Burned in Steam," AIAA Paper 86-1496, AIAA-ASME 4th Joint Thermophysics and Heat Transfer Conference, June 1-4, 1986, Boston, Massachusetts, 1986.

Y. Ch. Zev, A. E. Fahs, and J. Kol, "Experimental Investigation of Magnesium Combustion in Steam," AIAA Paper 86-1497, 1986.

Title: Hot Airwake Study

Investigator: G. V. Healey, Associate Professor of Aeronautics

Sponsor: Army Air Research and Development Command

Objectives: 1. To set up a steady turbulent boundary layer in the NACA smoke tunnel.  
2. To study by flow visualization the ground air flow characteristics and the flow shapes in the heated turbulent boundary layers in both stationary and oscillating modes.

Summary: The oscillating mechanism has been tested and the vortex-generating and traverse mechanisms have been fabricated. New hot wire equipment has been obtained.

1. Introduction: Helicopter/Ship Interface as an Alternate to  
Present Methods of Determining the Safe Operating Envelopes

2. Author: J. W. Waley, Associate Professor of Aeronautics

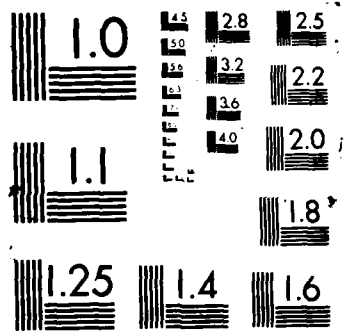
3. Location: Air Vehicle Division, Naval Air Systems Command

4. Objective: To determine the feasibility of simulating the landing of  
an arbitrary helicopter on an arbitrary non-aviation ship.

5. Summary: A detailed analysis/literature search was made on (a) free-  
stream airflow to the ship, (b) the ship motion (c) the  
helicopter motion in complex flowfields (d) simulators. The  
conclusions were:

1. The condition of the free-stream airflow to the ship  
can be determined with sufficient accuracy.
2. The DTNSRDS's ship motion program is a good basic one  
that needs some further development and, in particular,  
validation with a variety of different size real ships. The  
latter is a difficult task, in view of the fact that sea  
waves do not quite conform to the Bretschneider spectrum.  
The DTNSRDC seems well equipped to undertake this work.
3. The ship airwake is highly complex, virtually un-  
derstandable and will require a major effort to understand. Future  
airwake studies should address the ship airwake problem.  
Research into airwakes, funded by the Air Vehicle  
Division of the Naval Air Systems Command, is being carried  
out at the Naval Postgraduate School.
4. Future interface tests should determine the true wind velocity or the  
relative velocity.
5. The motion of the helicopter is well understood, so long as the  
airwake is understood. The airwake is the major problem.  
The airwake is the major problem.







6. The pace of research into turbulence modeling is very slow and needs acceleration. Before a decision can be made on the size of computer required for simulation of the interface, additional studies are required to determine to what extent the mathematical model of the helicopter and the physical model of the complex fluid flowfield can be simplified, while still retaining sufficient fidelity of the simulation. Benchmark tests for computer speeds can be misleading. It would probably be best to construct the computer program for the simulation of the interface in advance of the computer choice. If a dedicated computer is to be chosen, this process can be assisted by configuring the program to the architecture of several candidate computers and running it by itself. If sharing the computer with other users is envisioned, then the test should be made by applying some realistic loading to the computer while the simulation is in progress.

Publication:

"The Prospects for Simulating the Ship/Helicopter Interface" Naval Engineer's Journal, March 1987 (to be published)

Title: Computer Model for Windstream Test Facility

Investigator(s): J.A. Miller, Assoc. Professor and O. Biblarz, Assoc. Professor

Sponsor: Naval Weapons Support Center, Crane, Indiana

Objective: To study fluid dynamics of the Windstream Test Facility and propose improvements in flow characteristics and controlability. Also to construct a computer program for the control of velocity history.

Summary: Design and operational test results supplied by NWSC were studied. Suggestions for improvements communicated to sponsor.

Publication(s): Letter progress report dated 17 July 1986.

**Title:** Droplet Formation and Motion in an Oscillating Liquid Jet

**Investigator(s):** J.A. Miller, Associate Professor

**Sponsor:** Un-sponsored

**Objective:** To study the decomposition and breakdown of non-steady laminar and turbulent jets into droplets and the motion thereof by means of analytical and experimental methods

**Summary:** Experimental work begun at NPS and extended at the Max-Planck-Institute for Fluid Mechanics Research has lead to definitive understanding of the mechanism of instability and breakdown of nonsteady liquid jets. An analytic model has been devised which correctly predicts the results observed in the laboratory.

**Publication(s):** A paper entitled "Droplet Formation and Motion in an Oscillating Liquid Jet" has been accepted for presentation at the International Conference on Fluid Mechanics (July 1987) in Beijing, China. An invitation has been extended by the Polish Academy of Sciences to present a discussion of the results of the work at the XVIII Biennial Fluid Dynamics Symposium (Sept. 1987) in Warsaw.

**Theses Directed:** "Effect of Small Pressure Disturbances on the Breakdown of Round Laminar and Turbulent Jets," MSAE, Sept. 1985, Z.R. Gikas, CAPT, Hellenic Air Force

Title: Fuel Composition and Additive Effects on Combustor and Augmentor Tube Emissions

Investigator: D. W. Netzer, Professor of Aeronautics

Sponsor: Naval Air Propulsion Center

Objective: Experimentally investigate the combustion mechanisms of smoke suppressant fuel additives and the effects of JP fuel composition by evaluating their effects on the distribution of temperature, carbon particle size and concentration and  $\text{NO}_x$  concentrations within a gas turbine engine combustion chamber and the exhaust augmentor tube.

Summary: This is a continuing investigation. The experimental apparatus is currently based on a T63 combustor with fuel additive pumps and an aft pressure enclosure. The combustor employs an exhaust nozzle which exhausts into an augmentor tube. Soot mean diameters and concentrations are measured in the combustor, in the aft pressure enclosure and at the exit of the augmentor tube using three-wavelength light transmission measurements and multiple-angle forward light scattering measurements. Collection probes are also used. Variable combustor inlet air temperature is provided with a hydrogen-fueled vitiated air heater.

In general,  $D_{32}$  has been measured in the range of 0.15 to 0.25 microns. A value of  $D_{32}$  of 0.15 microns would yield an arithmetic mean diameter of approximately 0.07 microns. Collected exhaust products also show many particles in this size range, but it is not known whether or not these "large" soot particles are the result of the collection process.

The initial test series was conducted with the combustor operating at design air and fuel flow rates and design pressure with the following major results:

- (1) Additives increased soot size without effecting mass concentration.

- (2) Additives were less effective with lower combustor air inlet temperature.
- (3) Exhaust  $D_{32}$  was independent of fuel composition and fuel-air ratio.
- (4) A soot mean index of refraction of 1.95 - 0.66i resulted in the best data correlation for the light transmission measurements.

A second test series was conducted at the same pressure and fuel-air ratios but with reduced flow rates. Thus, the fuel atomizer was operating at less than design pressure drop (poor atomization and fuel distribution) and the air mixing rates (primary zone fuel-air ratio) were modified. Some significantly different results were obtained as given below.

- (1) Three wavelength technique data often did not result in consistent values of  $D_{32}$ , indicating a possible bi-modal size distribution and/or very low "effective" index of refraction as is characteristic for porous soot agglomerates.
- (2) Higher aromatic/lower hydrogen fuels resulted in slightly smaller  $D_{32}$  at the same exhaust temperature and higher exhaust temperature at the same fuel-air ratio.
- (3) Additives had no effect on  $D_{32}$  but reduced soot concentration.
- (4)  $D_{32}$  decreased with increasing fuel-air ratio.

The data indicate that combustor test conditions (atomization and primary zone fuel-air ratio) can significantly alter exhaust soot structure and/or size distribution.

$D_{32}$  was found to increase across the augments tube to values of between 0.31 and 0.43 microns. Collected exhaust products showed particles from less than 0.05 microns up to approximately 1.5 microns. Agglomeration in the collection probe and/or in the augments tube and wall collisions/shedding can all result in these large observed particles.

Publications:

C. H. Jway, D. J. Urich, J. S. Bennett, and D. W. Netzer, "Fuel Composition and Additive Effects on Sooting Characteristics in Gas Turbine Combustors and Engine Exhaust Augmentor Tubes," Naval Post-graduate School, Monterey, CA forthcoming.

Thesis Directed:

1. C. H. Jway, "An Investigation into the Effects of Fuel Additives and Fuel Composition on Soot Particle Size in a T-63 Gas Turbine Combustor Using Light Transmission and Scattering Techniques," Master's Thesis, June 1986.
2. D. J. Urich, "An Experimental Investigation of Soot Size and Flow Fields in a Gas Turbine Engine Augmentor Tube," Aeronautical Engineering, June 1986.
3. M. F. Young, "Sooting Characteristics in Gas Turbine Combustors," Master's Thesis, in progress.

Title: Solid Fuel Ramjet Combustion

Investigator: D. W. Netzer, Professor of Aeronautics  
A. Leitner, Research Contractor

Sponsor: Naval Weapons Center

Objectives:

1. To experimentally investigate techniques for fuel regression rate and thrust modulation.
2. To experimentally determine the effects of operating conditions and fuel composition on the combustion characteristics of metallized fuels.
3. To improve the computational capabilities of the computer model for SFRJ combustion.

Summary: This is a continuing investigation.

An experimental investigation was conducted to examine the effects of inlet air swirl and secondary gas injection on the combustion properties in a solid fuel ramjet. Tests were conducted with 18818, HTPB and PMM fuels. Inlet swirl characteristics were measured in non-reacting flows. The swirl tests were conducted at high and low air mass fluxes with equivalence ratios between 0.5 and 1.8. Swirl was found effective for increasing the fuel regression rate, but the magnitude was highly dependent upon motor geometry, fuel type and operating environment. The gas injection tests included hydrogen at low equivalence ratios, and nitric oxide and nitrous oxide at high equivalence ratios. Secondary injection generally resulted in increases in combustion pressure in agreement with equilibrium, adiabatic combustion expectations.

An experimental investigation was conducted of highly metallized (approximately 70% by weight) solid fuels burned in a two-dimensional solid fuel ramjet (SFRJ). High speed motion pictures

were taken of the combustion process through viewing windows located at two locations along the fuel slab length. Films revealed various ejection events ranging from small particle ejections to large flakes of burning and non-burning material leaving the surface. Nine different fuels were tested at air mass fluxes of 0.2 and 0.5 pounds pass per inch squared per second and pressures ranging from 35 to 200 psia. There was evidence that both minor binder ingredient changes (polymer and curative) and the inclusion of magnesium resulted in larger required inlet step heights to sustain combustion. Most of the metallized fuels did not burn well at pressures below approximately 40 psia. Low air mass fluxes generally resulted in larger metallic surface agglomerations, larger particles in the gas phase and more dominate shedding of surface layers.

The SFRJ computer code was modified to allow general boundary conditons in the -direction. In addition, the radiation subroutine was utilized and resulted in the expected increase in fuel regression rate. The modified code was used to examine the effects of scale on SFRJ combustion in the side dump configuration. In general, increased combustor size resulted in lower fuel regression rates.

Publications:

1. Milshtein, T. and Netzer, D.W. - "Three-Dimensional, Primitive Variable Model for Solid-Fuel Ramjet Combustor", *Journal of Spacecraft and Rockets*, Vol. 23, No. 1, Jan-Feb 1986, pp. 113-117.
2. Gany, A. and Netzer, D.W. - "Combustion Studies of Metallized Fuels for Solid-Fuel Ramjets", *Journal of Propulsion and Power*, Vol. 2, No. 5, Sep-Oct 1986, pp. 423-427.
3. Gany, A. and Netzer, D.W. - "Fuel Performance Evaluation for the Solid-Fueled Ramjet", *Int. Journal of Turbo and Jet-Engines*, Vol. 2, No. 2, 1985, pp. 157-168.



Theses  
Directed:

1. S.R. Lowe - "An Experimental Investigation of Combustion Modulation Techniques for a Solid Fuel Ramjet," Master's Thesis, June 1986.
2. C.K. Scott, II - "An Experimental Investigation of Various Metallic/Polymer Fuels in a Two-Dimensional Solid Fuel Ramjet," Master's Thesis, March 1986.
3. A. Karadimitris - "Solid Fuel Ramjet Metallized Fuel Burning Characteristics," Master's Thesis, in progress.

Title: Solid Propellant Combustion/Automated Data Retrieval From Holograms

Investigator: D. W. Netzer, Professor of Aeronautics  
J. P. Powers, Professor of Electrical and Computer Engineering

Sponsor: Air Force Rocket Propulsion Laboratory

Objective: Develop and evaluate experimental techniques for obtaining particle size data within the combustor and exhaust nozzle of solid propellant rocket motors.

Summary: This is a continuing investigation. An investigation has been conducted to develop techniques for obtaining quantitative data that can be used to relate rocket propellant composition and operating environment to the behaviour of solid particulates within the grain port and exhaust nozzle. The techniques employed are high speed motion pictures, SEM analysis of collected products, light scattering measurements at the entrance and exit of the exhaust nozzle and holograms within the grain port. A small windowed motor has been used to obtain the particle size data. In addition, techniques are being developed for automatic retrieval of particle size distributions from holograms taken of the combustion of solid propellants.

Both metallized and nonmetallized propellants have been used. The latter propellant is used together with the injection of particles of known size at the motor head-end. The light scattering techniques appear to work quite well, although apparatus alignment is quite critical for the optical path through the motor windows. Optically measured and collected exhaust particle sizes have been in good agreement.

Smoke limits the metal loadings and operating pressures where good quality holograms can be obtained. Diffuse scene beam illumination is generally required to smear the schlieren effects which result from the multitude of burning

particles. To date, good quality holograms have been obtained to pressures of 280 psi using an HTPB/AP propellant with 2%, 20 micron aluminum.

The automated retrieval of statistical size information of the particles from the holograms requires the following steps:

- record the hologram image on video tape,
- digitize the image on the computer,
- reduce the speckle of the image so that the particles may be identified as features of interest,
- separate the features from the background by removing the background,
- isolate and locate the features, and obtain a count of the total number of features within the field of view,
- obtain size information on area, x-width, y-width, and roundness, and
- produce a histogram of the particle size distribution.

Image acquisition of the reconstructed hologram is accomplished by viewing with a microscope and recording on VHS tape using a high sensitivity television tube. Image digitization was done by feeding the tape image into a commercial image digitization board made by Imaging Technology, Inc. for the IBM PC/AT microcomputer. A program was written to perform histogram analysis on the size data collected. Currently, evaluation of commercial statistical analysis packages available for the PC is being pursued. To date, the resolution limit of the automated retrieval system for holograms recorded through the motor windows is approximately 20 microns.

Analysis and comparison of the resolution degradation of the speckle reduction filters is in progress. Future work includes study of the effects of the grayscale threshold on the resolution of the processed image.

**Publications:**

D. W. Netzer and J. P. Powers, "Experimental Techniques for Obtaining Particle Behavior in Solid Propellant Combustion," AGARD Conference Proceedings No. 391, Smokeless Propellants, AGARD-CP-391, pp. 19-1-19-17.

Theses  
Directed:

1. T.D. Edwards, "Implementation of Three Speckle Reduction Filters for Solid Propellant Combustion Holograms," M.S.E.E., in progress.
2. D.N. Redman, "Image Analysis of Solid Propellant Combustion Holograms Using an Image-Action Software Package," M.S.E.E., June 1986.
3. J.S. Rosa, "Particle Sizing in a Solid Propellant Rocket Motor Using Scattered Light Measurements," Aero. Eng., Dec. 1985.
4. S.J. Yoon, "Holographic Investigation of Solid Propellant Combustion in a Three-Dimensional Motor," M.S.E.S., Dec. 1985.
5. K.G. Horton, "Particle Sizing in a Solid Propellant Rocket Motor Using Light Scattering Techniques," M.S.E.S., June 1986.
6. J.B. Rubin, "Holographic Investigation of Metallized Solid Propellant Combustion in a Three-Dimensional Motor," M.S.A.E., Sept. 1986.
7. M.G. Keith, "Light Scattering Measurements in Solid Propellant Rocket Motors," M.S.A.E., in progress.

TITLE: Compressor Tip Clearance Effects

INVESTIGATOR: R. P. Shreeve, Professor and Director, Turbopropulsion Laboratory, Department of Aeronautics, Ian Moyle (Exotech Inc.) and G. J. Walker (Naval Air Systems Command, Research Professor in Aeronautics) University of Tasmania, Australia

SPONSOR: Naval Air Systems Command

OBJECTIVE: To investigate the effects of changes in tip clearance on the performance of and flow fields within a multistage axial compressor with a view to proposing an improvement in the usual design procedure which ignores the gap.

SUMMARY: A 36 inch O.D. low speed three-stage axial compressor having a 7.2 inch cylindrical flow path is used in the investigation. Early measurements showed that the solid-body symmetrical blading design gave good flow quality to the second stage, but that the inlet guide vanes did not provide a proper inlet flow to the first stage. The inlet guide vane was redesigned and the compressor rebuild for clearance studies is underway. Pneumatic and hot film probes and buried wire gauges are the primary instrumentation. Tests in 1987-88 will involve both single and multi-stage builds with realistic interblade spacings; also, tip-clearance changes with variation in in-flow boundary conditions. The information obtained in the study will provide a basis of experience before the more complicated effects of transonic flow and wall geometry can be tackled.

PUBLICATIONS: Moyle, I. N., "Single Stage Test Baseline Data for a Symmetric Blading," Contractor Report, NPS67-86-003CR, Naval Postgraduate School, Monterey, CA., June 1986.

Walker, G. J., "Transitional Flow on Axial Turbomachine Blading," AIAA Paper 86-0010, AIAA 25th Aerospace Sciences Meeting, Reno, Nevada, January 12-15, 1987.

TITLE: Development of a Transonic Compressor Model

INVESTIGATORS: R. P. Shreeve, Professor and Director, Turbopropulsion Laboratory, Department of Aeronautics and Friedrich Neuhoff (Exotech Inc.), German Armed Forces University, Munich, W. Germany

SPONSOR: Naval Air Systems Command

OBJECTIVE: To develop a small transonic axial air compressor model and methods for measuring performance and flow behavior.

SUMMARY: Associated with the project "Transonic Compressor Investigations" is the development of the test compressor and test rig hardware to design speeds of 30,460 RPM. Test speeds of 80% of design were achieved while measurement surveys were made to establish and improve flow conditions within the stage. Despite reasonable efficiencies the rotor and stator were poorly matched and inlet flow modifications did not compensate. Future plans are to verify the drive turbine to design speeds and to evaluate a new stage designed to validate advanced computer design methods.

PUBLICATIONS: Neuhoff, F., "Investigation of the Interaction between Rotor and Stator of a Transonic Compressor," Contractor Report NPS67-85-011CR, Naval Postgraduate School, Monterey, CA., November 1985.

Neuhoff, F., "Modifications to the Inlet Flow Field of a Transonic Compressor Rotor," Contractor Report NPS67-85-008CR, Naval Postgraduate School, Monterey, CA., December 1985.

**TITLE:** Transonic Compressor Investigations

**INVESTIGATORS:** R. P. Shreeve, Professor and Director, Turbopropulsion Laboratory, Department of Aeronautics, and Friedrich Neuhoff (Exotech Inc.), German Armed Forces University, Munich, W. Germany

**SPONSOR:** Naval Air Systems Command

**OBJECTIVE:** To understand three-dimensional and unsteady effects and to obtain data with which to assess design and analysis methods for transonic blading.

**SUMMARY:** A heavily-instrumented single-stage transonic axial research compressor is used with high response (Kulite) instrumentation and computer-controlled acquisition techniques. The Dual-Probe Digital Sampling (DPDS) Measurement Technique has been developed and applied to obtain the distributions of velocity vector and pressure both blade-to-blade and hub to tip at the exit of the rotor to sonic relative tip Mach number. The data were analyzed to obtain blade-to-blade temperature and loss distributions and this enabled a first evaluation of transonic shock-loss models. Shock structure near design speeds was examined in a blow-down cascade model of the relative tip flow.

**PUBLICATIONS:** Neuhoff, F., "Time-Resolved and Time-Averaged Flow Evaluation for an Isolated Transonic Rotor", Contractor Report NPS67-85-009CR, Naval Postgraduate School, Monterey, CA, September 1985.

Heglund, M. G. - "Investigation of a Mach 1.4 Compressor Cascade with Variable Back Pressure Using Flow Visualization", Masters Thesis, Naval Postgraduate School, Monterey, CA., March 1986.

Neuhoff, F., Shreeve, R. P. and Fottner, L., "Evaluation of the Blade-to-Blade Flow from a High Speed Compressor Rotor," ASME paper No. 86-GT-117 presented at the 31st ASME International Gas Turbine Conference, Dusseldorf, W. Germany, June 8-12, 1986.

**TITLE:** Wave Rotor and Wave Engines

**INVESTIGATORS:** R. P. Shreeve, Professor and Director, Turbopropulsion Laboratory, Department of Aeronautics, and Dr. A. Mathur, Exotech Inc

**SPONSOR:** Naval Air Systems Command, Defense Advanced Research Projects Agency and Rolls-Royce, Inc.

**OBJECTIVE:** To develop computational techniques to analyze the performance of and flows within wave rotor devices and to show through an experimental program that they work. Also, to generate performance estimates of engine configurations which incorporate the wave rotor as a component.

**SUMMARY:** A one-dimensional Euler code based on the random choice method has been developed and adapted to model unsteady flows with discontinuities, typical of the flows in wave rotor passages. The unsteady code has been integrated with a turbofan engine performance code to compare configurations with and without the wave rotor component.

A wave rotor experiment has been assembled and initial tests have indicated good mechanical integrity of the rig at high speeds (~15000 r.p.m.) and consistent self-acceleration at 5000-6000 r.p.m. when run in the wave turbine mode. Future testing is envisaged with an air dynamometer to absorb the generated shaft power.

**PUBLICATIONS:** Mathur, A., "Code Development for Turbofan Engine Cycle Performance with and without a Wave Rotor Component," Contractor Report NPS67-86-006CR, Naval Postgraduate School, Monterey, CA, September 1986.

Salacka, T. F., "Review, Implementation and Test of the QAZ1D Computational Method with a View to Wave Rotor Applications," Master's Thesis, Naval Postgraduate School, Monterey, CA., December 1985.



**TITLE:** Wind Tunnel Studies of Compressor Cascade Flows

**INVESTIGATORS:** R. P. Shreeve, Professor and Director, Turbopropulsion Laboratory, Department of Aeronautics and G. J. Walker, (Naval Air Systems Command Research Professor in Aeronautics), University of Tasmania

**SPONSOR:** Naval Air Systems Command

**OBJECTIVE:** To obtain data using a large (60" x 10") subsonic cascade wind tunnel to verify computational codes used in the design and analysis of controlled diffusion (CD) blading, to measure the performance of a specific baseline design and to evaluate cascade analysis codes.

**SUMMARY:** Two CD blading designs have been tested and the design procedures - inviscid calculations coupled with boundary layer predictions such that separation is avoided - were shown to be valid. The first design, a transonic stator cascade is now providing an experimental test case for both on- and off-design viscous flow code predictions. First, previous test data at two incidence angles have been repeated and small errors corrected. Second, wake profiles have been measured downstream of the blading. Current efforts are aimed at obtaining full viscous flowfield behavior through the blade passages from 2-component LDV measurements, as incidence is increased and stalling occurs. Future work will involve the testing of proposed stall-resistant designs.

**PUBLICATIONS:** Sanger, N. and Shreeve, R. P., "Comparison of Calculated and Experimental Cascade Performance for Controlled Diffusion Compressor Stator Blading," Paper No. 86-GT-35, 31st ASME International Gas Turbine Conference, Dusseldorf, W. Germany, June 7-12, 1986; also Transactions of the ASME, Journal of Turbomachinery, Vol 108, July 1986, pps 42-50.

Dreon, J., "Controlled Diffusion Compressor Blade Wake Measurements," Master's Thesis, Naval Postgraduate School, Monterey, CA., September 1986.

TITLE: Aging Characterization Facilities for Composites

INVESTIGATORS: Edward M. Wu, Professor of Aeronautics

SPONSOR: Navy Research Laboratory

OBJECTIVE: Characterize Composite strength and life in parallel to fiber characterization to quantify the combined aging behavior of fiber and fiber/matrix interface and to formulate a statistical combined-stress failure criterion with application in the form of a post-processor to finite element stress analysis.

SUMMARY: Modern composites are superior structural materials because of their high reliability derived from micro-redundancy at the materials level. The materials micro-redundancy is of particularly importance to monolithic structures such as rocket motor cases and pressure vessels where structural redundancy is absent. The structural redundancy of composite is expected to be governed by the aging of the fiber (which increases the micro failure sites) and the aging of the matrix binder/interface (which diminishes the load diffusing effectiveness and which increases the probability of occurrence of spatially contiguous sites which decreases the strength). Materials aging is governed by kinetic processes which can be modeled with appropriate models and characterized by an adequate data base. This data will also provide the correlation of strength ranking to life ranking which is needed for reliability enhancement measures such as manufacture process improvement and proof-test methodology. The link of the materials data base and characterization model to actual structure reliability will be explored through formulation of a statistical combined-stress failure criterion with application in the form of a post-processor to finite element stress analysis.

PUBLICATIONS: E. M. Wu, "Influence of Interface on the Statistical Strength of Unidirectional Composites," The International Conference on Composite Interfaces, Cleveland, Ohio, May 27-30, 1986.

1st Lt. Pattama Suttisoryotin (Royal Thai Air Force), "Composite Structural Reliability Calculation by Finite Element and Statistical Strength Theory," Master Thesis, March 1986.

TITLE: Composite Reliability Characterization

INVESTIGATOR: Edward M. Wu, Professor of Aeronautics

SPONSOR: Army Materials Technologies Laboratory

OBJECTIVE: Reliability enhancement by integrating data base, failure mechanism identification, and predictive model to guide materials development, fabrication technology, diagnostic instrumentation and software for structural design.

SUMMARY: High reliability composites are needed for man--safe naval, aerospace and critical national security applications. These structures include many SDI space structures. In such applications, the composite material is under sustained tensile stress and subject to the well known phenomena of stress-rupture, i.e., apparently random and spontaneous catastrophic failure. Such failure would lead to loss of critical missions. Composite reliability methodology can guard against such failures. Composite Reliability methodology requires qualitative modeling of failure mechanisms and quantitative measurement of the relevant parameters. We focus on data collection on composite stress rupture life and its constituent fiber filament strength. A laser diffraction instrument for measuring fiber diameter was developed. Design and construction for stress rupture measurement of single filament life was initiated.

PUBLICATIONS: E. M. Wu, "Statistical Strength of Single Filament Fibers," Gordon Conference on Composites, Santa Barbara, CA., Jan 12 to 17, 1986.

Lt. Thomas Bennett, (USN), "A Comparison of Two Methods for Fiber Diameter Measurement and a System Design for the Study of Composite Reliability," Master's Thesis, Dec 1985.

Lt. F. D. Carozzo, Jr., (USN), "Experimental Procedure for Lifetime Testing of Graphite Bundles Under Constant Load," Master's Thesis, March, 1986.

Maj. Chung Won Lee (Korean Air Force), "Experimental Facilities for Fiber Life Testing," Master's Thesis, March 1986.

Lt. Mark Storch, (USN), "Computer Aided Fiber Diameter Measurement by Laser Diffraction," Master's Thesis, Sept 1966.

TITLE: Composites Stress Rupture Equipment  
INVESTIGATOR: Edward M. Wu, Professor of Aeronautics  
SPONSOR: Naval Surface Weapon Center

OBJECTIVE: Establish, at the Naval Postgraduate School, a stress-aging facility for fibers and for composites to provide an independent, unbiased and uninterrupted data base to meet Department of Defense and Navy needs.

Provide training opportunities for Naval officers on composites reliability (through course work and thesis research at the NPS).

SUMMARY: The durability characterization of high performance composites used in the Trident II rocket motor case requires a data base to be accumulated through accelerated testing. Life or aging data base requires long time to accumulate and may be accelerated by mechanical stress and/or physical environment (temperature and moisture, for example). Currently no such data base are available under the auspices of the Department of Defense or of the Navy. The major effort in this portion of the program is to establish stress rupture equipment for long term tests. The facilities will consist of portable stress-rupture testing machines which are capable of recording the elapse time of stress life and immune to external disturbances. Data generated by these facilities, when interpreted by kinetic process relations together with the chain-of-bundles model will provide an estimation of long term aging effect and a quantitative basis for reliability design.

In conjunction with other NSWC projects, forty-five stress rupture testing machines were acquired.

**DEPARTMENT  
OF  
OCEANOGRAPHY**

## DEPARTMENT OF OCEANOGRAPHY

### NEARSHORE STUDIES

Prof. E.B. Thornton and C.S. Wu are studying wave induced dynamics of the nearshore. Wave transformation models including nonlinear refraction and wave breaking are being developed. The wave transformation models are used to drive dynamical models. The models are tested using a data base acquired through participation in most of the major nearshore experiments in the past decade. The research sponsor is ONR and the State of California.

### COASTAL OCEAN STUDIES

Prof. M.L. Batteen is running wind forcing experiments in the California Current System (CCS). Her objective is to understand the role of wind forcing in eddy and jet formations in the California Current System. The sponsor is the NPS Research Foundation.

Prof. S.R. Ramp joined the Oceanography Department in September 1986 and began planning research off the California Coast. He will be involved in the Coastal Transition Zone Program, which will study the physics and biological implications of squirts, jets, and surface cold filaments in the California Current System. The work is sponsored by ONR and the NPS Research Foundation.

### EQUATORIAL AND TROPICAL OCEANOGRAPHY

Prof. R.W. Garwood and Dr. P. Chu, together with Dr. P. Muller, University of Hawaii, are collaborating on a theoretical investigation of the processes which occur in the equatorial and tropical mixed layer. This study which contributes to the Tropical Oceans-Global Atmosphere (TOGA) program was initially funded by the NPS Research Foundation.

### OPEN OCEAN STUDIES

Prof. R.W. Garwood and Mr. P.C. Gallacher's investigations of the response of the oceanic planetary boundary layer (OPBL) have lead to the development of numerical models for the prediction of the evolution of the upper ocean temperature, salinity and sound velocity structure in response to forcing by the atmosphere.

Prof. T.P. Stanton and E.B. Thornton are studying the properties of velocity shears and density gradients in the upper ocean. A towed package has been developed incorporating a high resolution coherent acoustic doppler velocity profiler, micro conductivity, and micro temperature sensors. The research is sponsored by the Office of Naval Research.

C.N.K. Mooers and M.M. Rienecker conducted an ocean prediction study in collaboration with Harvard University using the Harvard statistical-dynamical model for open domains. Their study focused on eddies, fronts, and jets in the California Current System. Twenty-two synoptic realizations of the upper

ocean have been acquired with oceanographic sampling from ships and planes. The sponsor is the Office of Naval Research.

### AIR-SEA INTERACTION

Dr. P. Chu and Prof. R.W. Garwood are sponsored by the NPS Research Foundation to investigate the thermodynamic and dynamic coupling between the oceanic and atmospheric turbulent boundary layers. Thermodynamic feedback between the two boundary layers may result in anomalous ocean temperatures due to atmospheric instability and precipitation.

### ARCTIC STUDIES

Prof. R.H. Bourke and R.G. Paquette use U.S. Coast Guard icebreakers to observe and analyze ocean fronts and thermal fine-structure near the Arctic ice margin, most recently in the area of the East Greenland Current. These studies have applications for environmental acoustics and under-ice submarine operations. The sponsors are the Arctic Submarine Laboratory and NSWC.

### OCEAN ACOUSTICS

Prof. C.R. Dunlap and R.H. Bourke are studying the performance of vertical line array sensors. The sponsor is the Naval Avionics Center and the Naval Air Systems Command.

Prof. C.R. Dunlap, E.C. Haderlie, and J.P. Powers are investigating the effects of the ocean on fiber optic cables to be used in fixed distributed acoustic systems. The sponsors are SPAWAR and DARPA.

Prof. R.H. Bourke and C.R. Dunlap are advising student theses on acoustic topics in the Arctic Ocean. The sponsor is NSWC.

Prof. C.R. Dunlap, R.H. Bourke and G.H. Jung are investigating simple methodologies for propagation loss prediction for bistatic sensors. The sponsor for this work is NORDA during FY86.

Prof. C.R. Dunlap, R.H. Bourke and T.F. Clark are analyzing environmental acoustic effects on IUSS performance. The sponsor is ONR during FY86.

Prof. C.R. Dunlap is investigating the development of an ocean drifting buoy which samples oceanographic, meteorologic and acoustic parameters and telemeters data ashore via the ARGOS satellite data relay system. This Naval Postgraduate School Ambient Noise Drifter System (NADS) is sponsored by NORDA during FY86.

Title: Wind Forcing of Eddies and Jets in the California Current System

Investigator(s) M.L. Batteen, Assistant Professor of Oceanography

Sponsor: NPS Foundation Research Program

Objective: The objective of this project is to understand the role of wind forcing in eddy and jet formations in the California Current System (CCS). To accomplish these goals we propose to (1) incorporate wind forcing into an existing primitive equation (PE) ocean model of the California Current, (2) vary the type of wind forcing and (3) compare the results with observations. This work will be part of a continuing NPS Foundation Research Program.

Summary: Wind forcing has been incorporated into an existing PE ocean model of the CCS with the additional model development of including surface heating to prevent continuous cooling nearshore when coastal upwelling occurs. The effects of wind forcing have been analyzed by varying the type of wind forcing. In particular, we have focused on cases of steady, southward winds, with and without the curl, in a flat bottom ocean. Preliminary results show the development of an equatorward, coastal jet, a poleward undercurrent, and upwelling on the eastern boundary, but no development of eddies and jets. Ongoing comparisons of the results with observations have shown that the coastal jet is too deep, so more model runs are presently being made. In particular, we are running three different cases of wind forcing: (1) with topography rather than with a flat bottom, (2) with a shallower ocean bottom (1000 m rather than 4500 m), and (3) with a more realistic upper layer temperature stratification. To try to generate eddies and jets in the CCS, we have recently input a random disturbance in the model after the coastal jet has developed. Results are forthcoming.



Conference  
Presentations:

M.L. Batteen R.L. Haney and C.N.K. Mooers, "The Influences of the Menodocino Escarpment, Mean Flow Instabilities and Wind Forcing on Eddy and Jet Formations in a Model of the CCS," Ocean Sciences Meeting, New Orleans, Louisiana, 13-17 January, 1986.

Theses Directed:

J.L. Heishman, "Sampling Strategies in Space and Time: Effects on Representation of Mesoscale Processes," Master's thesis, Naval Postgraduate School, Monterey, September 1986.

P.G. Renaud, "Wind Forcing Experiments in the California Current System," Master's thesis, Naval Postgraduate School, Monterey, December 1986.

**Title:** Chair in Arctic Marine Science

**Investigators:** R.H. Bourke, Associate Professor of Oceanography and S.F. Ackley, Adjunct Research Professor

**Sponsor:** Office of Naval Research

**Objectives:** To foster oceanographic research in the Arctic, acquaint naval officer students with Arctic problems, reduce results of pure research to operational usage, and publicize Navy interest in the Arctic.

**Summary:** Professor Bourke served as administrator of the Chair handling such details as selecting Chair candidates, writing IPA's and proposals and setting up visits and seminars for the Chair incumbent. Professor Ackley, an ice physicist and Head of the Snow and Ice Branch of the Cold Regions Research and Engineering Laboratory (CRREL) was the Chair incumbent during FY86. He had a productive year providing seminars and lectures, writing papers and attending conferences. Of special note were his contributions to research in sea spray icing where he wrote and delivered two papers on this subject and advised the scientists at FNOC and NEPRF on developing a sea spray icing forecast model. Professor Ackley also laid the groundwork to establish memorandum of understanding between NPS and CRREL to foster an exchange of students and staff between these two institutions. Professor Ackley ended his stay in the Chair by participating in a month-long cruise to the Weddell Sea.

Title: Marginal Sea-Ice Zone Studies 1986

Investigators: R.H. Bourke, Associate Professor of Oceanography and R.G. Paquette, Emeritus Professor of Oceanography

Sponsor: Arctic Submarine Laboratory

Objective: Carry out physical oceanographic research, including field measurements, in the marginal sea-ice zone of the Bering, Chukchi, and Greenland Seas. This work has the long-term applied objective of facilitating the operation of submarines under ice. It is part of the continuing MIZPAC and MIZLANT programs.

Summary: This is an ongoing program to study the frontal and finestructure phenomena associated with the ice edges of the Atlantic and Pacific Oceans. Measurements, primarily CTD lowerings, have been carried out from ice breakers since 1971 and include observations both in summer and winter. During FY86 we completed the data editing and analysis of the 1985 cruise to Fram Strait. A data report has been published and a Master's thesis is nearing completion based on this data. Two papers based on data acquired during the 1984 cruise to the East Greenland Polar Front (EGPF) have been accepted for publication in a special issue of J. Geophys. Res. dedicated to marginal ice zone research. In support of the effort to establish a polar environmental data bank at NAVOCEANO archival data tapes from the 1980, 1981, 1984, and 1985 cruises have been arranged into a common format. A Master's thesis was completed which examined the spatial coherency of the 1984 CTD data acquired in the EGPF. We prepared for and carried out a cruise to northern Baffin Bay and Nares Strait, the first oceanographic survey of these waters using modern instrumentation. During this cruise we also conducted an extensive bathymetric survey of the ocean bottom.

Publications: R.H. Bourke, M.D. Tunnicliffe, J.L. Newton, R.G. Paquette, and T.O. Manley, "Eddy Near the Molloy Deep Revisited," Journal of Geophysical Research (forthcoming).

Publications  
(cont'd):

R.H. Bourke, J.L. Newton, R.G. Paquette, and M.D. Tunncliffe, "Circulation and Water Masses of the East Greenland Shelf," Journal of Geophysical Research (forthcoming).

R.H. Bourke and R.G. Paquette, "Studies of the Marginal Ice Zone Along the East Greenland Coast," Naval Research Reviews (forthcoming).

Bourke, R.H., R.G. Paquette, and A.M. Weigel, "Results of an Oceanographic Cruise to the Greenland Sea, September 1985," Naval Postgraduate School Tech. Rept. NPS 68-86-007, Monterey, September 1986.

Conference  
Presentation(s):

R.H. Bourke, M.D. Tunncliffe, R.G. Paquette, and J.L. Newton, "Oceanographic Observations on the Northeast Greenland Shelf," Ocean Sciences Meeting of the American Geophysical Union, New Orleans, Jan 13-14, 1986.

R.H. Bourke, J.L. Newton, R.G. Paquette, and A.M. Weigel, "Oceanographic Observations of the Marginal Ice Zone in Fram Strait, Ocean Sciences Meeting of the American Geophysical Union, New Orleans, Jan 13-14, 1986.

Theses Directed:

J.M. Clipson, LCDR British Navy, "Water Mass Analysis of the East Greenland Current," Master's thesis, September 1986.

Title: Studies in Support of NSWC

Investigators: R.H. Bourke, Associate Professor of Oceanography and C.R. Dunlap, Adjunct Research Professor of Oceanography

Sponsor: Naval Surface Weapons Center (NSWC)

Objectives: To assist in thesis research on topics of interest to NPS and NSWC

Summary: NSWC has established an experience tour program for NPS Air-Ocean Sciences students to spend 6 to 12 weeks at NSWC and other locations conducting research of mutual benefit to NPS and NSWC. LT Oard commenced an investigation of Arctic Ocean ambient noise, primarily in the weapons frequency range. Her work will attempt to establish a prediction capability between the noise sources and noise level.

Publications: R.H. Bourke and R.P. Garrett, "Sea Ice Thickness Distribution in the Arctic Ocean," Cold Regions Science and Technology (forthcoming).

Conference Presentations: R.P. Garrett and R.H. Bourke, "Sea Ice Thickness Distribution in the Arctic Ocean," 2nd Ice Penetration Technology Workshop, Monterey, June 16-19, 1986.

Title: Bistatic Propagation to Towed Arrays

Investigator(s) C.R. Dunlap, Adjunct Research Professor of Oceanography, R.H. Bourke, Associate Professor of Oceanography and G.H. Jung, Emeritus Professor of Oceanography

Sponsor: Naval Ocean Research and Development Activity

Objective: To develop simple methodologies for long range, low frequency propagation loss prediction for use in bistatic towed array sensors.

Summary: A simplified TL model originated by D. Ross (1980) was reviewed for possible use in bistatic long range scenarios. LT Schaal, USN, obtained environmental acoustic data from the literature to test the Ross model in three different geographic locations. A literature review was conducted concerning recent bistatic acoustic research. A technical report is expected to be completed in March 1987 summarizing this study.

**Title:** Environmental Acoustic Effects on Vertical Line Array Sonobuoys and the ANODE Meter

**Investigator(s):** C.R. Dunlap, Adjunct Research Professor of Oceanography and R.H. Bourke, Associate Professor of Oceanography.

**Sponsor:** Naval Avionics Center/Naval Air Systems Command

**Objective:** To understand the role of a sloping ocean bottom on the performance of vertical line array (VLA) sonobuoys and the engineering development model of the ANODE meter. This is a new three year research project.

**Summary:** Measurements of signal to noise ratio (SNR), made over a sloping ocean bottom off Monterey during July 1985, were analyzed. U.S. and Canadian VLA sonobuoy performance was investigated. Measurements were compared with modeled results. Additional SNR measurements were made in August 1985 using both co-located VLAD and DIFAR sonobuoys. These data were also analyzed in FY86. Comparison of processed data with ray trace products were made. In addition to processing the FY85 data, efforts were made to improve the reliability of data collection by procuring redundant sampling and recording systems. The new research vessel, R/V POINT SUR, was outfitted for SNR and associated oceanographic data collection. Additional data were collected during June and August 1986 using the R/V POINT SUR and assistance from the Naval Air Development Center (Dr. Thomas Gabrielson). During FY86 a letter of appreciation was received from Commanding Officer Patrol Squadron NINETEEN for providing research results which enhanced the squadron air crews ability to employ VLAD.

**Publications:** S. Raugust, "Cruise Report, FARG Seatest 9, R/V POINT SUR, 5-7 August 1986", Environmental Acoustic Research Group Technical Report, 29 September 1986.

**Conference Presentation(s):** C.R. Dunlap, "Naval Postgraduate School Vertical Line Array DIFAR (VLAD) studies" Presentation at Naval Air Systems Command (NAVAIRSYSCOM) VLAD Working Group Meeting, Naval Air Development Center, 18-19 September 1986.

**Title:** Fixed Distributed Systems: Environmental Acoustics and Fiber Optics Communications

**Investigator(s):** C.R. Dunlap, Adjunct Research Professor of Oceanography, J.P. Powers, Professor of Electrical and Computer Engineering and E.C. Haderlie, Distinguished Professor of Oceanography

**Sponsor:** Defense Advanced Projects Research Agency and Space and Naval Warfare Systems Command

**Objective:** To investigate the environmental effects on fixed distributed acoustic systems by study of a sample system to be installed in Monterey Bay. Additional study is on the use of fiber optic cable for data transmission. This is a continuing research project.

**Summary:** An underwater battery monitoring system that transmits the data over a fiber optic cable was designed, built and tested. This monitor uses v-to-f and f-to-v integrated circuits to pulse encode and decode the data. The link was successfully tested in the laboratory and in the ocean.

Design efforts began on a multi-channel fiber optic data link from undersea experiments to shore. Two approaches are being investigated, the first is an analog link using FM optical carrier modulation to allow multiple analog channels to be frequency division multiplexed and transmitted over the fiber. A set of phase-lock loop decoders separate and detect the channels. The second approach uses a high-speed A/D convertor to digitize the data. A microprocessor controls the digitization, time-domain multiplexing, and frame synchronization. The clock-encoded data stream is received and demodulated at the receiving end.

A high data rate acoustic receiver was also investigated for possible use with fixed distributed systems. A study was conducted on hydrophone reliability effects on the performance of these systems in a changing ocean environment.



Summary (cont'd): An initial design study of guidelines for acoustic analysis of the fixed distributed system data was completed.

Theses directed:

G. Schlecte, LT, USCG, "A Microprocessor-controller for A/D data encoding", MSEE, March 1986.

Y.-D. Koo, MAJ, KA, "A Seawater Battery Monitor with Fiber Optic Remote Data Acquisition Capability", M.S., Physics, Dec., 1985.

L.E. Gray, LT, USN, "Sampling Rate Reduction for a High Data Rate Acoustic Receiver", M.S., June 1986.

B. Breux, LT, USN, Classified thesis, M.S. Operations Analysis, September 1986.

K. Jennings, Civ, NOSC "Design Guidelines for a Rule-Based Passive Surveillance System", M.S. Computer Science, September 1986.

**Title:** Naval Postgraduate School Ambient Noise Drifter System (NADS)

**Investigator(s)** C.R. Dunlap, Adjunct Research Professor of Oceanography

**Sponsor:** Naval Oceanographic Research Development Activity

**Objective:** This research project has its objective the development of an ocean drifting buoy which samples oceanographical, meteorological, and acoustical parameters and telemeters the data ashore via the ARGOS satellite data relay system. This is a continuing program to provide the fleet with synoptic ambient noise measurements and to investigate the inverse measurement of air-sea interaction parameters (integrated wind speed, wave heights, etc) by the use of ambient noise data.

**Summary:** During FY84-85 initial design and procurement of NADS subsystems were funded by Commander Space and Naval Warfare Systems Command as a part of the Applied Ocean Acoustics program. With the shift of 6.2 research programs from the systems command to the naval laboratories, NADS funding was suspended. However, during FY86 results of subsystem tests were reported to the scientific community and additional experiments were conducted. Measurements of NADS 1 meter wind speeds using a Savonius rotor anemometer were compared with tower and ship wind measurements during the TOWARD experiment. Anomalous "high" wind speeds were discovered on an intermittent basis. During FY86 this NPS finding was confirmed by other investigators and steps have been taken by the Polar Research Laboratories to correct this situation.

The NADS will use a thermistor array which has multiplexed data sent to the surface. FY85 tests of this system by the Naval Oceanographic Office, National Data Buoy Center, and Polar Research Laboratory (PRL) were unsuccessful. During FY86 NPS successfully tested a new PRL design for the NADS thermistor array in a three day experiment off Monterey Bay. An ARGOS local user terminal (LIIT) and a ARGOS test set were also procured

Summary (cont'd):

during FY86 primarily with funding support of the NPS Foundation. Additional research funds are being sought to provide for new sponsored research in FY87-89.

Conference  
Presentation:

C.R. Dunlap, K. Mahon, and S.C. Raugust, "Near Surface Wind Speed Measurements from an Ocean Drifting Buoy" Presented AGU Fall Annual Meeting, San Francisco, December 8-13, 1985.

Title: Ocean System Performance Assessment and Acoustic Array Characteristics

Investigator(s) C.R. Dunlap, Adjunct Research Professor of Oceanography, R.H. Bourke, Professor of Oceanography and T.F. Clark, Visiting Faculty Research Associate of Oceanography.

Sponsor: Commander Space and Naval Warfare Systems Command and Office of Naval Research

Objective: To analyze the effect of environmental and acoustic phenomena on Integrated Undersea Surveillance Systems (IUSS) detection capability. This is a continuing research project.

Summary: Norwegian sea data processing and analysis ceased in February 1986 due to changing research priorities of the sponsor (PMW 180-44). An analysis of ways to improve operational performance in the Eastern Pacific was completed and a technical report produced. Additional performance prediction (SPARS) data were collected in the Eastern Atlantic for comparison with observed IUSS data. A technical report summarizing the work is in progress. In addition, as required by one sponsor (ONR), a continuing education course of nine environmental acoustic lectures was presented.

Publications: A.R. Hochevar, R.H. Bourke and R.F. Henrick, classified article in USN Journal of Underwater Acoustics

D. Johnson, and C.R. Dunlap, classified Technical Report in preparation.

P. Stephanides, C.R. Dunlap and R.H. Bourke, classified Technical Report in preparation.

Title: The Equatorial Mixed Layer

Investigator(s) R.W. Garwood, Jr., Associate Professor of Oceanography

Sponsor: National Science Foundation

Objective: To identify and describe all the mechanisms by which turbulent kinetic energy is produced, dissipated and redistributed within the equatorial turbulent boundary layer and to establish the selective importance of surface forcing (air-sea interaction) and interior forcing (vertical and horizontal advection) in determining the state of the equatorial mixed layer system.

Summary: Since the start (June 1986) of this new two-year project, climatological data bases of the world's tropical oceans and surface forcing have been assembled and made readily accessible on a networked microprocessor system. A Postdoctoral position has been advertised and filled.

Title: Studies of the Oceanic Planetary Boundary Layer

Investigator(s) R.W. Garwood, Jr., Associate Professor of Oceanography

Sponsor: Office of Naval Research

Objective: To understand and to model the mechanisms by which the oceanic planetary boundary layer (OPBL) mixed momentum, mass and energy in the upper ocean in response to air-sea interactions.

Summary: Progress has been made in two primary areas: (i) A mathematical model for the redistribution of turbulent kinetic energy among components due to planetary rotation has been expanded to include active entrainment cases: (ii) Entrainment models have been applied to chemical traces at upwelling fronts in the California current system.

Publications: R.W. Garwood, Jr., P.C. Gallacher, and P. Muller, 1985: Wind direction and equilibrium mixed layer depth: General theory. J. Phys. Oceanogr., 15, 1325-1331.

R.W. Garwood, Jr., P. Muller, and P.C. Gallacher, 1985: Wind direction and equilibrium mixed layer depth in the tropical Pacific. J. Phys. Oceanogr., 15, 1332-1338.

E.D. Traganza, D. Redalje, M. Began, and R.W. Garwood, Jr., 1986: Chemical flux at upwelling fronts. Continental Shelf Res. forthcoming.

R.W. Garwood, Jr., P.C. Gallacher, and P. Muller, 1987: Reply to comments on Wind direction and equilibrium mixed layer depth: General theory' by H. Fernando. J. Phys. Oceanogr., 15, forthcoming.

T.R. Mettlach, R.L. Haney, R.W. Garwood, Jr., and S.J. Ghan, 1986: The response of the upper ocean to a large summertime injection of smoke in the atmosphere. J. Geophys. Res., forthcoming.

Conference  
Presentation(s):

J.J. McManus, R.W. Garwood, Jr., and C.R. Dunlap, 1985: Coupled mixed layer-acoustic model. Trans. Am. Geophys. Union, 66, 1335. Invited paper at Ocean Sciences Meeting, January 1986, New Orleans.

P.C. Gallacher and R.W. Garwood, Jr., 1985: Wind direction and mixed layer depth: Mid-latitude simulations. Trans. Am. Geophys. Union, 66, 1281. Ocean Sciences Meeting, January 1986, New Orleans.

Theses Directed:

W. Wilson, LT, USN. Statistical Relationship Between Greenland Sea Ice and El Nino, M.S. in Meteorology and Oceanography, June 1986.

R.E. Brainard, LTJG, NOAA. Fisheries Aspects of Seamounts and Taylor Columns, M.S. in Oceanography, September 1986. Turbulent Flow-Topography Interactions, Ph.D. in Physical Oceanography, 1989.

Title: Tropical Oceanic Boundary Layer

Investigator(s) R.W. Garwood, Jr., Associate Professor of Oceanography

Sponsor: NPS Foundation Research Program

Objective: To understand the role of the surface mixed layer in the dynamics of the tropical ocean.

Summary: A theoretical model for the enhancement of turbulent mixing due to the interaction between planetary rotation and the Reynolds stresses has been applied to the equatorial Pacific. The results suggested that the very deep turbulent mixing in the central tropical Pacific may be explained by the conversion of horizontal turbulent kinetic energy to vertical turbulent kinetic energy due to effects of the Coriolis acceleration upon the integral scale of the turbulence. Based upon these results and in collaboration with the University of Hawaii, a proposal was written to the National Science Foundation to study the Equatorial Mixed Layer. This proposal has been funded for a two year period, and a Postdoctoral position has been created at NPS in support of further application of these results to large-scale tropical upper ocean and air-sea interaction problems, including El Nino.

Publications: R.W. Garwood, Jr., P. Muller and P.C. Gallacher: Wind direction and equilibrium mixed layer depth in the tropical Pacific. J. Phys. Oceanogr., 15, 1332-1338, October, 1985.

Conference Presentation(s): R.W. Garwood, Jr., P. Muller and P.C. Gallacher: Wind direction and equilibrium mixed layer depth in the tropical Pacific. IAMAP/IAPSO Joint Assembly, Honolulu, August, 1985.

Theses Directed: J.F.F.A. Gaspar: The equilibrium mixed layer depth in the tropical Atlantic: The rotation stress and penetration of radiation effects. M.S. Thesis, Naval Postgraduate School, 76 pp., 1985.



Title: The Georges Bank Recirculation Experiment

Investigator(s) S.R. Ramp, Assistant Professor of Oceanography,  
D.G. Mountain, National Marine Fisheries, and  
R.J. Schlitz, National Marine Fisheries

Sponsor: The National Marine Fisheries Service

Objective: Investigate how the interannual variability in  
the amount of recirculated water and the timing  
of the onset of strong recirculation affects the  
interannual variability in the recruitment of  
commercially important fish stocks on the bank.

Summary: This experiment consisted of a large L-shaped  
moored current meter array on the Southeast  
corner of Georges Bank, with supporting  
hydrographic measurements. I was responsible  
for the planning (jointly with other  
co-principle investigators) for this experiment,  
coordinating it with the research efforts of  
others in the Gulf of Maine (D. Brooks, Texas  
A&M, current measurements; Wendell Brown, UNH,  
hydrography; C. Flagg, Brookhaven National  
Laboratory, current measurements in the  
Northeast Channel), instrument (current meter)  
and equipment (mooring hardware) procurement,  
instrument deployment, and instrument recovery.  
This experiment was a continuation of an  
experiment begun in FY85. I was also  
responsible for supervising the data processing  
for the instruments deployed and recovered in  
FY85.

Conference Presentation(s): S.R. Ramp, "The Interaction of Warm Core Rings  
with the Shelf Water and Shelf/Slope Front South  
of New England." An invited presentation at  
Harvard University, Cambridge, MA. Sept., 1986.

S.R. Ramp, "The Interaction of Warm Core Rings  
with the Shelf Water and Shelf/Slope Front South  
of New England." Presented at the Naval  
Postgraduate School oceanography seminar series,  
May, 1986.

S.R. Ramp, "Observing the Ocean from Above and  
Within: How the Gulf Stream Affects the  
Northeastern Continental Shelf." Presented at  
Hobart and William Smith Colleges, Geneva, New  
York, April 1986.

Title: Arctic Ice-Ocean Model Development

Investigator(s) A.J. Semtner, Jr., Professor of Oceanography

Sponsor: NPS Foundation Research Program

Objective: The objectives of this to develop a capability to carry out and analyze simulations with an Arctic ice-ocean model on large mainframe computers located at remote sites; and to analyze the sensitivity of the model to changes in parameters which govern the surface energy balance, so as to arrive at a realistic parametric configuration for interannual predictability studies.

Summary: All of the hardware for a work station was procured in the first month of the three-month period. Almost all of the software codes were produced and tested by the end of the second month. Operational procedures were implemented in regard to editing, scientific computing, word processing, graphics-terminal emulation, and communications. The only software feature not implemented was stand-alone graphics on the PC, which was unavailable due to delays by the National Center for Atmospheric Research (NCAR) in making a product available.

The capability to work with the coupled ice-ocean model was developed during the third month of the proposal period. The mainframe computer used was the NCAR Cray 1A computer, accessed in Monterey via a local phone call. Approximately 15 one-year integrations with the model were carried out to determine sensitivity to energy fluxes at the upper and lower ice boundaries. The major model sensitivity was in regard to incoming solar radiation as modified by the presence of low-lying Arctic stratus clouds. A modification of the amount of stratus within observational limits of uncertainty produces realistic ice extents and ice thicknesses relative to the earlier work.

Title: A Numerical Study of Frontal Instability with Application to the East Greenland Current

Investigator(s) D.C. Smith, IV, Assistant Professor of Oceanography

Sponsor: Office of Naval Research

Objective: The interaction of isolated eddies and the meandering East Greenland Current with the marginal ice zone is being investigated using a two-layer ocean model and coupled ice system.

Summary: An existing two-layer ocean model has been modified to include the effect of a marginal ice cover, such as is observed in the East Greenland Current region. Numerical experiments have been performed to examine the interaction of existing mesoscale ocean eddies with the ice edge. Various degrees of complexity in the ice momentum equations have been considered. It is found that the signature of anticyclonic eddies in the ice is quite different than that of cyclonic eddies. Anticyclones concentrate ice and cyclones lead to ice free regions. When continental slope bottom topography is included in the model, a segregation mechanism exists by which anticyclones propagate out from under the ice (oceanward) and cyclones propagate iceward.

Publications: A manuscript entitled "A Numerical Study of Mesoscale ocean eddy interactions with a marginal ice zone" authored by David C. Smith IV, Arlene A.A. Bird (Department of Oceanography; Naval Postgraduate School) and W.P. Budgell (Institute of Ocean Sciences, Canada) has been prepared and will soon be submitted to Journal of Geophysical Research.

Conference Presentation(s): D.C. Smith, IV and A.A. Bird "A Numerical Study of Mesoscale ocean eddy interaction with a marginal ice zone" American Geophysical Meeting Fall meeting, 1986.

**Title:** A Numerical Study of Isolated Eddy Interaction with an Oceanic Jet

**Investigator(s)** D.C. Smith, IV, Assistant Professor of Oceanography

**Sponsor:** National Science Foundation

**Objective:** The coalescence of isolated Gulf Stream rings with a meandering Gulf Stream is being investigated using a two-layer regional ocean model. Variable parameters in the study are size, strength and vertical structure of the eddy and jet.

**Summary:** A series of spin down experiments involving the interaction of isolated mesoscale eddies with a meandering Gulf Stream-like jet were performed. The sensitivity of eddy-jet coalescence to various model parameters such as eddy size, strength and location was examined. Of these, it was found that eddy coalescence is most sensitive to eddy location relative to evolving meanders. Cyclones can only merge with meanders with the same (cyclonic) sense of rotation. The merger of an eddy with an evolving meander appears to be consistent with inviscid vorticity conservation much as in previous eddy-eddy interaction experiments.

**Publications:** A manuscript describing the results of this research is being prepared for submission to the Journal of Physical Oceanography.

**Conference Presentation(s):** Results were presented at the spring meeting of the American Geophysical Union in a session entitled "Mesoscale Ocean Modelling". I was also chairman of the session. The talk was entitled "The behavior of nonlinear isolated eddies in a regional mesoscale numerical model".

Title: Density, Shear and Turbulence Measurements in the Upper Ocean

Investigator(s) T.P. Stanton, Adjunct Research Professor and E.B. Thornton, Professor

Sponsor: Office of Naval Research

Objective: To continue analysis of MILDEX and DOLPHIN 84 data sets and develop techniques to make 1m scale spatial surveys of dynamic stability and mixing activity in the upper ocean. These measurements will help relate the role of large scale shearing processes (e.g., inertial waves) to mixing in the open ocean.

Summary: Analysis of the MILDEX and DOLPHIN/ACANIA data sets has lead to three conference presentations describing the role near inertial shear activity in the dynamics of the mixed layer and upper thermocline. Two papers and a thesis are being prepared on these results. A profiling towed platform equipped with CTD, microconductivity, fluorescence, optical transmission and motion sensors was completed in time for the 14 day multi-institution OPTOMA 21 cruise. During this cruise, five 80 km length vertical sections of thermohaline structure, velocity shear and microconductivity were made in conjunction with a chemical and biological survey of a coastal jet extending 100 km west of Point Arena. A unique transverse acoustic doppler profiler was added to the platform for the 1 October PATCHEX cruise. The coherent doppler profiler is capable of measuring mm/s accuracy 3 component velocities over 50, 10 cm range bins below the tow yo platform. When combined with CTD measurements, 20 cm - 5 m range Richardson number profiles can be obtained to bridge the "spectral gap" left by current measurement techniques. Both the newly developed microconductivity and fine scale shear profiler were successfully deployed during PATCHEX.

Conference Presentation(s): T.P. Stanton, M.P. McCann, "Horizontal Variability in the Mixed Layer During MILDEX," AGU Fall Annual Meeting, San Francisco, Dec 9-13, 1985.

Conference  
Presentations  
(cont'd):

T.P. Stanton, "Mixed Layer Processes During  
MILDEX", Ocean Sciences Meeting, New Orleans,  
Jan 13-17, 1986.

**Title:** Bluff and Dune Recession Along Monterey Bay Coastline

**Investigators:** E.B. Thornton, Professor of Oceanography, and S.P. Tucker, Assistant Professor of Oceanography

**Sponsor:** Department of Boating and Waterways, State of California

**Objective:** The erosion rates are determined at regular intervals along the shoreline of Monterey Bay by measuring the top of the cliff recession from aerial photographs during the interval 1939-1984. The photographs are to be analyzed using a stereo-comparator. Errors will be minimized by accounting for scale variation by referencing objects surveyed in the field, compensating for errors due to relief displacement by measuring the X-parallax at each point and selecting photographs to avoid errors due to plane tilt.

**Summary:** The permanent beach erosion in Monterey Bay is episodic, occurring infrequently when high tide coincides with stormy weather, which allows wave action to erode the base of the cliffs. A model was developed to predict cliff erosion based on the hypothesis that erosion only occurs when the water level due to combined tides, wave set-up and run-up exceeds the toe of the cliff elevation. The erosion model was calibrated using a spectral wave climatology, predicted tides, and aerial photographs covering an 18 year period. Refraction of the wave energy is responsible for the variability of erosion rates along the shore. The model gives a reasonable prediction of the spatial variation of the mean recession rates.

**Publications:** E.B. Thornton, A.J. Sklavidis, W. Lima Blanco, D.M. Burych, S.P. Tucker, and D. Puccini, "Coastal Erosion Along Southern Monterey Bay," West Coast Regional Design Conf., ASCE, 370-401, 1985.

Title: Modeling of Wave Transformation in Monterey Bay

Investigators: E.R. Thornton, Professor of Oceanography, and C.-S. Wu, Adjunct Research Professor of Oceanography

Sponsor: Department of Boating and Waterways, State of California

Objective: This proposal is to perform numerical modeling of waves in Monterey Bay. The investigation is for continuation of the modeling efforts on refraction and diffraction of ocean waves over Monterey Submarine Canyon. The model is developed and being tested for various cases. An integrated database of bathymetry is proposed for running wave transformation processes. The U.S. Army WIS deep water directional spectra will be refracted to obtain coastal waves at different locations around the Bay. The shallow water waves could be used for studies of littoral processes, wave forces, and coastal planning.

Summary: A parabolic ray model was developed and tested for the plane beach case and a two-dimensional sinusoidal contour. The model solves wave number explicitly (Wu and Thornton, 1986) and produces superfast wave field solutions. The refraction model is used as a basis for the modified refraction model, which includes diffraction across the ray. The modified ray model was run on different topographies and under different wave attack. The ray refraction model is found not sensitive to small changes in offshore approach angle.

Publications: C.-S. Wu and E.R. Thornton, "Wave Numbers and Linear Progressive Waves", J. of Waterways, Port, Coastal and Ocean Engineering, vol. 112, no. 4, July 1986.

C.-S. Wu and E.R. Thornton, a Discussion on "3-D Model of Shoreline Response to Structure", J. of Waterways, Port, Coastal and Ocean Engineering, vol. 112, no. 5, 1986, in press.

C.-S. Wu and E.R. Thornton, "Combined Refraction Diffraction of Waves Over Monterey Submarine Canyon", paper submitted for the 20th International Conference on Coastal Engineering, Taiwan, Nov 1986.



Thesis Directed:

E.N. Oradiwe, "Sediment Budget for Monterey Bay,  
Naval Postgraduate School, M.S. thesis, May 1986.

Title: Nearshore Wave Properties

Investigator(s) E.B. Thornton, Professor of Oceanography

Sponsor: Office of Naval Research

Objective: Basic studies are being made on the kinematics of breaking waves within the surf zone in the field. The specific objectives of the proposed research are: (1) determine breaking criterion as a function of depth, beach slope and wave frequency and (2) determine the transformation of waves and longshore currents across the surf zone due to energy conversion and dissipation in the breaking process.

Summary: Research this past year continued analysis of the results of the major field experiments at Torrey Pines, California and Santa Barbara, California, and the development of predictive models. In addition, we participated in a major field experiment, SUPERDUCK, in collaboration with other Universities and Government Agencies. The experiment conducted from 12 September to 23 October 1986. Analysis of the data will be a major focus of research in FY87. A model describing the transformation of random wave heights and resulting longshore currents was developed based on energy flux balance. Dissipation is considered due to wave breaking and bed friction. Wave breaking is characterized after periodic bores. The random nature of the wave heights is described by the Rayleigh distribution. The model is able to predict the increase in averaged wave height due to shoaling and subsequent decrease due to wave breaking. Twenty-four M.S. theses have resulted from this research program.

Publications: R.T. Guza and E.B. Thornton, "Swash Oscillations on a Natural Beach," J. of Geophysical Research, 87, 483-491, 1982.

E.B. Thornton and R.T. Guza, "Energy Saturation and Phase Speeds Measured on a Natural Beach," J. of Geophysical Research, 87, 9499-9503, 1982.

Publications  
(cont'd):

E.B. Thornton and R.T. Guza, "Transformation of Wave Height Distribution," J. of Geophysical Research, 88, 5925-5938, 1983.

R.T. Guza and E.B. Thornton, "Velocity Moments in the Nearshore," J. Waterways, Harbours and Coastal Engineering, 111, 235-256, 1985.

R.T. Guza and E.B. Thornton, "Observations of Surf Beat," J. of Geophysical Research, 90, 3161-3172, 1985.

E.B. Thornton and R.T. Guza, "Chapter 4: Measuring the Surf Zone," Nearshore Sediment Transport Study Monogram, Elsevier Press (forthcoming).

E.B. Thornton and R.T. Guza, "Chapter 8: Wind Wave Transformation," Nearshore Sediment Transport Study Monogram, Elsevier Press (forthcoming).

R.T. Guza and E.B. Thornton, "Chapter 9: Runup and Surf Beat," Nearshore Sediment Transport Study Monogram, Elsevier Press (forthcoming).

E.B. Thornton and R.T. Guza, "Chapter 10: Nearshore Sediment Transport Study Monogram," Elsevier Press (forthcoming).

E.B. Thornton and R.T. Guza, "Chapter 16: Models for Surf Zone Dynamics," Nearshore Sediment Transport Monogram, Elsevier Press (forthcoming).

R.T. Guza, E.B. Thornton and R. A. Holman, "Swash on Steep and Shallow Reaches," Proceedings 19th Intl. Coastal Engineering Conf., ASCE, 708-723, 1984.

C.-S. Wu, E.B. Thornton, and R. T. Guza, "Nearshore Current Model Compared with Field Data," J. of Geophysical Research, 90, 4951-4958, 1985.

E.B. Thornton, C.-S. Wu and R.T. Guza, "Breaking Wave Design Criteria", Proc. 19th Coastal Engineering Conference, ASCE, 31-41, 1984.

Publications  
(cont'd):

E.B. Thornton and R.T. Guza, "Surf Zone Longshore Currents and Random Wave: Field Data and Models", J. Physical Oceanography, vol. 16, no. 7, 1165-1178, 1986.

R.T. Guza, E.B. Thornton, N. Christensen, Jr., "Observations of Steady Longshore Currents in the Surf Zone", J. of Physical Oceanography (forthcoming).

Title: Offshore Historical Wave Climate

Investigator: E.R. Thornton, Professor of Oceanography

Sponsor: Department of Boating and Waterways, State of California

Objective: Existing offshore observations and hindcasts for deep water waves in the vicinity of Monterey Bay will be compiled and evaluated. In addition, approximately 70 storms dating from 1905 will be hindcasted to determine extreme wave statistics. The offshore wave data will be used as input to a refraction model to determine shallow water waves statistics. The objective of this study is to determine deep water extreme wave statistics that can be used in the desing of structures, and a wave climatology that can be used for operational purposes and littoral drift calculations.

Summary: The 70 worst storms were hindcast specifically for Monterey Bay by consultant Pacific Weather Analysis. The data is presently being analyzed to determine shallow water statistics.

Title: Test and Evaluation of Sea, Swell and Surf Programs (SSSP)

Investigators: E.B. Thornton, Professor of Oceanography

Sponsor: Naval Environmental Prediction Research Facility

Objective: The FORTRAN code for the Sea, Swell and Surf Program (SSSP) is being converted to a BASIC code to run on a Hewlett-Packard 9845B-275 mini-computer. Test and evaluation will be performed on the model using extensive available wave and surf data from La Jolla, CA, Santa Barbara, CA, and Duck, North Carolina. These field experiments cover a wide variety of wave and surf conditions.

Summary: A sea, swell, and surf program was improved, tested, and evaluated on a micro-computer (HP-9845B). Sea swell is calculated by a two dimensional spectral model. The energy balance equation is tested for different cases of wind velocities and water depths.

Wave transformation is described by one dimensional random wave model in which the wave heights are described using the Rayleigh distribution. The obtained solution of the random wave field is used to predict the longshore currents. The model outputs of wave height and current are compared with data acquired from a wave tank and natural beaches. The model is found to accurately forecast wave heights, breaker location, breaker type and longshore currents for several sets of conditions. Two M.S. theses resulted from this research.

Reports: M.T. Gill, "Sea, Swell, and Surf Program (SSP) User's Guide", Report to the Naval Environmental Prediction Research Facility, October 1985.

Title: Support for Commander, Naval Oceanographic Command MC&G (Hydrography) Chair

Investigator(s) J.J. von Schwind, Associate Professor of Oceanography and Geodetic Sciences

Sponsor: Commander, Naval Oceanographic Command

Objective: To promote involvement of talented and experienced members of academe, industry, and government in educational and research problems of interest to the Naval Oceanography Program in the areas of Mapping, Charting and Geodesy (MC&G) and Hydrography.

Summary: The Chair was occupied by Dr. Muneendra Kumar of the Defense Mapping Agency, Hydrographic/Topographic Center. He organized and coordinated the research activities of Phase II of the SEAFLOOR BENCHMARK POSITIONING SYSTEM (SBPS) Experiment as well as acting as Chief Scientist in the data collection campaign. The SBPS experiment was initiated in 1985 with the main goals of establishing a network of benchmarks for marine geodetic control, to determine their three-dimensional coordinates, and to demonstrate the feasibility of emplanting and/or recovering a benchmark (or any other instrument) at a given location on the seafloor in quasi-real time with geodetic survey.

Conference Presentation(s): Technical paper on SBPS research at the MC&G Review Meeting organized by NORDA.

Technical paper on SBPS research at the PACON 1986 conference organized by MTS.

Technical paper on SBPS research at the International Federation of Surveyors (FIG) Conference.

Technical presentation on the Global Positioning System (GPS) at the University of Victoria.

Theses Directed: S. Klangvichit, "Traverse Adjustment," Master's Thesis, September 1986.

Theses Directed  
(cont'd):

K.T. Brown, "Texas Instruments 4100 GPS  
Positioning Software," Master's Thesis, September  
1986.

M. Mozgalla, "Establishment of Software to  
Process Global Positioning Data Obtained from  
TI4100 GPS Receivers," Master's Thesis, December  
1986.



**DEPARTMENT**  
**OF**  
**MECHANICAL ENGINEERING**

## DEPARTMENT OF MECHANICAL ENGINEERING

The primary thrust of the research program in Mechanical Engineering continues to advance the state of knowledge in areas important to the U.S. Navy, more specifically, those involving solid mechanics, shock and vibration, dynamic systems and control, heat transfer, fluid mechanics and hydrodynamics, and materials science.

In addition to the research activities of seventeen permanent faculty and eight visiting and adjunct faculty, the Department hosts the work of the CNT Chaired Professor in Surface Ship Technology. This position was filled during the reporting period by Professor K. T. Yang from Notre Dame University who is working on the Mathematical Modelling of Shipboard Fires.

Research results are published in the student theses, project reports, and in papers which are both presented at national and international conferences and published in the scientific and technical journals.

### SOLID MECHANICS, SHOCK AND VIBRATION (SSV)

Professor Cantin has been conducting research in conjunction with David Taylor Naval Ship Research and Development Center's Structural Analysis Department in rib-reinforced shell structures. The thrust has been aimed at microcomputer implementation of numerical codes. This year, ten different computers were used in the solution of bench mark problems in order to establish the computer capabilities for problems typically encountered in Naval Engineering.

Professor Shin has been active in Underwater Shock and Vibration studies. Funded by the Defense Nuclear Agency, he has initiated work into the understanding of stiffened tripping characteristics. Several carefully planned UNDEX tests were conducted comparing Z, wide flange and narrow flange T stiffeners. The results will aid in the formulation of mathematical models to predict the ultimate strength of submarine structures in resisting underwater shock. Additionally, funded by David Taylor Naval Ship Research and Development Center, Professor Shin, together with Adjunct Professor K.S. Kim, has been actively investigating the vibration damping characteristics of bolted and welded connections for structural plates and shells. These elements transmit machinery generated noise, and joint damping can help to minimize this effect. Professor Shin, in continued work with material damping properties, has developed techniques for the measurement of damping behavior of selected high damping alloys and initiated work in the structural analysis of highly flexible light weight members for use in the U.S. Navy's N-RCSS (Remote Ocean Sensing Satellite) system.

#### DYNAMIC SYSTEMS AND CONTROL (DSC)

This area, new to the Mechanical Engineering Department, started with the hiring of Professor D. L. Smith two years ago and Professor L.W. Chang last year. During this reporting period (FY86) Professor Smith continued work with NSWC/WOL in the development of the robotic firefighter. The main focus is to apply linear optimum control theory to the design of continuous controllers for the robotic arm used to direct fire extinguishant to a shipboard aircraft fire. The procedure used at present is for a human operator to approach the burning aircraft, drill an entrance hole in the skin and insert extinguishant. The robot device will use low power from the water main source and be designated to perform the same task. A test bed has been assembled for the purpose of measuring drilling loads and initial force measurements have been made. A candidate servo-valve has been evaluated for the controlling of the manipulator mechanism.

In related work funded by the NPS Foundation, the simulation of manipulator dynamics has been accomplished including important nonlinearities and avoiding problems of singularity. Also, work is underway to exploit the power of a microcomputer controller for providing control of the hardware.

Professor L. W. Chang, a recent addition to the faculty has initiated work sponsored by the NPS Foundation dealing with control algorithms for light weight flexible manipulator arms such as those needed for space applications or for high speed industrial robots. A physical experimental arm having a very flexible link with hydraulic actuation has been built. The computer simulation and the experimental validation have been conducted for the single-link manipulator. An improved model was developed to reduce the discrepancies between the experimental results and the simulation results. A control algorithm has been developed to control a partial-actuated system. The research is continuing.

#### HEAT TRANSFER, FLUID MECHANICS AND HYDRODYNAMICS (HTFMH)

In this area, Professors Nunn and Kelleher have continued ongoing work funded by NWC at China Lake in the modelling of heat transfer and thermal dynamics of airfoils immersed in rocket nozzle exhaust gas. The purpose of the work is to predict the temperature transients within the airfoil as it is used for thrust vector control. This year the PHOENICS code has been installed and used to predict the heat transfer characteristics. Additionally, IR thermography methods have been developed for measurement of heat transfer rates in bodies of complex shapes. The work is ongoing.

Professor Salinas is developing a simulation model for flows within the interior of jet engine test cells for NCEL, Port Hueneme. The Navy is planning a redesign of all such test facilities and Professor Salinas' model will be used to determine pressure and velocity fields as an aid in the redesign process. The results of a two dimensional analysis have been obtained. This project is ongoing.

Professor Marto, joined by adjunct Professor Wanniarachchi, continued their work on Nucleate Boiling Behavior of Refrigerant R-114 from various surfaces funded by David Taylor Naval Ships Research and Development Center. This work, aimed at enhancing heat transfer in evaporation units is hoped to lead to a reduction in the size and weight of shipboard power plants. The effects of oil in the mixture and surface configuration have been investigated--showing that the enhanced heat transfer tubes can improve coefficients by up to a factor of ten. The work is continuing using other tube configurations including tube bundles for which a new test apparatus will be constructed.

Additionally, with Professor J. W. Rose from Queen Mary College, London University, they are working on steam condensation problems in horizontal tubes.

Professor Pucci is also conducting research in cooling but related to the reduction of IR signatures in gas turbine ship exhaust stacks. Sponsored by Naval Sea Systems Command, he has continued a program in the testing of three basic designs of exhaust gas eductors. These systems mix cool ambient gas with hot exhaust gas resulting in reduced temperature emissions. Data relative to flow, pressure drop, and temperature lowering, including IR imaging and thermographic results, have been obtained. As a second project, again funded by Naval Sea Systems Command, Professor Pucci is supervising student thesis work aimed at generating a computer model for the design of inlet air and exhaust gas ducting for Naval gas turbing installations.

During this reporting period, the work of the Chaired Professorship in Surface Ship Technology lay in the modelling of fluid/thermal phenomena following initiation of a fire. Fire control is a major problem onboard ship. This model will help to explain the results of full size tests conducted by the Navy. Professor K.T. Yang from the Department of Mechanical Engineering at Notre Dame University, together with Dr. Kelleher, developed the model and is continuing the work.

Professor Kelleher and Professor Ligrani have been working on the Laminar to Turbulent transition for boundary layers in a Curved Channel. In these situations, secondary flows are induced causing changes in the boundary layer thickness and impacting local heat transfer capabilities. This work is funded by NASA Lewis Research Center. Professor Ligrani has been funded by NASA Ames Research Center in a separate effort to develop subminiature multisensor Hot-Wire Probes for Improved turbulence measurements, and also by the Air Force Wright-Patterson Aeronautical Laboratories to further the understanding of heat transfer anomalies in film cooled boundary layers when embedded vortices are present. The latter work has an impact on the cooling of gas turbine engine blades as turbine inlet temperatures are increased.

Distinguished Professor Sarpkaya has been continuing theoretical and experimental studies in the area of Hydrodynamics to determine the

rise and demise of trailing vortices and the inception of interfacial disturbances in homogeneous and density stratified media. This series of efforts is funded by the Office of Naval Research and leads to the ability to infer details concerning submarine characteristics from observed disturbances in the ocean. In another project ongoing with NSF funds, Professor Sarpkaya and his students are working on time dependent flow about bluff bodies (smooth and rough cylinders) to obtain more refined predictive capability of the fluid-structure interaction. In addition, Professor Sarpkaya has undertaken an extensive theoretical and experimental work on the determination of the causes of parachute collapse. This work is sponsored by the Sandia National Laboratories and is the subject of a Ph. D. dissertation by CCL S. Mostafa, working under the direction of Prof. Sarpkaya. All of these projects are continuing along both theoretical and experimental lines.

#### MATERIALS SCIENCE (MS)

Research in Materials Science has been undertaken by Professors McNelley and Perkins. Professor Challenger, also in this area was on leave at CNR-London during this period. The main thrust of the NPS program is to integrate the mechanical properties of metals or metal composite materials to their microstructural characteristics. Professor Perkins, funded by David Taylor Ship Research & Development Center, is working on the Damping Properties of Quiet Metal Alloys. The alloys, such as Cu-Mn, have a high internal damping capability which depends on mechanical processing history, and can be useful in machinery quieting. Professor McNelley in conjunction with Adjunct Professor S. Hales, have been pursuing research in the Superplastic Forming of Aluminum Alloys. Supported by the Naval Air Systems Command, this work is leading to the ability to manufacture parts with complex geometries in an inexpensive way. Additionally, sponsored by Wright-Patterson Aeronautical Laboratories, Professor McNelley has been studying porosity influences on M-50 bearing steel properties and especially rolling contact fatigue resistance.

Title: Bench Marks for Micro Computers

Investigators: G. Cantin, Professor of Mechanical Engineering and Michael Hartmann, Adjunct Professor of Mathematics.

Objective: Compare the various types of modern micro-computers that could be used for a laboratory facility such as the joint Aeronautics-Mechanical Engineering lab facility for CAD/CAE.

Summary: Three bench marks were designed and tested to determine if a particular micro could be used to do significant numerical computations without degradation of performance of a work station.

Results: Ten different computers were used to establish some guidelines on what to expect from a computer used for the type of computations and applications most commonly met by Aero and M.E. engineers. Five trips were made to Santa Clara in order to test various computers that were not available at NPS. The measurements made were all summarized in a paper presented at an ASME conference in Chicago during the summer of 1986.

Publication: G. Cantin and M. Hartmann, "On the Solution of Big Problems with Small Computers," PVP Conference (ASME) Summer 1986. The paper was contained in the Special Volume on the Use of Microcomputers.

Conference: G. Cantin, "On the Solution of Big Problems with Microcomputers," PVP Conference, Chicago, Summer 1986.

**Title:** Dynamic Models and Motion Controls of High-Performance Industrial Robots

**Investigator:** Liang-Wey Chang, Assistant Professor of Mechanical Engineering.

**Sponsor:** NPS Foundation Research Program

**Objective:** To develop a mathematical model and control algorithm which includes the flexibility effects for high-performance industrial robots.

**Summary:** The flexibility of the manipulator needs to be considered in the dynamic model of a high-performance robot, since high-performance robots operate at high speeds and carry heavy payloads. A mathematical model of the flexible arm has been developed. A physical experimental arm having a very flexible link with hydraulic actuation was built. The computer simulation and the experimental validation have been conducted for the single-link manipulator. An improved model was developed to reduce the discrepancies between the experimental results and the simulation results. A control algorithm has been developed to control a partial-actuated system. The algorithm can be applied to control a flexible robot which is a nonlinear partial-actuated system in general.

**Publications:** R.P. Petroka and L.W. Chang, "Computer Simulation and Experimental Validation of a Dynamic Model," (Equivalent Rigid Link System) on a Single-Link Flexible Manipulator," in progress.

L.W. Chang, "A Nonlinear Control for Partial-Actuated Systems," in progress.

K.K. Gannon and L.W. Chang, "An Enhanced Model and Experimental Validation on a Single-Link Flexible Arm," in progress.

**Conference:** R.P. Petroka and L.W. Chang, "Computer Simulation and Experimental Validation of a Dynamic Model (Equivalent Rigid Link System) on a Single-Link Flexible Manipulator," 57th Shock and Vibration Symposium, New Orleans, October 14-16, 1986.

**Thesis Directed:** R.P. Petroka, "Computer Simulation and Experimental Validation of a Dynamic Model (Equivalent Rigid Link System) on a Single-Link Flexible Manipulator," Master's Thesis, June 1986.

Title: Thermal Processes in the Inter-Connection of Semiconductor Devices

Investigators: Y. Joshi, Assistant Professor of Mechanical Engineering

Sponsor: Un-sponsored

Objective: To computationally model the thermal processes associated with semiconductor inter-connection operations of die and wire bonding.

Summary: The ever increasing component density and shrinking I.C. feature size has resulted in extremely high heat fluxes in present day semiconductor devices. The thermal resistance of a semi-conductor package is strongly affected by assembly operations such as wire and die bonding. Improving the quality of these inter-connections is therefore an important consideration in any efforts towards increasing system reliability. Simple approximate models have been made to simulate the transient heat transfer associated with the processes of eutectic die bonding and the recent TAB bonding process. The most important process parameters have been identified. Detailed computations of the effects of these parameters on bond quality will be studied.

Publication: Y. Joshi, "Thermal Analysis of the Tape Automated Bonding Process," in preparation.



Title: Transient Buoyancy Induced and Mixed Convection Flows

Investigators: Y. Joshi, Assistant Professor of Mechanical Engineering.

Sponsor: Naval Postgraduate School Foundation Program.

Objective: To obtain a fundamental understanding of buoyancy induced and mixed convection transient flows. Specific applications of these processes to current problems in electronic equipment cooling will also be studied.

Summary: Computational work has continued on the examination of transient buoyancy induced flow adjacent to a vertical surface. Recent calculations have shown that prior criteria for delineating the transient regimes are inconsistent. Improved criteria have been proposed. Transport computations have also been carried out for the commonly encountered wall plume, for the conditions of extreme Prandtl numbers. Experimental equipment has recently been acquired for studying transient buoyancy induced flows from discrete sources on a vertical adiabatic surface. This will be used to simulate controlled time varying thermal inputs.

Publication: Y. Joshi, "On the Termination of One-Dimensional Transport in Transient Buoyancy Induced Flow Adjacent to a Vertical Surface," Submitted for publication.

Y. Joshi, "Wall Plume at Extreme Prandtl Numbers," submitted for publication.

**Title:** Field Modeling of Fire and Smoke Spread in Confined Spaces

**Investigators:** Matthew D. Kelleher, Professor of Mechanical Engineering and K. T. Yang, NAVSEA Research Chair Professor (Viola D. Hank, Professor of Engineering at the University of Notre Dame)

**Sponsor:** Naval Sea Systems Command

**Objective:** The objective of this work is to develop a finite difference numerical model for the realistic determination of the time dependent fire and smoke spread in confined spaces and then to use the model to simulate various fire scenarios in submarines.

**Summary:** A numerical finite difference field model was developed to simulate full scale fires in closed vessels. In particular, the model was developed to simulate tests in the Fire 1 Test Facility at the Naval Research Laboratory in Washington, D.C. As a first step, a rectangular 3-dimensional geometry was used to approximate the actual geometry in the computer model. Then, a model with the actual spherical cylindrical geometry was developed. The computer code produced pressure, temperature, density, and velocity fields from given heat input data for the fires. The most important feature of the model was that it accounts for the pressure buildup due to the fire in a pressure vessel, such as Fire 1, or any other closed vessel, such as a submarine. Other features include surface radiation exchange and heat losses through the wall. Model features include surface radiation exchange and heat losses through the wall. Model results were validated with experimental data from Fire 1. The envisioned use of the model is in simulating fires in Fire 1 and eventually in submarines.

**Title:** Jet Vane Thrust Vector Control System Heat Transfer Modeling

**Investigators:** Matthew D. Kelleher, Professor of Mechanical Engineering and Robert H. Nunn, Professor of Mechanical Engineering

**Sponsor:** Naval Weapons Center

**Objective:** Development of analytical/empirical models to predict the heat transfer characteristics of airfoils immersed in a rocket nozzle exhaust.

**Summary:** Installed PHOENICS code for heat transfer modeling. Initial predictive calculations for two-dimensional steady turbulent compressible flows with shocks completed. Developed IR thermography methods for measurement of heat transfer rates in complex geometries.

**Presentations:** R. H. Nunn, "Jet Vane Heat Transfer Modelling," presented to KTA-9 meeting, NPS, July, 1986.

**Publications:** R. H. Nunn, and M. D. Kelleher, "Jet Vane Heat Transfer Modelling," NPS69-86-010, October 1986.

A. Leitner, "Thrust Vector Control Heat Transfer Modelling," NPS69-86-005, September 1986.

**Thesis Directed:** J. M. Spence, "Applications of IR Thermography in Convective Heat Transfer," MSME, March 1986.

A. Yukselen, "Heat Transfer Modelling of Thrust Vector Control Systems," MSME, March 1986.

**Title:** Laminar/Turbulent Transition in a Curved Channel with Heat Transfer

**Investigators:** Matthew D. Kelleher, Professor of Mechanical Engineering and Phillip M. Ligrani, Associate Professor of Mechanical Engineering

**Sponsor:** NASA/Lewis Research Center

**Objective:** The objective of this work is to experimentally investigate the laminar to turbulent transition in a curved rectangular channel and the effect of the transition process on the heat transfer.

**Summary:** In the first 8 months of work on the project, the following have been accomplished: (1) a new curved channel facility has been designed and constructed in order to visualize flow phenomena, (2) three different flow visualization schemes have been tested and evaluated for use in the channel, (3) the new channel has been assembled in the laboratories of the Naval Postgraduate School and is fully operational, (4) preliminary heat transfer surface design is underway, and (5) new subminiature hot-wire sensors are being developed for use in the channel.

Title: Development of Subminiature Multi-Sensor Hot-Wire Probes for Improved Turbulence Measurements

Investigators: P. M. Ligrani, Associate Professor,  
Department of Mechanical Engineering

Sponsor: NASA/Ames Research Center

Objective: To develop hot-wire probes with improved spatial resolution in order to probe near-wall portions of turbulent boundary layers where scales of motion are very small.

Summary: The newest generation of subminiature hot-wire sensors have the best spatial resolution and frequency response of all sensors used to measure turbulence. In this project, a new type of subminiature sensor will be developed to measure transverse and lateral velocity components. After construction of the sensor, it will then be qualified and test. Typical lengths are  $100 \times 10^{-6}$  m and typical diameter is  $.625 \times 10^{-6}$  m.

Eventually, measurements will be made of the near-wall structural characteristics of transitioning and turbulent boundary layers. High accuracy subminiature hot-wire sensors will be employed along with high precision traversing devices. Multiple instantaneous velocity components will be measured in the viscous sublayer, and other near-wall regions, where new understanding could lead to reductions in drag for airfoil surfaces. Other important turbulence structure will also be investigated to give a complete understanding of highly anisotropic, highly sheared, and inhomogeneous turbulent flow fields.

Publication: P. M. Ligrani and R. J. Moffat, "Structure of Transitionally Rough and Fully Rough Turbulent Boundary Layers," Journal of Fluid Mechanics, Vol. 162, pp. 69-98, January 1986.

P. M. Ligrani, "Subminiature Hot-Wire Sensor Construction," Naval Postgraduate School Report NPS-69-84-010, November 1984.

P. M. Ligrani and P. Bradshaw, "Subminiature Hot-Wire Sensors: Development and Use," Journal of Physics E - Scientific Instruments, 1986.

P. M. Ligrani and P. Bradshaw, "Spatial Resolution and Measurement of Small-Scale Turbulence in the Viscous Sublayer Using Subminiature Hot-Wire Probes," Experiments in Fluids, 1986.

Conference  
Presentations:

P. M. Ligrani and P. Bradshaw, "Subminiature Hot-Wire Sensors and Resolution of Small-Scale Turbulence," Fifth Symposium on Turbulent Shear Flows, Cornell University, August 19, 1985.

**Title:** Effects of Embedded Vortices on Heat Transfer in Film Cooled Turbulent Boundary Layers

**Investigators:** P. M. Liqrani, Associate Professor, Department of Mechanical Engineering

**Sponsor:** Wright Aeronautical Laboratories, Wright Patterson Air Force Base

**Objective:** To study the effects of intense secondary flows, especially embedded vortices, on heat transfer and the cooling schemes used for end-wall surfaces in the first turbine stage of gas turbine engines.

**Summary:** Many fluid mechanics phenomena, such as vortices, secondary flows, and separation, exist near end-walls in the first stage of turbines. Because of high heat loads to metal parts, the understanding of these phenomena is vital for the design of effective cooling systems to maintain metal surface temperatures at acceptable levels. One such cooling technique is film cooling, used to give a "blanket" of cool air between hot gas and metal surfaces. However, with secondary flows, in particular, with vortices embedded in boundary layers, the protection from film cooling may be reduced, drastically in some cases. In one project, an experimental investigation of the interaction of film cooling jets (or a single jet), and a boundary layer embedded vortex is to be undertaken. In additional projects, the effects of other types of secondary flows will be examined. Measurements will be made of surface temperatures, wall heat flux, and heat transfer coefficients as different parameters are varied. Flow visualization and surface temperature visualization will also be employed.

**Theses Directed:** S. L. Joseph, "Effects of an Embedded Vortex on Heat Transfer in Film Cooled Turbulent Boundary Layers," December 1986 (expected).

D. L. Evans, "Study of Embedded Vortex with Film Cooling Cross Flow," March 1987 (expected).

A. Ortiz, "Effects of Secondary Flows on Heat Transfer in Film Cooled Turbulent Boundary Layers," September 1987 (expected).

Title: Laminar/Turbulent Transition in a Curved Channel

Investigators: P. M. Ligrani, Associate Professor,  
and M. D. Kelleher, Professor, Department of  
Mechanical Engineering

Sponsor: NASA/Lewis Research Center

Objective: To obtain a better understanding of laminar/  
turbulent transition in a curved channel from  
experimentation. Flow visualization, wall heat  
flux measurement, and detailed probing will be  
used to obtain information about the flow.

Summary: In flow in curved channels having large aspect  
ratio (width to height), secondary flows such as  
Taylor-Görtler vortices and Tollmien-Schlichting  
waves are present. These cause significant  
variations in local wall heat transfer, and are  
also expected to change the way in which  
transition from laminar to turbulent flow occurs.  
Such flow will be investigated using a new  
visualization technique. Later, hot-wires will  
be used to probe the flow, and wall heat transfer  
measurements will be made.

Thesis Directed: M. Siedband, "Flow in a Curved Channel Undergoing  
Laminar/Turbulent Transition," March 1987  
(expected).



Title: Variable Property Effects in Film Cooled Turbulent Boundary Layers

Investigators: P. M. Ligrani, Associate Professor, Department of Mechanical Engineering

Sponsor: None

Objective: To develop empirical and analytic expressions to describe the effects of variable properties in film cooled turbulent boundary layers in high temperature, compressible environments.

Summary: Analysis shows that two different variable property effects influence wall heat transfer in film cooled turbulent boundary layers: (1) variation of density and (2) variation of thermal conductivity and absolute viscosity.

Publication: "A Note on Effects of Variable Properties in Film Cooled Turbulent Boundary Layers," (P. M. Ligrani and A. F. Walz), submitted to ASME Transactions - Journal of Heat Transfer, 1986.

Thesis Directed: A. F. Walz, "Effects of Variable Properties in Film Cooled Turbulent Boundary Layers," March 1986.

**Title:** Enhanced Condensation of Steam on Horizontal Tubes

**Investigators:** P. J. Marto, Distinguished Professor and Chairman of Mechanical Engineering, and J.W. Rose and A.S. Wanniarachchi, Adjunct Research Professors of Mechanical Engineering.

**Sponsor:** National Science Foundation

**Objective:** To experimentally determine the influence of various enhancement techniques upon steam condensation heat transfer coefficients on a single horizontal tube.

**Summary:** A single tube apparatus was designed and constructed to reliably measure steam condensation heat transfer coefficients. Over 60 finned tubes were tested to study the influence of fin geometry upon the film condensation heat transfer coefficient of steam. It was found that fin spacing was the most important variable. The best tube had a fin spacing of 1.5 mm. Rectangular fins with this spacing gave heat transfer coefficient enhancements of from 4 to 6 times the smooth tube value depending on steam pressure. Fin thickness and shape were found to influence the results slightly. Wall conductivity affected the results significantly. A wide variety of organic coatings have been evaluated for their steam endurance characteristics during the past two years. Several promising coatings were applied to horizontal tubes for heat transfer measurements - enhancements of from 3 to 9 times the smooth tube film condensation value were obtained. The work on finned tubes is continuing in an effort to explain the observed experimental behavior. An experimental investigation of heat transfer in the flooded region of a finned tube has begun.

**Publications:** A.S. Wanniarachchi, P.J. Marto, and J.W. Rose, "Film Condensation of Steam on Horizontal Finned Tubes: Effect of Fin Spacing," Journal of Heat Transfer, Vol. 108, No. 4, pp. 960-966, Nov 1986.

P.J. Marto, D.J. Looney, J.W. Rose and A.S. Wanniarachchi, "Evaluation of Organic Coatings for the Promotion of Dropwise Condensation of Steam," International Journal of Heat and Mass Transfer, Vol. 29, No. 8, pp. 1109-1117, Aug 1986.

K.M. Holden, A.S. Wanniarachchi, P.J. Marto, D.H. Boone, and J.W. Rose, "The Use of Organic Coatings to Promote Dropwise Condensation of Steam," Journal of Heat Transfer (accepted for publication 1987).

Conference  
Presentation:

P.J. Marto, "Recent Progress in Enhancing Film Condensation Heat Transfer on Horizontal Tubes - Keynote Paper," 8th International Heat Transfer Conference, San Francisco, August 17-22, 1986.

P.J. Marto, E. Mitrou, A.S. Wanniarachchi, and J.W. Rose, "Film Condensation of Steam on Horizontal Finned Tubes: Effect of Fin Shape," 8th International Heat Transfer Conference, San Francisco, August 17-22, 1986.

Theses Directed:

J.D. Bowen, "An Evaluation of Heat Transfer Deterioration of Hydrophobic Coatings During Dropwise Condensation of Steam," Master's Thesis, March 1986.

E. Mitrou, "Film Condensation of Steam on Externally Enhanced Horizontal Tubes," Master's and Engineer's Thesis, March 1986.

**Title:** Nucleate Boiling Behavior of R114 from Structured Surfaces

**Investigators:** P. J. Marto, Distinguished Professor and Chairman of Mechanical Engineering and A.S. Wanniarachchi, Adjunct Research Professor of Mechanical Engineering

**Sponsor:** David W. Taylor Naval Ship Research and Development Center

**Objective:** To experimentally study the nucleate boiling performance of R-114 and R114/oil mixtures from several commercially available boiling surfaces.

**Summary:** A single tube experimental apparatus was constructed to measure the nucleate pool boiling characteristics of R-114 and R114/oil mixtures. The test tube could be heated either electrically or with warm water. The external, nucleate pool-boiling heat transfer coefficient was measured for a smooth copper tube and for a variety of enhanced tubes. The heat transfer coefficient was enhanced over the smooth tube value by a factor of up to 10 in oil-free R-114. With oil concentrations greater than six percent, the boiling performance of the enhanced surfaces was reduced at heat fluxes in excess of 30 kW/m<sup>2</sup>. Nevertheless, the use of enhanced surfaces can significantly improve upon the boiling performance, leading to smaller evaporator units. A new apparatus will be constructed to test the tubes in a bundle.

**Publication:** A.S. Wanniarachchi, P.J. Marto and J.T. Reilly, "The Effect of Oil Contamination on Nucleate Pool-Boiling Performance of R-114 from a High Flux-Coated Surfae," ASHRAE Annual Meeting Portland, OR., June, 1986.

**Theses Directed:** S.M. McManus, "Nucleate Pool Boiling of R-114 Refrigerant and Oil Mixtures from Water-Heated Enhanced Surfaces", Master's Thesis, June, 1986.

L.M. Sawyer, "The Effect of Oil Contamination on Nucleate Pool Boiling Performance of R-114 from Enhanced Surfaces," Master's Thesis, June 1986.

**Title:** Investigation of the Influence of Porosity on Behavior of M-50 Bearing Steel

**Investigator:** T. R. McNelley, Associate Professor of Materials Engineering, Department of Mechanical Engineering

**Sponsor:** U.S. Air Force Wright Aeronautical Laboratories

**Objective:** To determine the effect on rolling contact fatigue behavior for M-50 steel of the presence of fine-scale porosity (of size 1.0-3.0  $\mu$ m) associated with insoluble carbides.

**Summary:** Porosity has been observed in the course of study of the effects of thermomechanical processing by warm rolling of M-50 steel. This porosity is believed to result from decohesion of the insoluble carbide - matrix interface during hot rolling of the steel. This size distribution of this porosity has been shown to be lognormal; the porosity can be eliminated by hot isostatic pressing (HIP) and the effect on rolling contact fatigue behavior of its elimination is being determined.

**Publications:** A. Garg and T. R. McNelley, "Estimation of the Martensite Carbon Content in As-Quenched AISI 52100 Steel by X-ray Diffraction," Materials Letters, Vol. 4 (1986), pp. 214-218.

F. A. Butterfield and T. R. McNelley, "Porosity Associated With Insoluble Carbides in M-50 Steel and Its Probable Effects on Rolling Contact Fatigue," Journal of Tribology, Transactions of the ASME, Vol. 108 (1986), pp. 352-358.

**Conference Presentations:** T. R. McNelley and F. A. Butterfield, "Porosity Associated with Insoluble Carbides in VIM-VAR AISI M-50 Steel and its Probable Effects on Rolling Contact Fatigue," paper no. 85-Trib-39, presented at the Joint American Society for Lubrication Engineers and American Society for Mechanical Engineers Tribology Conference, Atlanta, October 22-24, 1986.

Title: Ultra-Fine Grained Superplastic Aluminum-Magnesium Alloys: Thermomechanical Processing and Microstructure

Investigator: T. R. McNelley, Associate Professor of Materials Engineering, Department of Mechanical Engineering

Sponsor: Naval Air Systems Command

Objective: To develop refined microstructures of 1.0 - 5.0  $\mu\text{m}$  grain size in wrought Al- based alloys, including Al-Mg and Al-Mg-Li materials, to facilitate warm temperature, cavitation-free superplasticity.

Summary: Thermomechanical processing by warm rolling at 300°C to large strains has been shown to induce superplasticity in high-Mg Al-Mg and Al-Mg-Li alloys. Superplastic ductilities are attained at lower temperatures (ca. 300°C) and strain rates 20-50 times greater than normally reported for wrought high-strength Aluminum Alloys, and additionally are attained with no cavitation. These observations are attributed to continuous recrystallization of the high dislocation density present in the as-rolled condition. This mechanism results in grains 1.0 - 5.0  $\mu\text{m}$  in size, a size much finer than the 10-20  $\mu\text{m}$  attained by more conventional treatments utilizing discontinuous recrystallization. The continuous recrystallization of these alloys has been studied by transmission electron microscopy using convergent beam methods to study the grain structure and also by differential scanning calorimetry. In addition, studies involving simulated superplastic forming of these alloys have shown that the refined grain structures contribute to high strength at ambient temperature.

Publications: T. R. McNelley, E. W. Lee and M. E. Mills, "Superplasticity in a Thermomechanically Processed High-Mg, Al-Mg Alloy," Metallurgical Transactions, Vol. 17A (1986) pp. 1035-1041.

E. W. Lee, T. R. McNelley and A. F. Stengel, "The Influence of Thermomechanical Processing Variables on Superplasticity in a High-Mg, Al-Mg Alloy," Metallurgical Transactions, Vol. 17A (1986), pp. 1043-1050.

T. R. McNelley, E. W. Lee and A. Garg, "Superplasticity in Thermomechanically Processed High-Mg, Al-Mg-X Alloys," Proceedings of the International Conference on Aluminum Alloys - Their Physical and Mechanical Properties," pp. 1269-1284, edited by E. A. Starke and T. H. Sanders, Univ. of Virginia: EMAS, Warley, West Midlands, UK, 1986.

Conference  
Presentation:

E. W. Lee, T. R. McNelley, M. E. Alcamo and D. B. Berthold, "Evolution of Microstructure During Superplastic Flow in Al-10% Mg-0.1% Zr," presented at the Annual Fall Meeting of the Metallurgical Society of AIME and American Society for Metals, Toronto, October 7-10, 1985.

T. R. McNelley, E. W. Lee, R. T. Self and T. S. Hartmann, "Influence of Cu, Mn and Zr Additions on the Superplastic Behavior of Al-Mg-X Alloys," presented at the Annual Fall Meeting of the Metallurgical Society of AIME and American Society for Metals, Toronto, October 7-10, 1985.

T. R. McNelley and T. S. Hartmann, "The Effect of Recrystallization and Grain Growth on the Activation Energy for Superplastic Deformation in an Al-Mg-Zr Alloy," presented at 115th Annual Meeting of the Metallurgical Society of AIME, New Orleans, March 24-27, 1986.

E. W. Lee, A. Garg and T. R. McNelley, "Enhanced Ductility in 7475 Aluminum by Thermomechanical Processing," presented at the 115th Annual Meeting of the Metallurgical Society of AIME, New Orleans, March 24-27, 1986.

T. R. McNelley, E. W. Lee and A. Garg "Superplasticity in Thermomechanically Processed High-Mg, Al-Mg-X Alloys," presented at the International Conference on Aluminum Alloys - Their Physical and Mechanical Properties, the University of Virginia, Charlottesville, VA, June 16-20, 1986.

**Title:** Damping Properties and Applications of Quiet Metal Alloys

**Investigator:** Jeff Perkins, Professor of Mechanical Engineering

**Sponsor:** Naval Ships R&D Center

**Objective:** To characterize the damping properties and delineate the damping mechanisms in so-called quiet metal alloys such as Cu-Mn, Fe-Cr, Ti-Ni, Cu-Zn-Al and CuAlNi.

**Summary:** Specific damping capacity as a function of cyclic strain has been evaluated in detail for alloys based on Cu-Mn and Fe-Cr. This has been done for alloys in various heat treated conditions in order to discover the conditions which lead to optimum damping behavior. All the alloys display a strain threshold and damping saturation with increasing strain. Microstructural features have been studied via TEM and optical microscopy. Considerably more work is required to delineate damping mechanisms and factors which influence them in these alloys.

**Publications:** K. Adachi, and J. Perkins, "Deformation of Martensite in Polycrystalline Cu-Zn-Al Alloy," Metallurgical Transactions A, Vol. 17A, pp. 945-959, June 1986.

K. Adachi, J. Perkins, and C.M. Wayman, "Type II Twins in Self-Accommodating Martensite Plate Variants in a Cu-Zn-Al Shape Memory Alloy," Acta Metallurgica, Vol. 34, pp.2471-2485, 1986.

**Conference Presentations:** K. Adachi, J. Perkins, and C.M. Wayman, "Intervariant and Interplate Group Boundaries in 18R Cu-Zn-Al Martensites," International Conference on Martensitic Transformations (ICOMAT-86), Nara, Japan, August 1986.

J. Perkins, "The Two-Way Shape Memory Effect," International Symposium on Shape Memory Alloys, Guilin, PRC, September 1986.

K. Adachi, and J. Perkins, "The Effect of Thermal Cycling on Martensitic Transformations in a Cu-Zn-Al Alloy," International Symposium on Shape Memory Alloys, Guilin, PRC, September 1986.



Thesis Directed:

John Reskusich, LCDR, USN, "Cyclic Strain Amplitude and Heat Treatment Effects on the High Damping Behavior of INCRAMUTE Alloy Under Random Vibrational Loading in the 50 to 1000 Hz Frequency Range," Mechanical Engineer's degree, September 1986.

Title: Analytic Model of Gas Turbine Engine Installations

Investigator: P.F. Pucci, Professor of Mechanical Engineering

Sponsor: Naval Sea Systems Command

Objective: This activity is a continuation of a program to create a computer model for the design of inlet air and exhaust gas systems for gas turbine engines used on naval ships.

Summary: The computer model was expanded to include additional capabilities and to verify some limited experimental data.

**Title:** Exhaust Gas Eductor Design

**Investigator:** P.F. Pucci, Professor of Mechanical Engineering

**Sponsor:** Naval Sea Systems Command

**Objective:** Design, fabricate and test scale models of proposed exhaust gas eductors to be used on a new class of ships with gas turbine propulsion engines.

**Summary:** This activity is a continuing program in the design, fabrication and testing of exhaust gas eductor systems for propulsion gas turbine engines. During this period, three basic designs with variations on two of them, were tested and compared. Additionally, one test configuration was designed to simulate operation in cross-flow. In addition to flow rates, pressure and temperature data collected, infra-red imaging and thermography was used.

**Title:** Three-Dimensional Modeling of Flows Within Gas Turbine Engine Test Cells

**Investigator:** D. Salinas, Associate Professor of Mechanical Engineering

**Sponsor:** Naval Civil Engineering Laboratories, Port Hueneme

**Objective:** To formulate a model and thereafter to investigate the effects of jet engines, at several operating conditions, on test cell facilities.

**Summary:** NAVAIR has inaugurated a five-year plan to modernize old test cell facilities, and design and build new facilities. The overall cost of the project is about \$700 million. An important part of the project is to obtain an understanding of how the engine operating conditions and the structural configuration of the test cell affect the behavior of the system. The PHOENICS-81 heat transfer and fluid mechanics code was used to determine the temperature, pressure and velocity fields in the LeMoore test cell facility. A two-dimensional model provided extensive analytical results.

**Publications:** D. Salinas, and C. Kodres, "An Experimental and Analytical Investigation of Gas Turbine Engine Test Facilities," submitted for presentation at the AIAA 22nd Thermophysics Conference.

An NPS Technical Report is in preparation.

Title: Vortex Induced Disturbances on Fluid Interfaces

Investigator: T. Sarpkaya, Distinguished Professor of Mechanical Engineering

Sponsor: Chief of Naval Research

Objective: To carry out both theoretical and experimental studies to determine the fluid-mechanical mechanisms which govern the rise and demise of vortices and the inception of interfacial disturbances in homogeneous and density-stratified media.

Summary: Numerous experiments were carried out in a long and rather unique towing tank facility with various lifting surfaces moving at specified angles of attack in a homogeneous and a density-stratified medium. The characteristics of the resulting vortices, vortex rings, surface scars, striations, and ring disturbances have been evaluated in terms of the governing parameters. In addition a theoretical analysis has been carried out and a computer code has been developed to predict the characteristics of the surface disturbances. The results have shown excellent agreement with those obtained experimentally and led to the discovery of the circulation decay law.

Publications:

T. Sarpkaya, The Rise and Demise of Trailing Vortices in Homogeneous and Density-Stratified Media, Proceedings of the International Conference on Advanced Topics in Aerodynamics and Aeroacoustics, Springer-Verlag, 1983, pp. 1-3.

T. Sarpkaya, Trailing Vortices in Homogeneous and Density-Stratified Media, Journal of Fluid Mechanics, 136, (November 1983), pp. 85-109.

T. Sarpkaya and Turkmen, C., Effect of Core Size on the Rise and Demise of Trailing Vortices, NPS-69-82-010, December 1982.

T. Sarpkaya and D. O. Henderson, Surface Disturbances due to Trailing Vortices, Naval Postgraduate School Technical Report, NPS-69-84-004, March 1984.

T. Sarpkaya, Surface Signatures of Trailing Vortices, Journal of Fluid Mechanics, 1985 (in press).

T. Sarpkaya, Surface Signature of Trailing Vortices, Proc. of the International Conference on Vortical Flows in Aerodynamics, Aachen, Feb. 1985.

T. Sarpkaya, Trailing Vortex Wakes on the Free Surface, Proceedings of the 16th Symposium on Naval Hydrodynamics, UC Berkeley, July 1986, pp. 1-12.

T. Sarpkaya, and J. J. Daly, Effects of Ambient Turbulence and Stratification on the Demise of Trailing Vortices, NPS69-86-006, Naval Postgraduate School, Monterey, CA.

Theses directed:

William E. Gray, "Scars and Striations due to Trailing Vortices," Master's and Engineer's Thesis, March 1985.

Dwight O. Henderson, Jr., "Surface Disturbances due to Trailing Vortices," Master's and Engineer's Thesis, March 1984.

Kenneth G. Heffernan, "Trailing Vortex Attenuation Devices," Dual Master's Thesis, June 1985.

David S. Shikada, "Vortex Rings and Surface Signatures," Master's and Engineer's Thesis, September 1985.

John Joseph Daly, "Effects of Ambient Turbulence and Stratification on the Demise of Trailing Vortices," Master's and Engineer's Thesis, March 1986.

William D. Noble, "Characteristics of Vortices in Stratified Media," Master's Thesis, September 1986.

Title: Yaw and Current Effects on Hydrodynamic Resistance of Cylinders in Harmonic Flow

Investigator: T. Sarpkaya, Distinguished Professor of Mechanical Engineering

Sponsor: National Science Foundation

Objective: To carry out fundamental studies regarding the hydrodynamic resistance of smooth and rough cylinders immersed in time-dependent flows.

Summary: Extensive analysis and experiments have been carried out to understand the fundamental mechanisms governing the hydrodynamic resistance in unsteady flows. Analysis is based on the use of the discrete vortex model and the representation of the body by distributed singularities. Experiments have been carried out in a unique U-shaped oscillating flow tunnel. The impulsively-started flow experiments were carried out in a 25 feet high vertical water tunnel. The results have been reported in various publications.

Publications: T. Sarpkaya and John R. Wilson, Pressure Distribution on Smooth and Rough Cylinders in Harmonic Flow, Proc. of the Ocean Structural Dynamics Symposium '84, Oregon State Univ., Oregon, 1984, pp. 341-355.

T. Sarpkaya and M. Storm, In-Line Force on a Cylinder Translating in Oscillatory Flow, Applied Ocean Research, Vol. 7, No. 4, Oct. 1985, pp. 178-190.

T. Sarpkaya, Force on a Circular Cylinder in Viscous Oscillatory Flow at Low Keulegan-Carpenter Numbers, Journal of Fluid Mechanics, 1985 (in press).

T. Sarpkaya and C. J. Ihrig, Impulsively-Started Flow About Rectangular Prisms: Experiments and Discrete Vortex Analysis, Journal of Fluids Engineering of ASME, 1985 (in press).

T. Sarpkaya, Past Progress and Outstanding Problems in Time-Dependent Flows About Ocean Structures, Proc. of the International Conference on Separated Flow About Marine Structures, Norwegian Inst. of Tech., Trondheim, Norway, Vol. 1, pp. 1-36.

T. Sarpkaya, Analysis of Separated Time-Dependent Flow About Bluff Bodies through the use of the Discrete Vortex Model, First International Conf., on High Reynolds Number Flow Computation, Nobeyama, Japan, Springer-Verlag, 1985.

T. Sarpkaya and J. C. Heideman, Hydrodynamic Forces on Dense Arrays of Cylinders, Offshore Technology Conference, Proceedings, Paper No. OTC-5008, Vol. 1, pp. 421-428, May 1985.

Janikowsky, L. C. and T. Sarpkaya, Optimized Discrete Singularity Representation of Axisymmetric Bodies, AIAA Paper No. AIAA-85-0284, January 1985.

T. Sarpkaya, A Critical Assessment of the Methods of Analysis of Offshore Structures, Proceedings of the International Conference on Wave Flows in Hydrodynamics, Hannover, W. Germany, Springer-Verlag, June 1985.

T. Sarpkaya, On Fluid Loading of Offshore Structures: After Ten Years of Basic and Applied Research, ASME Energy Technology Conference (Proceedings of), February 1985, New Orleans.

T. Sarpkaya and M. Storm, In-line Force on a Cylinder in Oscillatory Flow, Applied Ocean Research, Vol. 7, No. 4, October 1985, pp. 178-190.

T. Sarpkaya, On Fluid Loading of Offshore Structures, Proceedings of the Offshore Operations Symposium, ASME, Vol. PD-1, February 1986, pp. 153-164.

T. Sarpkaya, Recent Developments in Separated Time-Dependent Flows, Advancements in Aerodynamics, Vol. 1, June 1986, pp. 516-522.

T. Sarpkaya, Force on a Circular Cylinder in Viscous Oscillatory Flow at Low Keulegan-Carpenter Numbers, Journal of Fluid Mechanics, Vol. 165, April 1986, pp. 61-71.

T. Sarpkaya and C. J. Ihrig, Impulsively-started Flow About Rectangular Prisms: Experiments and Discrete Vortex Analysis, Journal of Fluids Engineering, ASME, Vol. 108, March 1986, pp. 47-54.

T. Sarpkaya, Oscillating Flow over Bluff Bodies in a U-Shaped Water Tunnel, AGARD-CPP-413, Vol. 1, October 1986, pp. 6.1-6.15.



T. Sarpkaya, In-Line and Transverse Forces on Smooth and Rough Cylinders in Oscillatory Flow at High Reynolds Numbers, NPS69-86-003, July 1986.

Theses directed:

Michael Storm, "Wave and Current Induced Forces on Cylinders," Master's and Engineer's Thesis, June 1984.

Nathan Yuen, "Oscillatory Flow About Cylinders at Low Keulegan-Carpenter Numbers," Master's and Engineer's Thesis, September 1985.

James O'Keefe, "Time-Dependent Flow About Sharp-Edged Bodies at High Reynolds Numbers," Master's and Engineer's Thesis, March 1986.

Samir Mostafa, "Hydroelastic Response of Smooth and Rough Cylinders with Two-Degrees of Freedom," Ph. D. Candidate (to Complete in June 1987).

Title: Analytical and Experimental Investigations of the Damping Characteristics of the Bolted and Welded Structural Connections for Plates and Shells

Investigator: Y.S. Shin, Associate Professor of Mechanical Engineering

Sponsor: David W. Taylor Naval Ship R&D Center

Objective: To characterize the bolted and welded structural connections to enhance the damping, and to evaluate acoustic benefits of bolted connection for plates and shells.

Summary: The design of the structural connections is important from the standpoint of reducing system vibration amplitudes or enhancing joint damping capacity. The state-of-the art review was performed to evaluate the existing methods and their limitations, and also to identify the base technology needs. The generic experimental models were developed, analyzed and constructed. The modal analysis of the generic model was performed to insure that the joint experiences the shear type of modes.

The plate-to-shell shear type connections are incorporated in the test model. The test frequency range is DC to 5,000 Hz in both air and water. The damping characteristics of joint are to be evaluated including transmissibility of joint.

Publications: Y.S. Shin, K.S. Kim, and J.C. Iverson, "Analytical and Experimental Investigations of the Damping Characteristics of Bolted and Welded Structural Connections for Plates and Shells," (Progress Report), NPS 69-86-11, September 1986.

Thesis Directed: J.C. Iverson, LT, United States Navy, Engineer's Degree September 1987 (expected).

Title: Conceptual Studies on Dynamic Analysis of Coupled Large Reflector and Boom Interaction in Navy Remote Ocean Sensing System (N-ROSS) Satellite

Investigator: Y.S. Shin, Associate Professor of Mechanical Engineering

Sponsor: Space and Naval Warfare Systems Command

Summary: The coupled large reflector and boom in N-ROSS satellite have low mass density, and are highly flexible, resulting in many low-frequency modes of structural vibration disturbing the dynamic stability of the system. The possible problem areas are identified through the literature review. The dynamic model of LFMR (Low Frequency Microwave Radiometer) has been developed to perform parametric studies on point control, thermal effect, joint flexibility and joint damping.

Theses Directed: R.S. Laufenburg, LT, United States Navy, Master's Degree candidate, March 1987 (expected).  
C.S. Kang, MAJ, Engineer's Degree candidate, March 1987 (expected).  
N.F. Heffernan, LT, United States Navy, Engineer's Degree candidate, June 1987 (expected).

Title: Strain Dependent Non-Linear Damping Material Behavior

Investigator: Y.S. Shin, Associate Professor of Mechanical Engineering

Objective: To determine strain-dependent non-linear damping behavior of selected high damping materials.

Summary: The material selected from a variety of known quiet metal alloys is a high damping manganese-copper alloy called Sonoston. The measurement techniques employ cantilevered flat beam specimens in bending and cylindrical specimens in torsion. The specimens were subjected to three different heat and aging treatments. Pure random and sinusoidal sweep excitations are used as an excitation source in the frequency range of 10 to 500 Hz. The half power point method is mainly used to measure damping because the spectrum showed distinct peaks without modal coupling. The results of the investigation are presented graphically as damping factor vs. resonant frequency, damping factor vs. strain, damping factor vs. input acceleration, strain vs. frequency, strain vs. input acceleration, and input acceleration vs. resonant frequency.

Publication: D.D. Dew, LCDR, United States Navy, "Strain-Dependent Damping Characteristics of a High Damping Manganese-Copper Alloy," NPS 69-86-007, Joint Thesis-Technical Report, September 1986.

Conference Presentation: Y.S. Shin, D.D. Dew, and K.S. Kim, "Strain-Dependent Non-Linear Damping Characteristics of High Damping Alloys," accepted to present at ASME Vibration Conference, Boston, MA, September 27-30 1987.

Thesis Directed: D.D. Dew, LCDR, United States Navy, "Strain-Dependent Damping Characteristics of a High Damping Manganese-Copper Alloy," Engineer's Thesis, September 1986.

Title: Underwater Shock Response of Submerged Structure

Investigator: Y.S. Shin, Associate Professor of Mechanical Engineering

Sponsor: Defense Nuclear Agency

Objective: (1) To look into the insight of the stiffener tripping characteristics and its effect on gross shell responses by underwater explosion and hydrostatic testings, and (2) to evaluate the submarine-installed equipment response to underwater explosion.

Summary: Experimental investigations into the responses of air-backed, externally-stiffened flat plates have been studied. A series of four UNDEX tests were performed over the last two years. The design modifications were made on the boundary conditions of stiffeners. The excellent tripping in Z-type, narrow and wide flange T-type stiffened plates were observed in both hydrostatic and UNDEX testings.

The ring-stiffened circular cylindrical shell containing the simulated internal equipment is submerged in an infinite expanse of water and is subjected to (1) end-on and, (2) side-on loading from an underwater shock wave. A parametric study was performed (1) to determine how heavy the internal equipment must be before it affects the motion of the shell, and (2) to evaluate the dynamic amplification of the response of the internal equipment which should occur when the motion of the shell has a frequency about equal to a fixed-base frequency of the internal frequency.

Publications: M.S. Welch, and Y.S. Shin, "Numerical Analysis of the Underwater Shock-Induced Responses of Submarine Installed Equipment," Shock and Vibration Bulletin 55, Supplement 3, pp.1-12, March 1986.

J.H. Strandquist, III, and Y.S. Shin, "Investigation into the Effects of Using Detonating Cord to Remove a Conventional Propeller from a Water Borne Surface Ship," Shock and Vibration Bulletin 56, Part I, pp. 121-133, August 1986.

Conference Presentation: J.H. Strandquist, III, and, Y.S. Shin, "Investigation into the Effects of Using Detonating Cord to Remove a Conventional Propeller from a Water Borne Surface

Ship," 56th Shock and Vibration Symposium, Monterey, California, October 22-24 1985.

Theses Directed:

G.F. DeConto, LT, United States Navy, "Parametric Study of Elastic Response of Submarine-Installed Equipment Subjected to UNDEX Side-on Loading," Master's Thesis, March 1986.

S.A. Weinhardt, LCDR, United States Navy, "A Parametric Study of Elastic Responses of Submarine-Installed Equipment Subjected to UNDEX End-on Loading," Master's Thesis, March 1986.

H.L. Budweg, LT, United States Navy, "An Investigation into the Tripping Behavior of Longitudinally T-Stiffened Rectangular Plates Loaded Statically and Impulsively," Master's Thesis, March 1986.

Title: Firefighter Robot Prototype Development

Investigator: D. L. Smith, Associate Professor of Mechanical Engineering

Sponsor: Naval Surface Weapons Center

Objective: To conduct preliminary investigations for an advanced firefighter robot. To identify research issues and make recommendations for development.

Summary: A test bed for robotic drilling has been assembled. Drilling forces and moments have been estimated preparatory to a manipulator mechanism design effort. A candidate servovalve for a low power application such as this has been evaluated.

Theses Directed: L. D. Burrill, "A Feasibility Investigation for Optimal Robotic Control," Master's Thesis, September 1986.

R. L. Yobs, "Manipulator Load Forces in a Robotic Firefighter," Master's Thesis, March 1986.

Title: Optimal Control of Robotic Mechanisms

Investigator: D. L. Smith, Associate Professor of Mechanical Engineering

Sponsor: NPS Foundation Research Program

Objective: To investigate the application of optimal control theory to the control of robotic mechanisms.

Summary: Several key research issues surrounding modelling and optimal control have been identified.

The need for a non-singular nonlinear mechanism simulation model has been identified and an approach to avoiding singularity has been developed. Several schemes for linearizing the model for controller design have been investigated. Servovalve selection for the NPS low performance robot has been evaluated. Control implementation structure and approach has been selected.

Theses Directed:

W. F. McCarthy, "Simulation of High Speed Motion of Rigid, Revolute Mechanisms," Master's Thesis, December 1985.

D. R. Lewis, "Modelling of a Low Performance Rigid, Revolute Robot Arm," Master's Thesis, December 1985.

K. Mohammed, "Non-Singular Modelling of Rigid Manipulator," Master's Thesis, December 1986 (expected).

J. Harris, "A Heirarchical Optimal Controller for Rigid Robotic Manipulators," Engineer's Thesis, June 1987 (expected).



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A SUMMARY OF THE NAVAL POSTGRADUATE SCHOOL RESEARCH  
PROGRAM(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA  
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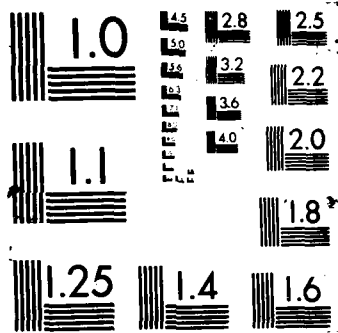
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## INVESTIGATOR INDEX

Abenheim, D. -----	131, 139
Ackley, S.F. -----	321
Amos, J.W. -----	132, 136
Andrus, A. -----	99, 100, 101
Ansari, S.L. -----	58-60
Armijo, L.A. -----	86
Baker, G.S. -----	13-14
Baker, S.R. -----	149-50, 183-86
Ball, R.E. -----	283
Barr, D.R. -----	102
Batteen, M.L. -----	319-320
Biblarz, O. -----	284, 295
Blackburn, L.E. -----	276
Bodapati, S. -----	285, 286
Boger, D.C. -----	49, 57
Bonsper, D. -----	276
Bourke, R.H. -----	321, 322-23, 324, 325, 326 331
Boyle, J.S. -----	221-22, 224-25, 264
Boynton, R.E. -----	273
Bradley, G.H. -----	103-4
Brown, G.G. -----	103-4, 105
Brubaker, E.R. -----	274, 275
Buchanan, P.G. -----	133
Buf, T.X. -----	50-51
Bukofzer, D.C. -----	197
Buskirk, F.R. -----	151, 152
Cantin, G. -----	359
Chang, C.-P. -----	221-22, 223, 224-25, 226-28
Chang, L.-W. -----	360
Clark, T.F. -----	331

Cooper, A.W. -----	153, 154, 155-56, 157-58, 211
Coppens, A.B. -----	189-90
Cotton, M.L. -----	13-14, 206
Cristi, R. -----	198
Crittenden, E.C. -----	153, 155-56, 157-58
Dafley, B.D. -----	136, 137, 138
Danielson, D.A. -----	31-32
Davidson, K.L. -----	174, 175-76, 229-30, 231, 232, 233-34, 235-36, 237, 238-39, 240-41, 264
Davis, D. -----	5, 6, 7, 8-9
Dawson, J.E. -----	276
Demurjian, S.A. -----	10-12
Devito, C. -----	33
Doik, D.R. -----	52
Dunlap, C. -----	324, 325, 326, 327-28, 329-30, 331
Durkee, P.A. -----	242, 243, 244, 245, 265
Eagle, J.N. -----	99, 106, 107
Eitelberg, M.J. -----	53-54, 55-56
Eldor, H. -----	106, 107
Elsberry, R.L. -----	246, 247, 248, 249, 250-52
Esary, J.D. -----	108
Euske, K.J. -----	57, 58-60
Forney, R.L. -----	134
Forrest, R.N. -----	99, 106, 107
Franke, R. -----	34
Fredricksen, H. -----	35, 36
Fuhs, A.E. -----	287, 288, 289, 290-91
Garrett, S.L. -----	159, 160, 161-62, 183-86, 187-88
Garrity, P.J. -----	136, 138
Garwood, R.W. -----	332, 333-34, 335
Gaver, D.P. -----	109, 110-11

Gerba, A. -----	199, 207
Glass, N.E. -----	163-64
Goldstein, A.A. -----	39-40, 41
Haderlie, E.C. -----	327-28
Hale, R.A. -----	256-57, 258
Haney, R.L. -----	253-54, 261
Hank, V.D. -----	263
Harrison, D.E. -----	165-66
Hartman, M. -----	359
Healey, J.V. -----	292, 293-94
Henderson, D.R. -----	61, 62, 63
Herbig, K.L. -----	135
Hsiao, D.K. -----	10-12
Huber, H. -----	7
Ingber, L. -----	167, 168-69, 170
Jacobs, P.A. -----	109, 110-11
Jauregui, S. -----	200
Jayachandran, T. -----	37, 112
Jones, C.R. -----	64, 66
Joshi, Y. -----	361, 362
Jung, G.H. -----	325
Kaestner, R. -----	84
Kartchner, K.M. -----	136, 137, 138
Kelleher, M.D. -----	363, 364, 365, 369
Kirk, D.E. -----	201
Kocher, K. -----	88
Kodres, U.R. -----	13-14, 15, 206
Ku, K. -----	189-90
Lamm, D.V. -----	65
LaPatra, J. -----	66
Larson, H.J. -----	112
Lee, C.-H. -----	201, 202, 203
Lee, H.-M. -----	204-5

Leitner, A. -----	300-2
Lentz, W.J. -----	155-56
Lewis, P.A.W. -----	113-14
Liao, S.S. -----	49, 75
Ligrani, P.M. -----	365, 366-67, 368, 369, 370
Liou, C.-S. -----	248
Lyons, N. -----	66
MacLennan, B.J. -----	16-17
Magnus, R.H. -----	132, 136
Marto, P.J. -----	371-72, 373
Mathur, A. -----	309
McCaffery, J. -----	67-68
McMasters, A.W. -----	69, 121
McNelley, T.R. -----	374, 375-76
Mehay, S.L. -----	70
Mendez, R. -----	36
Mensh, D.R. -----	153
Mikkelson, T. -----	231
Milch, P.R. -----	115-16
Miller, J.A. -----	295, 296
Milne, E.A. -----	153, 154, 157-58, 171
Moore, T.P. -----	69, 71-72
Morgan, M.A. -----	171
Moses, O.D. -----	73, 74, 75
Mountain, D.G. -----	336
Moyle, I. -----	306
Myers, G. -----	200
Neighbours, J.R. -----	151, 152
Neta, B. -----	36, 38
Netzer, D.W. -----	297-99, 300-2, 303-5
Neuhoff, F. -----	307, 308
Newton, R.E. -----	266
Nichols, R.H. -----	172

Nunn, R.H. -----	364
Nuss, W.A. -----	248
Owen, G. -----	36
Panholzer, R. -----	206
Paquette, R.G. -----	322-23
Parker, P.J. -----	136, 137, 138
Parry, S.H. -----	117-18
Peng, M.S. -----	260, 267
Perkins, J. -----	377-78
Pirog, R.L. -----	276
Platzer, M.F. -----	285, 286
Poock, G.K. -----	119
Powers, J.P. -----	160, 303-5, 327-28
Preisendorfer, R.W. -----	256-57
Pucci, P.F. -----	379, 380
Ramp, S.R. -----	336
Read, R.R. -----	120
Renard, R.J. -----	255, 256-57, 258, 259
Rennick, M.A. -----	260, 261, 267
Richards, F.R. -----	121
Roberts, N.C. -----	76-78
Rockower, E.B. -----	122, 123
Rodeback, G.W. -----	157-58
Rose, J.W. -----	371-72
Rosenthal, R.E. -----	105, 124
Russak, I.B. -----	36, 39-40, 41
Salinas, D. -----	381
San Miguel, J.G. -----	79
Sarpkaya, T. -----	382-83, 284-86
Schacher, G.E. -----	173, 174, 175-76, 229-30, 233-34, 235-36, 238-39, 240-41
Schlitz, R.J. -----	336-37
Schneidewind, N.F. -----	80, 81, 82

Schoenstadt, A.L. -----	117-18, 266
Semtner, A.J. -----	337
Shaw, W.J. -----	233-34, 262, 263, 264
Shin, Y.S. -----	387, 388, 389, 390-91
Shreeve, R.P. -----	306, 307, 308, 309, 310
Shudde, R. -----	99
Sivasankaran, T.R. -----	83
Smith, D.C. -----	338, 339
Smith, D.L. -----	392, 393
Solnick, L.M. -----	84, 85
Sovereign, M. -----	167, 170
Stanton, T.P. -----	340-41
Sticht, T.G. -----	86
Stolfi, R.S. -----	139
Suchan, J.E. -----	87
Taylor, J.G. -----	125, 126
Thomas, G. -----	70, 88, 89-90
Thomson, D.W. -----	255
Thornton, E.B. -----	340-41, 342, 343-44, 345-47, 348, 349
Titus, H.A. -----	206, 207, 208, 209, 210, 211, 212
Tritten, J.J. -----	140
Tucker, S.P. -----	342
Vaughan, L.E. -----	273, 276
Von Pagenhardt, R. -----	276
Von Schwind, J.J. -----	350-51
Walker, G.J. -----	306, 310
Wall, K.D. -----	276
Walters, D.L. -----	177, 178, 179, 180, 264
Wanniarachchi, A.S. -----	371-72, 373
Ward, E.N. -----	157-58
Wash, C.H. -----	221-22, 244, 246, 248, 265
Wayman, J. -----	36



Weitzman, R.A. -----	86, 91, 92
Whipple, D.R. -----	62
Williams, R.T. -----	226-28, 259, 260, 266, 267
Wilson, O.B. -----	181-82, 183-86, 187-88, 189-90
Wood, R.K. -----	105, 115-16
Wozencraft, J. -----	66
Wu, C.-S. -----	343-44
Wu, C.T. -----	18-20
Wu, E.M. -----	311, 312, 313
Yang, K.T. -----	363
Yee, J. -----	66
Yoon, S.W. -----	189-90
Yost, D.S. -----	141
Ziomek, L.J. -----	213
Zyda, M.J. -----	21-22, 23-25

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