(2)

NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

NPS-012-88-003

A SUMMARY OF THE NAVAL POSTGRADUATE SCHOOL RESEARCH PROGRAM

REPORT FOR THE PERIOD

OCT 1986 TO SEPT 1987

Approved For Public Release
Distribution Unlimited

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NPS-012-88-003	5 MONITORING ORGANIZATION REPORT NUMBER(S) NPS-012-88-003
6a. NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b. OFFICE SYMBOL (If applicable) RAO	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Monterey, CA 93943	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
A SUMMARY OF THE NAVAL POSTGRADUATE SCHOOL RESEARCH PROGRAM

12. PERSONAL AUTHOR(S)
Faculty of the Naval Postgraduate School

13a. TYPE OF REPORT	13b TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Summary	FROM 10/1/86 TO 9/30/87	88 Aug 30	379

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report contains 198 summaries of research projects which were carried out under funding to the Naval Postgraduate School Research Program. This research was conducted under the areas of Computer Science, Mathematics, Administrative Sciences, Operations Research, National Security Affairs, Physics, Electrical and Computer Engineering, Meteorology, Aeronautics and Astronautics, Oceanography, and Mechanical Engineering. The Table of Contents identifies specific research topics.

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Dr. G.T. Howard	22b TELEPHONE (Include Area Code) (408) 646-2098 22c OFFICE SYMBOL RAO/012

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

☆ U.S. Government Printing Office: 1988—606-243

INTRODUCTION

Faculty research activities at the Naval Postgraduate School during the fiscal year 1987 are summarized in this volume. Most projects also benefit from student contributions from research leading to a thesis in pursuit of an advanced degree.

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 NPS directly supports the educational programs and contributes to the solution of real Navy and other DoD problems.

The Naval Postgraduate School provides a unique interface between academic institutions and the U.S. Navy. 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 institutional requirement to educate officers in areas of Navy interest and to support the educational programs with relevant research.

The Naval Postgraduate School wishes to acknowledge the efforts of Ms. Rachelle Parks for her efforts in preparation of this volume.

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

NAVAL POSTGRADUATE SCHOOL
Monterey, California

PROCEDURES FOR REQUESTING NAVAL POSTGRADUATE SCHOOL
TECHNICAL REPORTS AND THESES

Copies of publications with unlimited distribution may be obtained from either of the following agencies depending upon the particular circumstances:

Individuals affiliated with a research and development activity within the U.S. Government or its associated contractors, subcontractors, or grantees, under current U.S. Government contract, order from:

DEFENSE TECHNICAL INFORMATION CENTER
Cameron Station
Alexandria, VA 22314-5000

Organizations or individuals who do not fall within the above categories may order from:

NATIONAL TECHNICAL INFORMATION SERVICE
U.S. Department of Commerce
Springfield, VA 22161

A given document may be obtained by submitting a bibliographic citation including: (1) author, (2) title, (3) publication date, and (4) the Naval Postgraduate School Report Number or reference to the document as a Naval Postgraduate School thesis.

General inquiries concerning faculty and student research at the Naval Postgraduate School should be addressed to:

Superintendent
Naval Postgraduate School
Code 012, Research Administration Office
Monterey, CA 93943

TABLE OF CONTENTS

DEPARTMENT OF MECHANICAL ENGINEERING

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 department research efforts have allowed the development of extensive research facilities that feature microcomputers, minicomputers, computer graphics devices, image and signal processing equipment, workstations, and database computers.

COMPUTER SOFTWARE DESIGN

Professor Gordon Bradley and his students have continued their research in cognitive sciences and reusable software. Their objective is to apply cognitive sciences and software engineering principles to software, particularly the reusable programs, to produce better designs. They have also done research on executable modeling languages for mathematical programming using a type calculus to determine if a model is well formed.

COMPUTER SECURITY

Professor D. K. Hsiao performed research in the area of coded algorithms and models to partition the database of classified information allowing users of different clearances to access data suitable for their clearances without accessing information restricted to other users.

MULTI-LINGUAL DATABASE SYSTEM

Professors David K. Hsiao, S. A. Demurjian, and their thesis students studied the problem of supporting multiple database models in a single database management system. The goal of this project is to verify whether the multi-lingual system can effectively characterize the many data models, data languages, and processes.

MULTI-MEDIA DATABASE SYSTEM

Professor C. T. Wu continued his investigation of an information system to support multi-media databases. A data model prototype representing three phases of manufacturing was used to demonstrate true integration of manufacturing phases. A visual user interface model was improved and expanded.

MULTI-MICROCOMPUTER ARCHITECTURE

Professor U. R. Kodres and his thesis students expanded their investigation of single chip computers to build a larger multi-computer network, concentrating on problems of producing effective run-time systems for real-time applications, efficient run-time packages for Ada language systems for non-tightly connected architectures of multitransputer sytems, and extending tightly connected monitor systems of tightly connected architectures to loosely connected architectures of transputers.

SOFTWARE PORTABILITY

Professor D. L. Davis and thesis students worked on the problem of software portability focusing on developing functional specifications of computing system components and their timing properties using as a theoretical base the theory of Petri nets. An abstract processor developed in an earlier stage of this research to allow programs written for it the same portabilitly as high level language programs was used to implement improvements in timing of the instruction fetch cycle and both parallel and sequential memory accessing.

SYSTEM ARCHITECTURE FOR REAL-TIME GRAPHICS

Professor M. J. Zyda and his students examined the architecture necessary to support high-performance computer graphics interactions betweeen multiple workstations running the Unix operating system. Software usable in both the Berkeley 4.3 Unix and ATT System V.3 Unix was developed and tested in the graphics and video lab. A C2 workstation prototype was developed as a testbed for this software under the Silicon Graphics IRIS window manager.

ROBOTICS

Professor R. B. McGhee and his students developed software for vision and path planning for the Adaptive Suspension Vehicle (ASV), a large hexapod walking machine and one of the most advanced and complex robotic vehicles in existence today, developed at Ohio State University under a DARPA contract. In related work with the ME and ECE departments they are applying ASV control technology to a small autonomous undersea vehicle (AUV) currently under construction at NPS. Profs. McGhee, Rowe, and Zyda and their students are developing a Mobility Expert System for USATEC at Ft. Ord. This expert system will be valuable in mission and route planning for both manned and unmanned vehicles. Eight Lisp machines and five high-perfomance graphics workstations are being used to perform all the above research.

SOFTWARE ENGINEERING

Prof. V. Berzins developed a theory of combining software systems modifications that preserves content correctness with specific applications to software maintenance and evolution in response to DOD/DON requirement changes. Professor LuQi and her students worked on the theoretical foundation for translating a nonprocedural and specific language into Ada. The project established the connection between dataflow diagrams and imperative programming languages and established the feasability of treating real-time constraints with automatic linking to an executable model. This contributed to DOD/DON goals of applying Ada to all tactical embedded systems.

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

Investigator: D.L. Davis, Associate Professor of Computer Science

Sponsor: Missile Software Branch, Naval Weapons Center

Objective: This research is focused on designing and acquiring components for a CASE (Computer Aided Software Engineering) environment appropriate to the development of Ada software for embedded systems. In addition, metric tools for the evaluation of embedded software are being developed to meet the special needs of the Missile Software Branch at China Lake.

Summary: With the introduction of more and more digital computers (microprocessors) into weapons, weapons 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. These 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 identify and develop tools and methods appropriate to the need of embedded software development. The current research has focused on developing software metric tools and a requirements specification for a CASE system suited to the development of embedded software. The software metric tool ADAMEASURE, developed by NPS students under this project, is now being used by NWC China Lake in the evaluation of Ada software developed under contract to NWC. It can be used to analyze Ada programs with both the Halstead and Kafura metrics to determine program quality. In other works at NWC, NPS thesis students are working with Petri nets to analyze the safety properties of mission critical software designs being developed at NWC.

Theses Directed: K. Fairbanks and J. Nieder, "ADAMEASURE: An Ada Software Metric," Master's Thesis, December 1986.

P. Herzig, LCDR USN, "ADAMEASURE II: An Ada Software Metric Tool," Master's Thesis, June 1987.

Theses Directed: (cont.)

W. Frey, LCDR USN, "Ada Computer Aided Software Engineering Environment Study for the Missile Software Division, Naval Weapons Center, China Lake," Master's Thesis, June 1987.

A. Keough, LT USN, "TERMIO: An Ada Standard Terminal Interface Design," Master's Thesis, June 1987.

D. Hayward, "An Analysis of Software Safety Using Petri Nets," Master's Thesis, December 1987.

Title: Hierarchical Design Systems

Investigator: D.L. Davis, Associate Professor of Computer Science

Sponsor: Naval Ocean Systems Center

Objective: The problem of finding ways to improve the reusability and portability of system components through high level software, is an important and pervasive one. The objective of the current work is to establish a formal approach to this problem by developing a rigorous foundation for the specification of resource interfaces. Such interfaces can be used to describe the resource reuqirements of interface independently of the interface implementation, thus providing for portability, and reusability of the system above the interface.

Summary: A formal approach to the problems of software protability and reusability has, in recent years, been recognized as the approach that holds the best promise for substantive progress. The objective of this project is the development of a practical methodology with rigorous foundation for specifying computing system resources independently of implementation. The methodology being developed makes no distinction between components that are conventionally implemented in hardware and software. Thus system requirements specified with this methodology are described abstractly, and different implementations, using different technologies, could meet the requirements of the specification. Also the methodology is not limited to a particular level of abstraction. It can be used equally to describe primitive hardware components, or linguistic features of a high level programming language. Thus this project has taken a different perspective from similar efforts, such as hardware description languages, or software specification languages.

Work to date on this project has focused on developing functional specifications of a variety of computing system components, as a test of the practical side of the methodology. In addition, implementations based on formal specifications have also been developed to test the practical use of the methodology. More recently, research into the specification of the timing properties of system components has been considered as an extension of the specification of functional properties. The theoretical foundation for

Summary: (cont.)

this extension is the theory of Petri nets, and so (cont.) far, the effort appears promising. Most of the practical experiments have been done with the specifications of an abstract processor, and with the new timing extensions, we have been able to specify the relative timing of the instruction fetch cycle and both parallel and sequential memory accessing properties.

In another part of the same work, we are exploring the problems of automating the system specification process, particularly what means can be developed for allowing the user to ask the specification system about properties that should be inferred from the properties that he has given to a component. There are serious theoretical limitations here, since such issues are similar to the problems of automatic theorem proving.

Publications:

D. L. Davis, "Interfacing and Integrating Hardware and Software Design Systems," Proceedings of the NATO AGARD Symposium on Design, Development and Testing of Complex Avionics Systems, Las Vegas, NV May 1987.

D. L. Davis, "A Summary of Research into Resource Abstraction at NPS," NPS Technical Report forthcoming in 1988.

Title:	Architectural Issues of SEATACS
Investigators:	David K. Hsiao, Professor of Computer Science; Steven A. Demurjian, Research Instructor of Computer Science
Sponsor:	Naval Ocean Systems Center
Objectives:	SEATACS is a software engineering environment for naval tactical computer systems. Like any environment, it must provide data and tools basic for each of ten phases of tactical computer software development. These phases include specification, design, implementation, testing, maintenance, integration, and management of tactical software for naval weapon systems. It is believed that to support SEATACS we need a multilingual and multimodal database system for the management of software engineering tools and data in a centralized environment with distributed hardware and applications. The experimental Multilingual and Multimodal Database System at NPS is to serve as a testbed for each investigation.
Publications:	S. A. Demurjian and D. K. Hsiao, "The Multilingual Database System," Proceedings of the 3rd International Conference on Data Engineering, IEEE Computer Society, (Feb. 1987), pp. 44-53. D. K. Hsiao, "Database Systems as Controllers, Managers, and Linguists - A Study of the Relationship of Database and Operating Systems," Proceedings of the 3rd International Conference on Data Engineering, IEEE Computer Society Press, (Feb. 1987), pp. 26-27.
Conference Presentation:	D. K. Hsiao, "Database Systems as Controllers, Managers, and Linguists," IEEE Data Engineering Conference, Los Angeles, February 3-5, 1987
Thesis Directed:	H. Coker, Jr., "Accessing a Functional Database via CODASYL - DML Transactions," Master's Thesis, June 1987.

Title:	Database Computers for Effective Control and Efficient Security Processing
Investigator:	D. K. Hsiao, Professor of Computer Science
Sponsor:	National Security Computer Center and Naval Security Group Command
Objective:	To propose algorithms and models in codes to partition the database of classified information so that users of different clearances can access data which are cleared for their access without passing through data which are not cleared for their access. For this type of access the efficiency issues in terms of novel database computer architecture and database-system general organization are to be examined.
Publication:	S. A. Demurjian, D. K. Hsiao, and R. G. Marshall, Design Analysis and Performance Evaluation Methodologies for Database Computers, Prentice-Hall, June 1987.
Conference Presentation:	S. A. Demurjian, D. K. Hsiao "Database Security," The Computer Security Curricula Workshop, sponsored by NSCC, June 8-12, 1987.

Title: The Multilingual Database System Support for Software Engineering Environments

Investigators: David K. Hsiao, Professor of Computer Science; Steven A. Demurjian, Research Instructor

Sponsor: Naval Air Development Center

Objectives: NADC has a large systems engineeering environment known as FASP. It was believed that the multilingual database system of NPS may provide many data models and data languages to the engineering of software modules and systems of naval air-to-air and air-to-surface weapons. Software engineering activities are considered as database-driven activities where for individual software development phases data models characterize the tool sets and the data languages control the tooling and engineering processes. It is the aim of this research to verify whether the multilingual database system can characterize the tool sets and processes effectively.

Publications: S. A. Demurjian and D. K. Hsiao, "Towards a Better Understanding of Data Models through the Multilingual Database Systems," Naval Postgraduate School Technical Report, NPS52-87-018, May 1987, (Accepted with revisions by IEEE Transactions in Software Engineering)

H. Coker, S. A. Demurjian, D. K. Hsiao, B. Rodeck, and J. Zawis, "The Multi-Model Database System," Naval Postgraduate School Technical Report, NPS52-87-026, June 1987.

Conference Presentation: D. K. Hsiao, "The Multilingual and Multi- Modal Database Systems," IFIP WG2.6 (Database) Meeting, London.

Thesis Directed: S. A. Demurjian, "The Multilingual Database System - A Paradigm and Test-Bed for the Investigation of Data-Model Transformations, Data-Language Translations, and Data-Model Semantics," Doctoral Thesis, January 1987 (This thesis work was supported by NADC and other Navy sponsors, conducted at NPS, and accepted by the Ohio State University).

Title: Real-Time Database Computers

Investigator: David K. Hsiao, Professor of Computer Science

Sponsor: Naval Ocean Systems Center

Objectives: Real-time database computers have applications in surface-to air and surface-to-surface weapons systems. Real-time database computers are characterized by the presence of large amounts of data and a number of databases. Furthermore, the computers are driven by the input data and stored data to meet the time constraints of a combat situation. Our focus, therefore, shall be on the design, analysis, and prototyping of real-time database computers, to be used as backend computers that deal with three sets of data, i. e., three types of databases:

(1) the well-identified, clearly-classified, properly-screened and highly-resolved data, i. e., input (target) data,

(2) the reference data consisting of locations, positions, types, and other data (not target data) of interest, and

(3) the operational data for the computation and generation of responses (known as the firing control data).

The first object of the development of a real-time database computer is a temporal data model. This may include the specification of the new data model for real-time data and the application of existing and the development of new methodologies to evaluate our modeled computer.

Publications: D. K. Hsiao, "The Impact of the Interconnecting Network on Parallel Database Computers," Naval Postgraduate School Technical Report NPS52-87-019, (May 1987); to appear in The Proceedings of the 5th International Workshop on Database Machines.

S. A. Demurjian, G. D. Fenton, D. K. Hsiao, and J. R. Vincent, "A Computer-aided Benchmarking System for Parallel and Expandable Database Computers," Naval Postgraduate School Technical Report NPS52-87-016, to appear in The Proceedings of 1987 Fall Orient Computer Conference.

Conference Presentation:	D.K. Hsiao, "Multibackend Database Computers, "Navy Database Colloquium, sponsored by NOSC and NSGC, June 15-16, 1987.
Thesis Directed:	F. E. Kelbe and D. Majors, "Benchmarking Preparation for and Aggregate and Sorting Retrievals in the Multibackend Database System," Master's Thesis, June, 1987.

Title: Synthesis of Multimedia Database Management System

Investigator: V.Y. Lum, Professor of Computer Science

Sponsor: Naval Ocean Systems Center

Objective: The objective of this project is the development of a multimedia database managemement system which can support various types of data such as text, graphics, image, voice, and signals.

Summary: In many military applications data comes in a variety of forms unlike the ones in the commercial environment. Current DBMS are not effective in dealing with them. Further, military applications have other requirements that are not the same as those in commercial applications. For example, a particular military application may not have a large number of transactions to be processed, yet the system may be pressed to respond because the situation may mean the difference between life and death in many cases.

Publication: V. Y. Lum, C. T. Wu, and D. K. Hsiao, "Integrating Advanced Techniques into Multimedia DBMS," NPS Technical Report forthcoming in 1988.

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 and other related fields.

Summary: Applicability of the proposed data model was explored by using it to model three major phases of manufacturing. It was shown that this data model can express the semantics involved in these phases naturally. The data model, therefore, provides a basis for achieving a true integration of various manufacturing phases. The study of user interface issues was extended, and we made a number of improvements on our initally proposed visual user interface. Also, the use of inference capability was studied, specifically the applicaion of logic in developing an intelligent database system.

Publications:

C. T. Wu, D. E. Madison and T. G. Wilbur, Jr., "A Data-Oriented Approach to Integrating Manufacturing Functions," Computers in Mechanical Engineering, forthcoming February, 1988.

C. T. Wu, "Toward a Fully-Computerized Database Maintenance for Non-Traditional Applications," Proceedings of the 1987 ACM-IEEE Computer Society Fall Joint Computer Conference, Dallas, TX, October 1987, pp. 469-474.

C. T. Wu, "GLAD: Graphics Languages for Database," Proceedings of the 11th International Computer Software and Applications Conference, Tokyo, Japan, October, 1987, pp. 164-170.

C. T. Wu, (Abstract with Sharon Crowder), "Visual Information Management System for an Effective Performance of Office Tasks," Proceedings of the Second International Conference on Human-Computer Interactions, Honolulu, HI August, 1987.

Publications: (cont.)

C. T. Wu and D. E. Madison, "An Integration in Computer Integrated Manufacturing,"Proceedings of the International Computer Engineering Design Conference, Boston, MA, August 1987, pp. 394-398.

C. T. Wu and D. E. Madison, "An Expert System Interface and Data Requirements for the Integrated Design and Manufacturing Process," Proceedings of the Third International Conference on Data Engineering, Los Angeles, CA, February, 1987 pp. 610-618.

C. T. Wu and D. E. Madison, "A Database Approach to Computer Integrated Manufacturing: Process Planning Using Group Technology," NPS Technical Report No. NPS52-87-036, August, 1987.

C. T. Wu and D. E. Madison, "A Database Approach to Computer Integrated Manufacturing: Scheduling and Shop Floor Layout, NPS Technical Report No. NPS52-87-047, November 1987.

C. T. Wu and D. E. Madison, "Toward Fully-Computerized Database Maintenance for Non-Traditional Applications," NPS Technical Report No. NPS52-87-031, July 1987.

C. T. Wu, "GLAD: Graphics Language for Database," NPS Technical Report No. NPS52-87-030, July 1987.

C. T. Wu, D. E. Madison, and T. G. Wilbur, Jr., "A Data-oriented Approach to Integrating Manufacturing Functions," NPS Technical Report No. NPS52-87-024, June 1987.

Conference Presentations:

C. T. Wu, "Towards a Fully-Computerized Database Maintenance for Non-traditional Applications," 1987 ACM-IEEE Fall Joint Computer Conference, Dallas TX, Oct. 1987.

C. T. Wu, "GLAD: Graphics Language for Database," 11th International Computer Software and Applications Conference, Tokyo, Japan, October 5-9, 1987.

C. T. Wu and D. E. Madison, "An Integration in Computer Integrated Manufacturing," The International Computer Engineering Design Conference, Boston, MA August, 1987.

Conference Presentations: (cont.)

C. T. Wu and D. E. Madison, "An Expert System Interface and Data Requirements for the Integrated Design and Manufacturing Process," Third International Conference on Data Engineering, Los Angeles, CA, February, 1987.

Theses Directed:

T. G. Wilbur, Jr., LCDR, USN, "Expert Database Support of the Integrated Manufacturing Process," Master's Thesis, December, 1986

J. P. Gorman, LCDR USN, "Towards a Solution to the Proper Integration of a Logic Programming System and a Large Knowledge Based Management System, December 1987." Master's Thesis, December 1987.

Title: An Architecture for Interactive Real-time Graphics Between Networked Workstations

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

Sponsor: Naval Ocean Systems Center

Objective: The primary goal of this research was to examine the architecture necessary to support high-performance computer graphics interactions between multiple workstations running the Unix operating system.

Summary: Software was developed for this work that opened communications sockets between IRIS workstations and Unix/Vax systems. This software was developed for both Berkeley 4.3 Unix and ATT System V.3 Unix. The software was tested by its use in a number of software systems developed in the Graphics and Video Laboratory. A C2 workstation prototype was developed on the IRIS as the testbed for this communications software. The C2 workstaion software was developed under the Silicon Graphics, Inc. IRIS Window Manager.

Publications: M. J. Zyda, "Workstation Graphics Capabilities for the 1990's and Beyond," Plus: The Total Computer Magazine, forthcoming in 1988.

J. M. Sando, LCDR, USN, T. S. Wetherald, LCDR, USN, and M. J. Zyda, "Using the Eikonix Digitizer Camera with the IRIS Graphics Workstation," Technical Report NPS52-87-038.

R. M. Adams, LCDR, USN and M. J. Zyda, "A Software Architecture for a Commander's Display System," Technical Report NPS52-87-009, April 1987.

Theses Directed: R. A. Adams, LCDR, USN, "A Software Architecture for a Commander's Display System," Master's Thesis, March 1987.

J. Manley, LT, USN, "A Unix-based, Multimedia Computer Conferencing System," Master's Thesis, December 1986.

C. Frank, LT, USN, "An Improved Software Architecture for the Commander's Display System," Master's Thesis, December 1987.

H.O. Mariscal, LT, Peruvian Navy, "A Font Editor in Support of Command and Control Symbology," Master's Thesis, December 1988.

Title: High-Performance Interactive Graphics for a Multinetwork Controller

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

Sponsor: Naval Ocean Systems Center

Objective: The primary goal of this project was to examine the computer graphics animation capabilities required to monitor the flow of information through a multinetwork controller and the user-interface necessary to support such animations. There were two major subgoals for this project. The first was to determine the type of computer graphics that best convey in as rapid a manner as possible the information flow and message routing through the multinetwork controller. The second subgoal was to propose a user-interface for the system that facilitated the use of the network monitoring animations produced.

Summary: A set of animations useful for the display of the flow of information in the multinetwork controller and various user interfaces were examined for the project. A system entitled "UNETGRAF" was produced under the Window Manager on the Silicon Graphics, Inc. IRIS workstation. Documentation for that system and the software for that system were delivered to NOSC at the end of the fiscal year.

Publications:

L. W. Griggs, Capt, USMC, R. A. Adams, Maj., USAF, and M. J. Zyda, "An Interactive Computer Graphics Network Monitor for a Tactical Communications Network," Technical Report NPS52-87-035, August 1987.

T. J. Beda, LCDR, USN, C. T. Wu, and M. J. Zyda, "An Improved User Interface for an Interactive Figure Illustrator," Technical Report NPS52-87-025. June 1987.

L. W. Griggs, Capt, USMC and M. J. Zyda, "Real-time Graphics in Support of the Unified Networking Technology Project: A Progress Report," Technical Report NPS52-87-017, May 1987.

Theses Directed:

T. J. Beda, LCDR, USN, "An Improved Interface for a Technical Figure Illustrator," Master's Thesis, June 1987.

L. W. Griggs, Capt, USMC, "An Interactive Computer Graphics Network Monitor for a Tactical Communications Network," Master's Thesis, June 1987.

Title: Real-time Modelling and Animation Tools in Support of Three-dimensional Simulation

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

Sponsor: U. S. Army Combat Developments Experimentation Center

Objective: The goal of this research is to develop real-time modeling and animation tools to support three-dimensional simulation. This work is to be carried out on the highest perfomance computer graphics workstations available in the Graphics and Video Laboratory in the Department of Computer Science.

Summary: We began our work on developing real-time animation tools by examining the capabilities and limitations of both currently available and near-term, high-performance graphics workstations. We built a prototype simulation of the FOG-M missile system on one such station in order to characterize what can and cannot be done with respect to real-time animations with the high-performance workstations currently available in the Graphics and Video Laboratory of the Department of Computer Science. Our ultimate goal is the development of a coherent, high-level system useful for rapidly prototyping simulations for the weapons testing scenario. This project is a multiyear project and continues in FY 1988.

Publications:

M. J. Zyda, R. B. McGhee, R. S. Ross, D. B. Smith, and D. G. Streyle, "Flight Simulators for Under $100,000," IEEE Computer Graphics & Applications, Vol. 8, No. 1, January 1988.

R. S. Ross, R. B. McGhee, M. J. Zyda, and N. C. Rowe, "A Context-dependent Classification Paradigm for Land Mobility Problems," Proceedings of the 3rd Annual Expert Systems in Government Conference, October 1987, p. 2.

R. F. Richbourg, N. C. Rowe, M. J. Zyda, and R. B. McGhee, "Solving Global Two-dimensional Routing Problems Using Snell's Law and A* Search," Proceedings of 1987 IEEE International Conference on Robotics and Automation, Vol. 3, 1987 p. 1631.

D. B. Smith, D. G. Streyle, R. B. McGhee, and M. J. Zyda, "An Inexpensive Real-Time Interactive Three-Dimensional Flight Simulation System," Technical Report NPS52-87-034, July 1987.

Publications: (cont.)

J. H. Potts, R. B. McGhee, and M. J. Zyda, "The Decomposition of an Arbitrary Three-dimensional Planar Polygon into a Set of Convex Polygons," Technical Report No. NPS52-87-004, February 1987.

L. G. Mason, R. E. Rautenberg, and M. J. Zyda, "Computer Graphics Interactive Workshop for Two-Dimensional Fractals," Technical Report No. NPS52-87-001, January 1987.

G. W. Taylor, R. B. McGhee, and M. J. Zyda, "Parametric Representation and Polygonal Decomposition of Curved Surfaces," Technical Report No. NPS52-86-028, December 1986.

J. S. Falby, C. T. Wu, and M. J. Zyda, "A Data Structure for a Multi-illumination Model Renderer," Technical Report No. NPS52-86-026, December 1986.

C. H. Tan, R. B. McGhee, and M. J. Zyda, "A Simulation Study of an Autonomous Steering System for On-road Operation of Automotive Vehicles," Technical Report No. NPS52-87-025, December 1986.

Theses Directed:

D. B. Smith, Cpt. USMC and D. G. Streyle, LT USCG, "An Inexpensive Real-time Interactive Three-dimensional Flight Simulation System," Master's Thesis, June 1987.

P. Smith, Cpt. USMC, "A Prototype Ray Tracer," Master's Thesis, June 1987.

J. Falby, LCDR USN, "A Data Structure for a Multi-Illumination Model Renderer," Master's Thesis, December 1986.

L. G. Mason, LCDR USN, "Computer Graphics Interactive Workshop for Two-Dimensional Fractals," Master's Thesis, December 1986.

J. H. Potts, Cpt. USMC, "The Decomposition of an Arbitrary, Three-dimensional, Planar, Polygon into a Set of Convex Polygons," Master's Thesis, December 1986.

G. W. Taylor, Cpt. USMC, "Parametric Representation and Polygonal Decomposition of Curved Surfaces," Master's Thesis, December 1986.

Theses Directed: (cont.)

T. Meier, LCDR USN, "Experiments with Textures for Real-time Polygon Fill," Master's Thesis, December 1987.

M. R. Oliver, LCDR USN and D. J. Stahl, LT USN, "Real-time 3D Simulation Systems," Master's Thesis, December 1987.

DEPARTMENT

OF

MATHEMATICS

DEPARTMENT OF MATHEMATICS

The research program of the mathematics department was focused mainly on numerical analysis and statistics, though some work was also done on elasticity, game theory and abstract linear algebra.

Numerical Analysis

I.B. Russak and A.A. Goldstein have been developing methods for the application of quasi-Newton algorithms to functions which are known only at a small number of points, and subject to errors.

R.H. Franke has continued to develop techniques for interpolation of meteorological data from randomly-obtained data.

B. Neta and A.L. Schoenstadt, working jointly with Professor R.T. Williams of Meteorology and Professor R.E. Newton of Mechanical Engineering, are continuing work on a project to develop and test a finite element atmospheric prediction model.

On a separate project, B. Neta is developing a finite element method of variable resolution for the shallow-water barotropic model. This method will accomplish a considerable decrease in storage requirements over currently used methods.

B. Neta, working jointly with Professor P. Nelson of Texas A&M University (College Station, TX) and Professor C.P. Katti of Nehru University (New Delhi, India) has been developing new methods for the solution of stiff initial value problems in ordinary differential equations.

Statistics

T. Jayachandran has consulted on the analysis of data on certain personnel, as well as credit data, as a way of addressing security concerns.

T. Jayachandran, working jointly with Professor H.J. Larson of Operations Research, is helping to improve the aircraft maintenance program at an Air Force base through the use of spectrometric oil analysis.

Elasticity

D.A. Danielson is working on the development of a new theory for elastic beams undergoing large deformation, but small strain.

Game Theory

G. Owen, working with Professor B.N. Grofman of the University of California (Irvine, CA), has continued research into decision-making in deliberative bodies, as well as voting in general elections.

Linear Algebra

C.L. DeVito has generalized the open-mapping and closed-graph theorems in a direction which is very different from any found in the literature.

Title: A Nonlinear Beam Theory for the Mechanical Behavior of Rotor Blades

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

Sponsor: NPS Foundation Research Program

Objective: To develop a new theory for elastic beams undergoing arbitrarily large deformation but small strain.

Summary: The effects of shear deformation, warping, and initial curvature were incorporated into a rigorous nonlinear beam theory. A complete mathematical theory incorporating variational principles, equilibrium equations, boundary conditions, and constituitive laws was obtained. The theory was shown to predict behavior that agrees with published theoretical and experimental results for extension and torsion of a pretwisted strip. Efforts are now underway to use the theory to model the coupling between the modes of deformation in rotor blades made of composite materials, and to model the lateral buckling of stiffners welded to the hulls of submarines.

Title: Investigation of a Major Result in Operator Theory

Investigator: C.L. DeVito, Associate Professor of Mathematics

Sponsor: NPS Foundation Research Program

Summary: The closed-graph theorem and the open-mapping theorem, because of their numerous applications, have been generalized by many authors to various classes of locally convex spaces (a particularly useful type of infinite dimensional space). Unfortunately, many of these classes are defined by means of technical properties; properties which have little relation to the more natural properties of locally convex spaces. This makes the theorems awkward to state and difficult to apply. Also, there is little coherence to these generalizations. We have instead, a collection of disjoint results each of value in only very specific problems. Our objective is to clarify and give some coherence to these results. We were able to do this by using a class of spaces, the ab-spaces, which we introduced in another investigation. This class contains many of the classes spoken of above and has some very useful properties; properties which make them suitable for applications. By drawing on some of our earlier work with ab-spaces, we were able to generalize both the open-mapping and closed-graph theorems in a very natural, and hence, easily applicable way.

Publication: A paper in which the major result (spoken of in the title) is generalized in a direction which is very different from any found in the literature has been written and submitted for publication.

Title: Interpolation of Scattered Meteorological Data

Investigator: Richard Franke, Professor of Mathematics

Sponsor: Office of Naval Research

Objective: To develop mathematical principles which may be utilized to interpolate meteorological information from randomly located points to a uniform grid while maximizing observation utility.

Summary: The investigation was in two different areas: (1) the performance of methods based on statistical ideas and the appropriate choice of covariance functions for multivariate schemes. Computations have demonstrated that the second order autoregressive (plus a constant) correlation function is suitable and will be used in the next numerical model at FNOC. (2) Simulations of a simultaneous consideration of background and observed data using Laplacian smoothing splines show that such a scheme may be advantageous when data is sparse or background errors have low spatial correlation.

Publications:

Franke, Richard, Edward Barker, and James Goerss, "The Use of Observed Data for the Initial Value Problem in Numerical Weather Prediction," in Computers and Mathematics with Applications (forthcoming), also issued as NPS-53-87-002.

Franke, Richard, "Statistical Interpolation by Iteration," in Monthly Weather Review, Vol. 116, 1988 pg. 961-963, also issued as NPS-53-87-003.

Franke, Richard, "Objective Analysis by Simultaneous Treatment of Background and Observations," in Preprints of Tenth Conference of Probablility and Statistics in Atmospheric Sciences, Edmonton, Alberta, Canada, October 1987.

Title: Scattered Data Approximation

Investigator: Richard Franke, Professor of Mathematics

Sponsor: Unsponsored

Objective: To continue research into the general problem of approximation of surfaces from scattered data.

Summary: Two areas were emphasized during the past year. First, a survey of recent developments was prepared, and in conjuction with that a large bibliography of multivariate approximation was compiled, in collaboration with L. L. Schumaker. In a second project jointly conducted with previous M.S. student, John McMahon, a paper was prepared on selection of knot locations for least squares thin plate splines. In a new direction, joint work with NRC postdoctoral fellow, Dieter Lasser, on offset surfaces from scattered data was begun.

Publications:

Franke, Richard, "Recent Advances in the Approximation of Surfaces from Scattered Data," in Topics in Multivariate Approximation, Academic Press, C. K. Chui, L. L. Schumaker, and F. I. Utreras, (eds), 1987, 79-98. (Also issued as NPS-53-87-001).

Franke, Richard and Larry L. Schumaker, "A Bibliography of Multivariate Approximation," in Topics in Multivariate Approximation, Academic Press, C. K. Chui, L. L. Schumaker, and F. I. Utreras, (eds), 1987, 275-335.

McMahon, John and Richard Franke, Knot Selection for Least Squares Thin Plate Splines, NPS-53-87-005 (submitted).

Title: Statistical Analysis of Security Related Data on Armed Services Personnel

Investigator: T. Jayachandran, Professor of Mathematics

Sponsor: PERSEREC, Monterey, CA

Summary: I served as a consultant on statistical issues for several of the ongoing projects at PERSEREC. I participated in discussions on: (a) the analysis of data on Navy personnel with less than honorable discharges, (b) development of an expert system to study credit data, and (c) creation of an appropriate data base on the mainframe computer. I provided several suggestions on how to organize the data bases and the appropriate statistical analyses.

Title: Numerical Solution of Initial-Value Problems

Investigators: P. Nelson, Professor of Mathematics, Texas A&M University, B. Neta, Associate Professor of Mathematics, C.P. Katti, Assistant Prof. of Mathematics, Nehru Univ., New Delhi, India

Sponsor: National Science Foundation, Special Foreign Currency Program

Objective: Develop new algorithm for initial value problems

Summary: It is proposed to study two distinct topics and methods relating to the numerical solution of initial-value problems. The first of these relates to the numerical solution of stiff initial-value problems by means of the method of invariant imbedding. Two different versions of this method are developed for possible application to stiff initial-value problems, and examples are given to show that each has the potential to separate (linear) stiff problems into coupled algebraic and slowly-varying differential systems. The second part of the proposal deals with the solution of second-order initial-value problems by means of hybrid finite-difference methods. These are modified linear multistep methods which incorporate a function evaluation at an off-step point. These methods have the potential of achieving maximum order without destroying the zero-stability. P-stability of such methods will be investigated.

Publications: B. Neta (with P. Nelson and C.P. Katti), "Convergence of Certain Parallel Source Iteration Schemes in Particle Transport," will be presented in Third SIAM Conference on Parallel Processing for Scientific Computing, December 1-4, 1987, Los Angeles.

B. Neta (with C.P. Katti), "Solution of a Linear Initial Value Problems on a Hyper-cube," under preparation.

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 supplies the computer with information on the neighbors of each grid point. Other results are given in an 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, "Several New Methods for Solving Equations", International Journal of Computer Mathematics, accepted for publication.

B. Neta, "The Transfer Function Analysis of the Turkel-Zwas Scheme for the Shallow-Water Equations," Journal of Computational Physics, submitted for publication.

Title: Improving Quasi-Newton Algorithms in the Noisy Function Case

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

Objective: Quasi-Newton (Q.N.) algorithms form one of the most popular methods for optimization problems. The method does not perform well in the case when the only data consists of function values and these have errors in them. It is desirable to improve the method so that it may we used in the noisy case as well.

Summary: In the case when only function value data is available, then gradients must be evaluated from function values. Errors in the function values result in inaccurate gradient computation and loss in accuracy in the algorithm. Improved estimates of the gradient are obtained by using a smoothing process together with a suitably determined mesh of points.

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 developing a competitive quantity split method capable of coping with various price gaming strategies used by defense contractors under dual source environment. David Lamm examined pricing strategies and implications on the buyer. Douglas Moses investigated the relationship between contractor financial condition prior to performance on a contract and the pricing strategy adopted by the contractor during the contract.

LOGISTICS

Research in logistics focuses on providing support to the Supply Corp in inventory modeling. 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 development of improved wholesale repairables replenishment model. Professors McMasters and Sivasankaran jointly worked on the development of expert systems to facilitate decision making by inventory managers at Navy Stock Points.

INFORMATION SYSTEMS

Dan Dolk continued his 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 worked on a project proposing a stochastic model of organizational choice strategies based on garbage can concepts and implementing a model by way of an expert system. He also began a project, under the sponsorship of Personnel Security Research Center, to identify rules used by experts in the analysis of credit reports and implement a prototype expert system that uses these rules in deriving conclusions about financial profiles of individuals.

IEEE Computer Society Standards Activity Board sponsored Professor Schneidewind, research on developing a standard for software quality metrics. Professor Schneidewind also began a project on software productivity enhancement study. The project was sponsored by Navy Management Systems Office and will be assisted by Professors Abdel-Hamid and Sivasankaran. Professor Abdel-Hamid was supported by the NPS

Foundation Research Program in his study of enhancing the portability of quantitative software cost estimation models.

COMMUNICATION SYSTEMS

Professors Carl Jones, Norman Lyons, and Tung Bui 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

Professor Ken Euske was supported by Defense Personnel Security Research and Education Center in his analysis of personal security-related financial data for individuals in sensitive positions. Douglas Moses examined the information content of the components of accounting measures of earnings by assessing their relationship with future earnings. The project was sponsored by the NPS Foundation Research Program.

MANPOWER ANALYSIS

Professors George Thomas and Stephen Mehay continued to undertake several projects, all sponsored by the U.S. Army Recruiting Command. Mark Eitelberg investigated the issue of screening and recruiting manpower for highly sensitive military occupations and addressed the supply depletion caused by very selective standards. David Henderson examined several key issues relating to military compensation, i.e., the optimality of bonuses, the advantages and disadvantages of a salary system, and the use of deferred versus current compensation.

PERSONNEL, TRAINING AND TESTING

Professor Loren Solnick examined whether the type of college attended (primarily black or not) and the educational resources of the college affect the job success of black college graduates employed in the private sector. Professor Benjamin Roberts examined relevant qualifications, characteristics, and capabilities of adjudicators and developed guidelines for selection and training. The project was sponsored by Defense Personnel Security Research and Education Center.

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. Professor Ken Thomas worked on conceptual modeling of conflict and its management in organizations. Professor Suchan studied Naval officers, perception of leadership in high and low impact written communication styles.

Professors McMasters and Moore provided TRADOC Research Element Monterey (TREM) assistance with the maintenance and development of Army models of military organizational effectiveness. Professor Moore further developed a screening index and software which can be used for a rapid, low cost initial evaluation of the resiliency inherent in specific designs.

Title: Development of a Model for Competitive Quantity Split under Dual Source Environment

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

Sponsor: Naval Air Systems Command, Cost Analysis Division

Objective: The objective of this project is to develop a competitive quantity split method capable of coping with various price gaming strategies used by defense contractors under dual source competition.

Summary: Price gaming by contractors is widely discussed in acquisition circles. It can be found in negotiated contracts as well as in competitively awarded contracts. In our earlier study of step-ladder bids of several missile programs we identified three gaming strategies used by contractors.

Two counter strategies are available to the government. The first, applicable when the two contractors have disparate production experience, is to split the quantity as evenly as possible under the minimum total cost rule in order to enhance the future competitive environment. The second, applicable when both competitors are in a position to compete in price, is to require the submission of bids consistent with historical price reduction curves and production rate experience.

Publication: Technical report in progress.

Thesis Directed: W.A. Minor, LT, USN, Master's thesis in progress.

Title:	A Model Management System for Software Engineering
Investigator:	D. R. Dolk, Associate Professor of Information Systems
Sponsor:	U.S. Army TRADOC Systems Analysis Activity
Objective:	The objective of this project is to design and implement a prototype system for the description and manipulation of combat simulation models using Geoffrion's structured modeling formalism.
Summary:	A relational information resource dictionary system (IRDS) was designed and implemented. The RDS 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. A structured model representation of an existing combat simulation model was developed. A preliminary process-oriented model control language was developed as a means of incorporating the dynamic element into the static structural representation.
Publication:	D.R. Dolk: "A Model Management System for Combat Simulation"; Technical Report NPS-54-86-014; November 1986.
Conference Presentation:	J.E. Kottemann and D.R. Dolk; "Process-Oriented Model Integration," ORSA/TIMS St Louis: Oct 26-28, 1987.
Thesis Directed:	D.J. Patrick, CAPT, United States Air Force; "The Applicability of Structured Modeling to Discrete Event Simulation Models"; Master's Thesis; March 1987.

Title: Analysis of Personal Security-Related Financial Data for Individuals in Sensitive Positions

Investigator: K. J. Euske, Associate Professor of Accounting

Sponsor: Defense Personnel Security Research and Education Center (PERSEREC)

Objective: The specific objectives of this research effort are to develop concepts for analysis and to review products that are developed by analysts at PERSEREC.

Summary: One factor that may be important in the identification of individuals in sensitive positions who may commit espionage is their financial health and behavior. To date there has been a lack of research to determine if data from existing financial sources could be used to evaluate the financial health and behavior of individuals in sensitive positions. One of the objectives of the Defense Personnel Security Research and Education Center (PERSEREC) is to conduct research in this area. The specific goal of the PERSEREC research effort is to determine what data bases are useful and how they could be used. For such a research effort it is necessary to: (1) develop concepts for analysis and (2) review products that are developed by the analysts.

The objective of this project is to assist PERSEREC in the identification of methods to screen characteristics of financial health and behavior of individuals in sensitive positions and review products that are developed by analysts at PERSEREC. We have thus far identified two different types of models that can be useful in this process. One is the use of discriminant analysis. We are currently talking to policy makers in the Defense Investigative Service (DIS) to adopt a discriminant function similar to that used by the Internal Revenue Service. Adoption of this analysis technique should both save the federal government significant amounts of money in adjudication of cases and allow more frequent and more sophisticated financial screening of individuals in sensitive positions. The new method would allow a yearly review instead of only once every five years, and at a lower cost. Additionally, the review techniques would use much more sophisticated financial risk prediction models than those currently used. The second method that has been demonstrated to be useful is artificial intelligence (AI). One of the other

Summary (cont.)	faculty members working on a related project has developed an AI model to review individual case records that are deemed to be high risk.
Publication:	K. J. Euske and Deborah P. Ward, "Accounting Information as an Indicator of Individual Integrity: Finding the Link", in progress.

Title:	An Economic Analysis of the Military Compensation System
Investigator:	D.R. Henderson, Associate Professor of Administrative Sciences
Sponsor:	Commander, Naval Military Personnel Command
Objective:	The objectives of this study are to examine several key issues relating to military compensation. Several areas for analysis are: the optimality of bonuses, the advantages and disadvantages of a salary system, the use of deferred versus current compensation, and the decoupling of the close correlation between pay, rank, a..d LOS.
Summary:	Various criticisms of bonuses were analyzed. My tentative findings are that most of the criticisms are not damning, and that bonuses offer a very low-cost way of paying military personnel. Indeed, the study concludes that the Navy should use bonuses more, not less. Also, the draft is considered as a form of compensation and is found to be inferior to the all-volunteer force.
Thesis Directed:	Michael Crouch, LT, USN, "The Social Welfare Losses of Conscription: An Evaluation for the 1980's," Master's Thesis, December 1986.

Title: Army Unit Capability Study

Investigators: A.W. McMasters, Associate Professor of Operations Research and Administrative Sciences 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 held with Army TOE designers at 8 of 13 TRADOC schools and 2 of 3 TRADOC coordinating centers during the spring of 1986. In the fall of 1986, the analysis of the interview data was completed. We found that force designers are not using the Army's two existing models (the AMORE model and the AURE model) for estimating the resiliency of TOE designs except under special circumstances. The TOE designers aren't using these models because they are difficult to run, there's a large amount of input data required and the results are hard to interpret.

The interviews led to the development of a proposal to create and test a TOE resiliency screening process for use by force designers (see previous entry *under* subsection a).

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 useful design tool once it is made user-friendly, and a simple means for providing input data can be found. The proposed Systematic Organizational Design (SORD) model was examined and found to have considerable development work remaining.

Publication: Technical Report, "An Investigation of the Use of Resiliency Analysis by U.S. Army Force Structure Designers - Part I," forthcoming.

Title: Stock Point Expert Systems

Sponsor: Naval Supply Systems Command

Investigators: A.W. McMasters, Associate Professor of Operations Research and Administrative Sciences; T.R. Sivasankaran, Assistant Professor of Management Information Systems

Objective: This is a continuing project to develop expert systems to facilitate decision making by inventory managers at Navy Stock Points.

Summary: The Naval Supply Systems Command is developing a network of programmable workstations to support the daily activities of the inventory managers at the Navy's Stock Points. This capability provides an opportunity for developing an "expert system" to facilitate decision making by those managers. Such a system attempts to emulate the knowledge and experience of the best managers. This automated assistance in the processing of complex retail inventory management problems can potentially shorten the overall processing cycle, improve effectiveness, and enhance productivity. This year, two major activities of these managers were investigated. These were the processing of delinquent due-in stock from the Defense Logistics Agency and the resolving of critical situations involving items being managed. This latter activity usually involves cancelling excess on order because demand has slowed or placing an order for an item having a large number of backorders. Preliminary expert systems were developed for these activities.

Theses Directed: W.D. Schill, "A Expert System for Inventory Managers at Retail Stock Points," Master's Thesis, March 1987.

G.W. Westfall, "Knowledge Acquisition for an Expert System at Retail Stock Points," Master's Thesis, December 1986.

Title:	Software for U.S. Army TOE Resiliency Screening
Investigator:	T.P. Moore, Assistant Professor of Management Science
Sponsor:	US Army Combat Developments Experimentation Center
Objective:	To implement a screening procedure which can be used by TOE developers to perform a rapid, low cost initial evaluation of the resiliency inherent in specific TOE designs. User friendly software will be developed for IBM compatible personal computers.
Summary:	This project officially began on September 1, 1987. Consequently, only a small amount of work was accomplished prior to the end of the reporting period for this faculty activity report. This work included the analysis of survey data concerning the use of personal computers by TOE designers. This information was used to determine the specific type of computer to be used to test the software.

Title: US Army TOE Resiliency Screening Methodology Study

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

Sponsor: US Army TRADOC Analysis Center - Ft. Leavenworth

Objective: To develop and test a screening index which can be used by TOE developers to perform a rapid, low cost initial evaluation of the resiliency inherent in specific TOE designs.

Summary: The intent of this research was to obtain the quantitative data to support the development of mathematical procedure for computing index numbers which are indicative of the inherent resiliency of an Army platoon, company or battalion. A survey was written and sent to 171 Army Officers and civilians who have or may have a role in the design of Army TOEs. The data collected in this survey is presently being analyzed using Saaty's analytical hierarchy process. It will be possible to create several alternative procedures for resiliency index computations based on this data.

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

Technical Report, "Alternative Index Computations for Estimating Inherent Resiliency in Army TOE Units," in progress.

Title:	The Information Content of Accounting Accruals: Empirical Tests in an Earnings Forecasting Context
Investigator:	O.D. Moses, Assistant Professor of Administrative Sciences
Sponsor:	NPS Foundation Research Program
Objective:	To empirically investigate the information content of the components of accounting measures of earnings by assessing their relationship with future earnings.
Summary:	This was basic research examining the usefulness of earnings component information by assessing the association between components and their use by financial analysts predicting future earnings. Data on earnings was decomposed into two broad components: accruals and cash flows. Various statistical tests indicated that earnings components provide meaningful signals of future earnings.
Publication:	O.D. Moses, "On the Association Between Cash Flow Signals and Forecasts of Future Earnings," in progress.

Title: Financial Measures and Contractor Pricing Strategy: Empirical Tests in the Defense Aerospace Industry

Investigator: O.D. Moses, Assistant Professor of Administrative Sciences

Sponsor: Unsponsored

Objective: To investigate the relationship between contractor financial condition, prior to performance on a contract, and the pricing strategy adopted by the contractor during the contract.

Summary: Unit prices for systems manufactured by contractors in the defense aerospace industry were examined. Two pricing strategies were identified: Skimming (high first unit price followed by substantial reduction in unit price) and penetration (low initial price followed by minimal price reduction). Relationships between measures of financial condition and pricing strategies were investigated. General findings indicate that more risky contractors tend to adopt skimming pricing strategies while contractors pooly utilizing capacity or contractors with excess resources tend to adopt penetration pricing strategies. General implications are that financial measures available prior to contract performance are associated with the subsequent pricing strategy adopted.

Publications: K.J. McGrath and O.D. Moses, "Financial Condition and Contractor Pricing Strategy," Program Manager, (September-October 1987), pp 11-19.

O.D. Moses, "Organizational Slack and Risk Taking Behavior: Tests of Product Pricing Strategy," submitted to the Academy of Management Journal.

O.D. Moses, "On the Relationship Between Financial Measures and Contractor Pricing Strategy: Empirical Tests in the Defense Aerospace Industry," Naval Postgraduate School Technical Report, NPS54-87-008, September 1987.

Conference Presentations:	O.D. Moses, "The Effect of Financial Condition on Product Pricing Strategy", American Accounting Association annual meeting, Cincinnati, August 17-19, 1987.
Theses Directed:	K.J. McGrath, Captain, USMC, "Predicting Pricing Strategy from Financial Condition," Master's Thesis, December 1986.
	J.C. Johnstone, LT, USN, and P. D. Keavney, LT, USN, "Pricing Strategy, Pricing Stability and Financial Condition in the Defense Aerospace Industry," Master's Thesis, June 1987.

Title: Identification of Relevant Qualifications, Characteristics, and Capabilities of Adjudicators, and Development of Selection and Training Guidelines for Adjudicators

Investigator: B.J. Roberts, Professor of Administrative Sciences

Sponsor: PERSEREC

Objective: Assess existing jobs on the core job dimensions and; determine the effect of job changes on adjudicators.

Summary: The Job Diagnostic Survey was employed in this study as a necessary first step in the diagnosis of work systems. Management has recognized the risk in using intuition which often results in attributing excessive weight to the characteristics of the person in understanding behavior and insufficient weight to the characteristics of the situation. The use of the JDS represents a theory-guided approach to work assessment and possible work redesign. The instrument was constructed to tap each major class of variables in the theory of work motivation utilized in the study. The diagnosis proceeded to inform the reader of what aspects of jobs most need improvement. While dimensions of Task Significance and Autonomy were generally high, the dimensions of Skill Variety, Task Identity, and Feedback raised issues that should be pursued in more detail. This finding is reinforced by the indication of a generally poor fit between individual growth need scores and Motivating Potential Scores for many adjudicators.

Publication: Roberts, B.J. Job Characteristics of Military Adjudicators. PERSEREC Technical Report, September, 1987.

Title:	Software Productivity Enhancement Study
Investigators:	N.F. Schneidewind, Professor of Computer Science, T. Abdel-Hamid, Assistant Professor of Information Systems, T.R. Sivasankaran, Assistant Professor of Information Systems
Sponsor:	Navy Management Systems Office (NAVMASSO)
Objective:	Improve the quality of NAVMASSO's software development and maintenance.
Summary:	This project only started in August 1987 so there was not time for substantial work during the reporting period. Informal working papers and published papers which are pertinent to the research were sent to the sponsor.

Title: Software Quality Metrics

Investigator: N.F. Schneidewind, Professor of Computer Science

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:

N.F. Schneidewind, "The State of Software Maintenance", in IEEE Transactions on Software Engineering, Vol. SE-13, No. 3, March 1987, pp. 303-310.

N.F. Schneidewind, "Introduction to the Special Section on Software Maintenance," in IEEE Transactions on Software Engineering, Vol. SE-13, No. 3, March 1987, pp. 301-302.

N.F. Schneidewind, "The IEEE Software Quality Metrics Draft Standard: Relationship with Systems Commonality," Proceedings of the NASA Workshop on Commonality in Computing for NASA Flight Systems, Lyndon B. Johnson Space Center Houston, TX, October 28, 1986.

Conference Presentations:

Norman F. Schneidewind, "How the IEEE Standard (Draft) for a Software Quality Metrics Methodology Could Assist in Achieving Maintainable Software," Invited Panelist: "Metrics for Software Maintenance Management," Conference on Software Maintenance - 1987, Austin TX, September 22, 1987.

N.F. Schneidewind, Invited Chair: Plenary Panel Session: "Perspectives on Software Maintenance," Conference on Software Maintenance-1987, Austin, TX, September 22, 1987.

Conference Presentations: (cont.)	N.F. Schneidewind, Invited Presentation: "The IEEE Software Quality Metrics Draft Standard: Emphasis on S/W Maintainability," 5th Annual Logistics Symposium, San Francisco Bay Area Chapter, Society of Logistics Engineers and Department of Administrative Sciences, (Naval Postgraduate School), Naval Postgraduate School, May 16, 1987.

Title: An Expert System for Organizational Choice-Strategies

Investigators: T.R. Sivasankaran, Assistant Professor of Administrative Sciences

Sponsor: NPS Foundation Research Program

Objective: The objective of this research is to propose a stochastic model of organizational choice strategies based on garbage can concepts and implement a model by way of an expert system.

Summary: If the choice-outcome relationships can be observed and evaluated organization-wide, it is conceivable to extract predictiveness from random streams, and build a model that blends the rational and random decision-making schools of thought. Such a model if computerized can be used to advise the decision makers of the choices available in a decision situation, estimate the expected benefit resulting from each choice, and lay down choice strategies which would optimize the long run benefits for the organization.

Publication: T. Sivasankaran and T. Bui, "A Stochastic Model of Organizational Choice Policies," in Ieee Transactions on Systems, Man and Cybernetics, (Submitted).

Thesis Directed: Sun M. Kang, "An Interactive Organizational Choice Processing System to Support Decision Making Using a Prescriptive Garbage Can Model," Master's Thesis, June 1987.

Title:	An Expert Systems Approach to the Analysis of Individual Financial Profiles
Investigator:	T.R. Sivasankaran, Assistant Professor of Administrative Sciences
Sponsor:	Defense Personnel Security Research and Education Center (PERSEREC)
Objective:	To identify rules used by experts in the analysis of credit reports, and to implement a prototype expert system that uses these rules in deriving conclusions about the financial profiles of individuals.
Summary:	It is expected that the Artificial Intelligence system that is being implemented will be able to detect individuals who are on the verge of bankruptcy, or who live beyond their means. Since money has been a major motivating factor in recent espionage cases, such a system has the potential of identifying individuals who may possibly turn to selling information affecting national security.
Conference:	T. Sivasankaran and T. Bui, "An Expert System to Presentation: Detect Espionage Activities through the Analysis of Individual Financial Profiles," in Proceedings of the Western Conference on Expert Systems, Anaheim, June 2-4, 1987.
Thesis Directed:	G. Salazar is doing a thesis on this research. He is expected to graduate in March 1988.

Title: Educational Background and Job Success Among Black College Graduates

Investigator: L.M. Solnick, Associate Professor of Labor Economics

Sponsor: NPS Foundation Research Program

Objective: To determine whether the type of college attended (primarily black or not) and the educational resources of the college affect the job success of the black college graduates employed in the private sector.

Summary: The study addresses two related questions about the educational background of black college graduates: Does attending a primarily black college affect job success, as measured by wage growth and promotion rates? Is it the racial composition of the colleges or their educational resources that influence job success? Detailed educational, demographic and job-related data for more than 500 black employees of a major U.S. manufacturing firm were analyzed. Blacks who attended black colleges received smaller wage increases and fewer promotions than comparable blacks who attended non black colleges. Most of the observed differences were attributable to the poorer resources of the black colleges, not to their racial mix.

Relevance to DoN/DoD: Educational background may significantly affect career achievements. The success (or lack thereof) of officers may be due in part to educational background. A similar study of Naval Officers might identify factors associated with career success.

Publications: "Educational Background and Job Success of Black College Graduates," NPS Technical Report, 54-87-009, September, 1987.

"Educational Background and Job Success of Black College Graduates," condensed version to appear in Proceedings, Decision Sciences Institute 19th Annual Meeting, November 1987.

Conference Presentations:

"Educational Background and Job Success of Black College Graduates," Eastern Economic Association Annual meeting, Washington, D.C., March, 1987.

"Educational Background and Job Success of Black College Graduates, (revised), Decision Sciences Institute National Meeting, Boston, November, 1987.

Title: Naval Officers' Perception of Leadership in High and Low Impact Written Communications

Investigator: J.E. Suchan, Associate Professor of Administrative Sciences

Sponsor: NPS Foundation Research Program

Objective: To determine if a high-impact writing style is faster to read and results in better comprehension than the traditional low-impact bureaucratic style and to determine the attributes that readers ascribed to a writer using the high-impact and the low-impact style.

Summary: An extensive survey of nearly 400 naval officers and enlisted personnel was conducted to assess the relative communication effectiveness of a high-impact written communication style and the traditional low-impact bureaucratic style. Survey results indicated that the readers of the high-impact communication took 17%-23% less time (depending on the group sampled) to read the document than readers of the low-impact document. The concomitant dollar savings, derived from a set of conservative assumptions that reflected the realities of military compensation, ranged from $19 million to $47 million per year. Also, readers of the high-impact communication retained more information than readers of the low-impact one. This significant difference in comprehension provides strong justification for adopting a high-impact style Navy wide.

Finally, respondents in general perceived that the writer of the high-impact report exhibited greater leadership tendencies than the writer of the low-impact document. However, the difference in perception of leadership between readers of the high and low-impact report was not as great as anticipated. Naval language customs and habits--a preference for a low-impact bureaucratic style--significantly affected reader responses, resulting in a greater than anticipated favorable leadership perception of the writer of the low-impact report.

Publications:

J.E. Suchan and R.J. Colucci, "An Analysis of Communication Efficiency and Cost Between High Impact and Bureaucratic Written Communications," Management Communications Quarterly, (under review).

J.E. Suchan, "Public Sector Professionals' Perception of Leadership Toward High Impact and Bureaucratic Communications," (in progress).

J.E. Suchan and R.J. Colucci, "Attributes Public Sector Professionals Ascribe to Writers of High Impact and Bureaucratic Communications," Proceedings, The Association for Business Communication International Conference, (forthcoming).

Conference Presentation:

J.E. Suchan and R.J. Colucci "Attributes Public Sector Professionals Ascribe to Writers of High Impact and Bureaucratic Communications," The Association for Business Communication International Conference, October 1987.

Thesis Directed:

R.J. Colucci, "An Analysis of the Financial Implications of High Impact Versus Low Impact Communications in the United States Navy," Master's Thesis, June 1987.

Title: Conceptual Modeling of Conflict and Its Management in Organizations

Investigators: K.W. Thomas, Professor of Administrative Sciences

Sponsor: NPS Foundation Research Program

Objective: To develop an integrated theoretical framework which describes conflict and the management of conflict in organizations. A major purpose is also to derive implications for the constructive management of conflict within organizations.

Summary: Recent theoretical and empirical research on organizational conflict and its management was reviewed. Concepts and findings were synthesized into an integrated set of theoretical models: (a) a process model of the sequence of events within a conflict episode; (b) a structural model of the major parameters of the organizational system which influence the course of the conflict episode; (c) a model of the short and long-term goals of conflict management; (d) a model of the major types of interventions available to third parties to manage conflicts; and (e) a more abstract, general model of conflict and conflict management which shows the interdependencies between the elements of the proceeding models.

Publications:

K.W. Thomas, "The Conflict-Handling Modes: Toward More Precise Theory," Management Communication Quarterly, forthcoming.

K.W. Thomas, "Norms as an Integrative Theme in Conflict and Negotiation: Correcting Our 'Sociopathic' Assumptions," In M.A. Rahim (Ed.), Managing Conflict: An Interdisciplinary Approach. New York: Praeger, forthcoming.

K.W. Thomas, "Conflict and Conflict Management: Reflections and Update," Journal of Occupational Behavior, forthcoming.

K.W. Thomas, "Conflict and Negotiation Processes in Organizations." In M.D. Dunnette (Ed.), Handbook of Industrial and Organizational Psychology, 2nd Ed. Chicago: Rand McNally, in progress.

Conference Presentations:

K.W. Thomas, "Norms as an Integrating Theme in Conflict Management: Correcting Our 'Sociopathic' Assumptions," First International Conference of the Conflict Management Group (now the International Association for Conflict Management).

K.W. Thomas, "An Overview of Conflict and Conflict Management," symposium session on "Organizational Conflict: Looking Back, Looking Forward," First International Conference of the Conflict Management Group (now the International Association for Conflict Management), Fairfax, Virginia, June 22-25, 1987.

DEPARTMENT

OF

OPERATIONS RESEARCH

DEPARTMENT OF OPERATIONS RESEARCH

The research program in the Department of Operations Research seeks to advance the field's state of knowledge in areas important to the Navy, Department of Defense and military planning. The field and applications are interdisciplinary, and the potential exists for a huge variety of applications. The summaries that follow are organized by academic specialty with specifics of application attached in hierarchical fashion.

The specific areas currently represented are large scale optimization, stochastic modeling, statistics and data analysis, search and detection, modeling and decision aids, and warfare modeling and analysis. The efforts of twenty-two department faculty and their students are reported. Sponsors are listed on the individual summaries.

Tangible output appears in the form of student theses, reports to sponsors, NPS Technical Reports, conference presentations and referenced journal articles in the open literature.

OPTIMIZATION

Large scale optimization generally deals with the construction and efficiency of algorithms for selecting values for a large number of variables in order to optimize a deterministic objective function. Professors Bradley and Brown continue their work on exploiting structure to treat large mixed integer problems. Applications range from capital budgeting to manpower planning.

Professors Brown, Rosenthal and Wood have collaborated to identify a class of pure network assignment and transportation problems which are receptive to their new high speed technique. Applications by Professor Rosenthal to the problem of officer assignment during mobilization has been a successful USMC application.

STOCHASTIC MODELING

The structuring, development and study of estimation procedures for random parameter stochastic models which describe certain reliability, failure rate, or other point process event systems are being accomplished by Professors Gaver and Jacobs. Applications include the readiness and combat performance of an air intercept squadron facing sudden attack. Professors Gaver and Jacobs also collaborate to generate methods to use combined information profitably in some signal source identification problems.

Professor Lewis is continuing his work on model development for non-normal time series, simulation and enhancement of graphics output. Professor Woods has returned to the department and is resurrecting his work on the development and performance of reliability growth models which play important planning roles in the defense industry.

STATISTICS AND DATA ANALYSIS

Shrinkage and empirical Bayes multiparameter estimation schemes are under study by Professor Read with application to the "small cell" problem in estimating USMC officer attrition rates. Professor Read is also involved in statistical aspects of monitoring the calibration of torpedo test ranges operated by NUWES. Adjunct Professor Tysver continues his work on data quality and track smoothing for NUWES. Summaries of these latter two efforts appear in the Annual Summary Report NPS-61-88-001PR.

Professors Larson and Jayachandran continue their work on experimental design and analysis in support of the military aircraft spectometric oil quality measurement program.

Professor Lewis is investigating interfaces between large scale data sets. Rapid availability and identification of aberrant facets is a major goal.

SEARCH AND DETECTION

Professor Eagle is involved in techniques for searcher path construction in seeking a moving target. He reports substantial improvement in the speed of his algorithms. Professor Washburn is collaborating with L. C. Thomas to assess various ASW platform designs using search game concepts.

MODELING AND DECISION AIDS

Professor Milch continues his work for USMC in modeling the assignment of officers, staffing goals and scheduling. In addition, he is beginning a study of the impact upon career paths of the DoD Reorganization Act.

Professor Poock continues the development of speech input technology to the Integrated Tactical Decision Aid. Professor Rockower is continuing his work on measures of effectiveness in support of the EW curriculum. Extension and application to the systems analysis of NULKA (formerly Ship Launched Electronic Decoy) is taking place. Professors Andrus, Forrest and Shudde are continuing their work of evaluating algorithms for use in tactical decision aids for OP-953.

WARFARE MODELLING AND ANALYSIS

Professors Parry and Schoenstadt continue their development and validation of ALARM as part of the Airland Combat Model.

Professor Taylor continues his studies of Soviet military organization structure and its effect on their decison making. His research specifically concentrates on the areas of troop control and use of air defense missile systems are being treated.

Professors Hughes and Eagle are involved in the research and development of specialized techniques for Naval engagement analysis in support of the requirement to understand the threat from special sensors to United States submarines.

Title: Large-Scale Optimization

Investigators: G.G. Brown, Professor of Operations Research and 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 manpower planning. 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 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, G. Graves, and M. Honczarenko, "Design and Operation of a Multicommodity Production/Distribution System Using Primal Goal Decomposition," Management Science, 33, 1987.

G. Brown. G. Graves and D. Ronen, "Scheduling Ocean Transportation at Crude Oil," Management Science, 33, pp. 335-346, 1987.

G. Brown, C. Ellis, G. Graves, and D. Ronen, "Wide Area Dispatch of Mobil's Tank Trucks," Interfaces, 17, pp. 107-120, 1987. (International Management Science Achievement Award Finalist).

G. Bradley and R. D. Clemence, Jr., "A Type Calculus for Executable Modeling Languages," Technical Report NPS52-87-029, Naval Postgraduate School, July 1987. (Presented at the Martin Beale Memorial Symposium, London, England, July 6-9, 1987). (Forthcoming IMA Journal of Mathematics in Management).

Publications: (cont.)

G. Bradley and R.D. Clemence. Jr., "Model Integration with a Typed Executable Modeling Language," (Forthcoming proceedings of the 21st Annual Hawaii International Conference on System Sciences, January 1988), NPS52-87-045, October 1987.

Conference Presentations:

G. Brown and A. Vassiliou, "ARES: An Optimization Based System for Operational and Tactical Guidance at Disaster Relief Efforts," ORSA/TIMS, New Orleans, Louisiana, May 4, 1987.

G. Bradley and R.D. Clemence. Jr., "A Type Calculus for Executable Modeling Languages," Martin Beale Memorial Symposium, London, England, July 6-8, 1987.

G. Brown, "Perspectives on Optimization" Keynote Address to New Zealand Operations Research Society, Wellington, New Zealand, August 24, 1987.

G. Bradley, "Capital Budgeting in the Telephone Industry," CPMS Summer Workshop, Reston, Virginia, September 13-18. 1987.

Theses Directed:

C. Staniec, MAJ, USA, "Solving the Multicommodity Transhipment Problem," Ph.D. Dissertation, June 1987.

A. Vassiliou, MAJ, Hellenic Army "ARES: A System for Real-Time Operational and Tactical Decision Support," Master's Thesis, December 1986.

R.D. Clemence, Jr., MAJ, USA, "A Type Calculus For Modeling Languages," Ph.D. Dissertation, Naval Postgraduate School, Monterey, CA (in preparation).

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, Associate 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:	Development and Evaluation of a Method for Computing Optimal Search Paths when Path Constraints Exist
Investigator:	J.N. Eagle, Associate Professor of Operations Research
Sponsor:	Chief of Naval Operations
Objective:	The primary objective was to develop an optimal solution procedure for the constrained search problem and to test this procedure against existing dynamic programming methods.
Summary:	The problem addressed is that of computing the path a searcher should take to maximize the probability of detecting a moving target by some specified time in the future. The primary applications are the search for submarines by ASW forces or the search for vessels or people adrift at sea. The problem was formulated as a nonlinear network flow problem. A branch-and-bound procedure was attempted. A bound was developed which required the solution of a convex nonlinear network flow problem. Solution of this problem was found to be computationally feasible because the linear subproblems were acyclic shortest path problems solvable in polynomial time by dynamic programming. Solution times were found to be 2 to 3 times faster than those provided by earlier dynamic programming methods.
Publication:	J.N. Eagle and J.P. Yee, "An Optimal Branch-and-Bound Procedure for the Constrained Path, Moving Target Search Problem," in progress Operations Research.
Conference Presentation:	J.N. Eagle, "An Optimal Branch-and-Bound Procedure for the Constrained Path, Moving Target Search Problem," presented at the Sixth International Conference on Mathematical Modelling, St. Louis, Missouri, August 3-6, 1987.
Thesis Directed:	J.F. Caldwell, Jr., LT, USN, "Investigation and Implementation of an Algorithm for Computing Optimal Search Paths," Master's Thesis, September 1987.

Title:	Statistical Analysis of Multivariate Observations
Investigators:	D.P. Gaver, Distinguished Professor of Operations Research, P.A. Jacobs, Professor of Operations Research
Sponsor:	National Security Agency
Objective:	To solve various statistical and probabilistic problems arising in the area of signal detection and signal source identification.
Summary:	Several observers cooperate to identify members of a population of items that are transmitting. The observers' measurements of basic item-identifying (known) parameters are error prone; errors are frequently non-Gaussian (gross-error-prone). Various methods are introduced and studied for combining the observers' observations so as to achieve as high a probability of correct identification as possible.
Thesis Directed:	H.K. Tay, CPT, Singapore Army, "Problems of Identification with a Small Number Independent Cooperative Observers," Master's Thesis, September 1987.

Title: Stochastic Modelling and Data Analysis

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

Sponsor: Office of Naval Research

Objective: To develop, apply, 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, the government and military in general.

Summary: Analytical models have been developed to study the readiness and subsequent combat performance of an air-interceptor squadron facing sudden attack. An estimator for the probability of a long time until hitting a state in a semi-Markov process based on an asymptotic renewal theoretic result has been developed and studied. Analytic models for deteriorating units with symptomatic emissions have been developed and inspection policies for the units studied. Estimation procedures have been developed and studied for random parameter stochastic models arising in reliability, failure rate, or other point process event rate data. A Kalman filter type model with Student-t measurement errors has been studied and robust Kalman filter type procedures developed.

Publications:

L.C. Thomas, P.A. Jacobs and D.P. Gaver, "Optimal Inspection Policies for Standby Systems," Communications in Statistics - Stochastic Models, 3 pp. 259-273, 1987.

D.P. Gaver and I.G. O'Muircheartaigh, "Robust Empirical Bayes Analysis of Event Rates," Technometrics, 29. pp. 1-15, 1987.

D.P. Gaver and P.A. Jacobs, "Processor-Shared Time-Sharing Models in Heavy Traffic," SIAM J. Comput, 15, pp. 1085-1100, 1986.

D.P. Gaver and J.P. Lehoczky, "Statistical Inference for Random Parameter Markov Population Process Models," Contributions to the Theory and Application of Statistics, Statistics. ed. E. Gelfand. Academic Press, pp. 75-99, 1987.

Publications: (cont.)

D.P. Gaver and J.P. Lehoczky. "Statistical Analysis of Hierarchical Stochastic Models: Examples and Approaches," Annals of Operations Research, 8, pp. 217-227, 1987.

I.G. O'Muircheartaigh and D.P. Gaver, "Prediction of Polytomous Events: Model Description, Algorithm Development and Methodological Aspects, With an Application," Naval Postgraduate School Technical Report, NPS55-87-010, Sep, 1987.

Conference Presentations:

D.P. Gaver and P.A. Jacobs, "On Estimating Measures of Performance for Queues and Survival Models," 16th Conference on Stochastic Processes and Their Applications, Stanford, California, August 1987.

L.C. Thomas, D.P. Gaver and P.A. Jacobs, "Inspection Policies for Deteriorating Units with Symptomatic Emissions," 16th Conference on Stochastic Processes and Their Applications, Stanford, California, August 1987.

A. Al-Zayani, D.P. Gaver and F.R. Richards, "Formulation and Analysis of Combat-Logistic Problems," Joint National Meeting TIMS/ORSA, New Orleans, Louisiana, May 1987.

D.P. Gaver and B. Harris, "A Statistical Overview of PRA Methodology," 147th Annual Meeting of the American Statistical Association, San Francisco, California, August 1987.

D.P. Gaver, and E.G. Coffman, Jr., "Buffers and Mailboxes," International SIAM Conference, Paris. France, July 1987.

Theses Directed:

S.W. Kim, MAJ, Korean Army, "A Simulation Study of Estimates of a First Passage Time Distribution for a Semi-Markov Process," Master's Thesis, March 1987.

A. Kukliansky, LCDR, Israeli Navy, "Tracking Procedures for Non-Normally Distributed Measurement Errors," Master's Thesis, September 1987.

R.D. Telson, LT, USN, "Enhancing and Evaluating Sonar Detection Performance Through Signal Injection Aboard Fleet Ballistic Missile Submarines; A Pilot Program," Master's Thesis, September, 1987.

Theses Directed: (cont.)

C. Smith, CPT, USA, "Pilot Study on the Applicability of Variance Reduction Techniques to the Simulation of a Stochastic Combat Model," Master's Thesis, September 1987.

J. Lillard. LT, USN, "Operational Availability Measures in Naval Weapons System Test and Evaluation," Master's Thesis, September 1987.

Title: Statistical Support Services for the Joint Oil Analysis Program

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

Sponsor: Air Logistic Center, Kelly AFB

Objective: To review performance of the CEMS IV statistical algorithm, review the Joint Oil Analysis Program correlation program, consider sampling interval useage, provide decision tables for use with the Portable Wear Metal Analyzer.

Summary: The CEMS IV algorithm was exercised on site and found to be performing as expected. A thorough review was undertaken of the computations made with the data collected in the correlation program and suggested changes were presented which are expected to remove an apparent built-in bias of the repeatability measures as computed for the absorption instruments used in the program. The changes suggested were implemented, and contrasted with the current procedure, using historic data. It is expected that an ongoing comparison will be undertaken with current data. The sampling interval methodology currently employed was investigated and suggestions were made about possible improvements. Decision tables for the PWMA await the introduction of production instruments into the inventory.

Conference Presentation: H.J. Larson, "CEMS IV OAP Algorithm," presented at the Spectroscopic Oil Analysis Technology Conference, Palm Beach Gardens, March 24 to 26, 1987.

Theses Directed: B.H. Min, MAJ, Korean Army, "The Curve Fitting of Portable Wear Metal Analysis," Master's Thesis, March 1987.

J.T. Stewart, LT, USN, "A Comparison of Measurements from the A/E35U-3 and PWMA Spectrometers," Master's Thesis, September 1987.

Title: Exploratory Analysis of Large Scale (Personnel Security) Data Sets

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

Sponsor: Defense Personnel Security Research and Education Center

Objective: The purpose of this research is to investigate interfaces between large scale data sets, statistical data bases and interactive data analysis packages. The object is to make the data rapidly available for analysis, and in particular to use modern statistical methods to identify outliers and aberrant facets of the data.

Summary: The project this year was concerned primarily with getting the computing facilities with which to attack this problem. A new version of GRAFSTAT was installed, running under the newly acquired APL2. This version of APL and also GRAFSTAT have an SQL (standardized query language) interface to large data bases. SQL languages for micros were also investigated. We also acquired an interface to statistical packages like SAS from Professor Ralph Ginsberg, University of Pennsylvania. Development of this NKRG system is continuing.

Title: Stochastic Modelling, Time Series Analysis and Simulation

Investigator: P.A.W. Lewis, Professor of 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 to develop methods for the analysis, display and editing of large scale, non-normal time series.

Summary: Several new models for non-normal time series have been derived. One of these using a square-root Beta transform to generate a broad class of time series with ARMA correlation structure and 1-Laplace marginal distributions. Since the process is a random linear combination of 1-Laplace random variables, the process is easily extended to bivariate situations. This would be necessary for modelling E-W and N-S components of wind velocity data. A significant step forward in the development of the SIMTBED program has been made with the modification of the program to have a restart capability. This will allow it to use micros and workstations to their fullest capability. Work is now starting on enhancing the graphics output with color, especially that obtainable from cheap dot-matrix printers. This will enable us to see the effects of multiple factors more clearly. A complete revision and rewrite of SUPER SIMTBED is being undertaken to incorporate new computing and statistical ideas.

Publications:

P.A.W. Lewis and E.J. Orav, Simulation Methodology for Operations Analysts, Statisticians and Engineers, Wadsworth/Brooks Cole, forthcoming.

P.A.W. Lewis and E.J. Orav, Advanced Statistics and Simulation, Wadsworth/Brooks Cole, forthcoming.

P.A.W. Lewis and A.J. Lawrance, "Higher Order Residual Analysis for Nonlinear Time Series with Autoregressive Correlation Structure," International Statistical Review, Vol. 55, pp. 21-35, 1987.

Publications: (cont.)

P.A.W. Lewis and L. Breaker, "On the Detection of a 40 to 50 Day Oscillation in Oceanic Properties Along the California Coast," Estuarine, Coastal and Shelf Science, forthcoming.

P.A.W. Lewis, "Use of Color in Differentiating Factor Levels in Simulation Output," Proceedings of the Seventh Annual National Graphics Conference, Vol. III, 1986.

P.A.W. Lewis, L.D. Dewald, Ed McKenzie, "A Bivariate First Order Autoregressive Time Series Model in Exponential Models," Management Science, forthcoming.

P.A.W. Lewis, E. McKenzie and P.K. Hugus, "Gamma Processes" International Statistical Review, in progress.

P.A.W. Lewis, "Graphical Analysis of Some Pseudo-Random Number Generators," American Statistician, in progress.

Conference Presentations:

P.A.W. Lewis, "SIMTBED: A Portable Graphical Output Analysis Program for Simulation," Gregynog Birmingham/Wales Universities Annual Conference. Gregynog, Scotland, April 26, 1987.

P.A.W. Lewis, "SIMTBED: A Portable Graphical Output Analysis Program for Simulation," NSF Special Seminar, Washington, D.C., March 12, 1987.

P.A.W. Lewis, "SIMTBED: A Portable Graphical Output Analysis Program for Simulation," Mathematics Seminar, University of Strathclyde, Scotland, May 1, 1987.

P.A.W. Lewis, "Smarter Control Variables," IMSL Mathematics/Statistics Seminar, Houston, Texas, May 7, 1987.

P.A.W. Lewis, "Algorithms for Generating Non-Normal Stochastic Processes," Computer Science/Statistics Interface, Philadelphia, Pennsylvania, March 10, 1987.

P.A.W. Lewis, "Variance Reduction Using Conditional Expectation and the Beta-Gamma Transform," London Universities Seminar, London, England, April 29, 1987.

Conference Presentations: (cont.)

P.A.W. Lewis, "Variance Reduction Using Conditinal Expectation and the Beta-Gamma Transform," ORSA National Meeting, New Orleans, Louisiana, May 9, 1987.

P.A.W. Lewis, "Smarter Control Variables," Computer Science Seminar, Yorktown Heights, New York, April 15, 1987.

Title:	Airland Research Model (ALARM)
Investigators:	S.H. Parry, Associate Professor of Operations Research and A.L. Schoenstadt, Professor of Mathematics
Sponsor:	U.S. Army TRADOC Analysis Command
Objective:	The overall objective of ALARM is to develop, implement, and validate several new methodologies for a Corps/Division level Airland Combat model. The specific objectives for this year of research are to continue development of algorithms for the Generalized Value System (GVS), to develop a database for implementation of GVS, to implement algorithms for mapping of digitized terrain data to network arcs and nodes, and to demonstrate the GVS in VIC.

Title:	Speech Input to the Integrated Tactical Decision Aid
Investigator:	G.K. Poock, Professor of Operations Research
Sponsor:	Naval Ocean Systems Center
Objective:	To integrate speech input into the decision aid so one can run the aid by talking to it.
Summary:	A VOTAN connected speech system was interfaced to the integrated tactical decision aid and it can run with speech input. In addition we found many bugs in the software of this operational system and NADC is making corrections to the next release of the software to the fleet.

Title: Attrition Rate Generation for Manpower Models

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

Sponsor: U.S. Marine Corps

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. Particular attention is to be paid to the "small cell" problem.

Summary: This is a continuing project. We are concerned with that aspect of projected losses that involves attrition from the service for whatever reason. For use in the various models, loss rates need to be particularized according to a number of cross classified factors. Research to date has shown that substantial improvement in rate estimation can be achieved through the use of "shrinkage" type estimators applied to a transformation of the raw rates. The class of James-Stein estimators has been applied in a variety of ways, and commitments have been made to the following steps: i) Cells need to be aggregated into groups whose attrition behavior is internally homogeneous. ii) A variance stabilizing transformation is applied to the empirical rates of each group. iii) The estimation of the shrinkage parameters are made for each group. iv) The shrinkage technique is applied. v) The transform is inverted in order to return to the original scale. vi) Cross validation techniques are applied in both the original and transformed scales. The cross validation step involves the choice of a figure of merit. Recent discussions with NPRDC has led to a change to mean absolute deviation rather than squared deviations. This change is not without effect and further study on this point is planned. This years work involved the development of general Fortran software and the extension of our pilot calculations to the entire set of MOS categories. Thus far, the indications provided by the pilot calculations are confirmed. The technique is a viable one. Specific application manpower planning models have been identified. Each has its own requirements and idiosyncracies. The details of these interfaces are being addressed.

Thesis Directed: N. Yasin, "Application of Logistic Regression to the Estimation of Manpower Attrition Rates," Master's Thesis, March 1987.

Title: Resystemization Modelling Support

Investigators: 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 wholesale repairables replenishment model development continued. A formula for computing the mean supply response time in the steady state replenishment environment was derived. The model was also modified to allow order quantities to be input parameters rather than as complex workload constraints. The model form which minimizes the total investment in the Navy Stock Fund subject to a mean supply response time goal was run using real-world data provided by the Navy's inventory control points (ICPs). The current Navy model was also programmed in Fortran on the IBM 3033 and comparisons between the performances of the two models were made. The results were presented to the sponsor and the ICPs.

Theses Directed: R. E. Hammer, "Wholesale Replenishment Models: Model Evaluation," Master's Thesis, June 1987.

G. H. Pearsall, "Analysis of a Proposed Wholesale Replenishment Model," Master's Thesis, December 1986.

Title:	MOE Development for Electronic Warfare Training and Readiness
Investigator:	E.B. Rockower, Associate Professor of Operations Research
Sponsor:	Chief of Naval Research
Objective:	This is part of a continuing program to study measures of effectiveness for electronic warfare, and to support the E.W. curriculum at NPS by providing thesis related travel, etc.
Summary:	Measures of effectiveness were evaluated relating to E.W. effectiveness in anti-ship missile defense utilizing expendable seduction and distraction decoys. Upon selection of an appropriate MOE an optimization study was performed and compared with existing Navy doctrine for determining inventory needs for expendable decoys. Results of the study were briefed to the sponsor and to other interested Navy personnel. Suppport of NPS EW students for thesis related travel was provided under this project.
Thesis Directed:	M. Shumaker, LT, USN, "A Systems Analysis of the United States Navy's Inventory Needs for Expendable Anti-Ship Missile Defense Decoys," Master's Thesis, September 1987.

Title: Ship Launched Electronic Decoy Development Program Support

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

Sponsor: Naval Sea Systems Command

Objective: Support the Ship Launched Electronic Decoy (SLED, now called NULKA) Program through modeling and analysis regarding employment, tactical doctrine, and training inventory requirements.

Summary: A model was developed for evaluating the effectiveness of the off-board expendable decoy, now known as NULKA, in a multiple ship environment. The effectivenes of a decoy employed while a battle group is under missile attack may be degraded if the missile is decoyed onto a neighboring own-force ship. The sensitivity of ship survivability to battle group ship-density, decoy performance, and employment tactics were studied.

NULKA inventory requirements, reflecting both current Navy employment and training doctrine and, alternatively, an optimization study, were determined. Results from this project were reported directly to the sponsor.

Title:	Large-Scale Network Optimization for Marine Corps Officer Assignment During Mobilization
Investigator:	R.E. Rosenthal, Associate Professor of Operations Research
Sponsor:	United States Marine Corps
Objective:	To design and implement a large-scale network optimization model for assigning Marine Corps officers to billets during mobilization.
Summary:	A new large-scale network optimization model for assigning officers to billets during mobilization has been developed for Headquarters, USMC, and is slated for installation in FY88 as a permanent replacement for an existing procedure that has been in use since 78. The new model improves the turnaround time from days to minutes, reduces computation costs by substantial amounts yearly, and, in tests on FY87 exercise data, resulted in significantly better allocations of the officer pool. The improved quality of assignments was measured with respect to three criteria: the number of billets filled, the "goodness of fit" between officers and the billets to which they are assigned, and the cost of officer relocation.
Conference Presentation:	R.E. Rosenthal and S.H. Rapp, "Large-scale Network Optimization for Marine Corps Officer Assignment During Mobilization," ORSA/TIMS Joint National Meeting, St. Louis, Missouri, October 1987.
Thesis Directed:	S.H. Rapp, CAPT, USMC, "Design and Implementation of a Network Optimizer for Officer Assignment During Mobilization," Master's Thesis, Operations Research, Naval Postgraduate School, September 87.

Title:	Cybernetic Concepts (Phase III)
Investigator:	J.G. Taylor, Professor of Operations Research
Sponsor:	USAF Systems Command
Objective:	To investigate Soviet cybernetic concepts that are critical for American understanding of the design, operations, and automation of Soviet troop-control systems.
Summary:	Considering open-source Russian-language Soviet military materials (mainly books), this research refined Western understanding of Soviet military-control concepts and the impact of cybernetics on them. It revealed that Soviet useage (reflecting Soviet conceptualization of such control processes) is much richer in its ability to differentiate between control of different types of combat systems and combat units. It investigated the Soviet taxonomy of military-control concepts and then examined Soviet cybernetic concepts and their impact on troop control (upravleniye voyskami) within this context. Key Soviet military-control concepts were identified and investigated. with the emphasis being on understanding such concepts.
Publication:	J.G. Taylor, "Cybernetic Concepts and Troop Control," NPS Letter Report, September 1987 (124 pages).
Conference Presentation:	J.G. Taylor, "Soviet Theory of Troop Control: Soviet Conceptualization of Command and Control," Fifth Annual FTD/NPS C3 Workshop, Wright-Patterson AFB, Ohio, December 1986.
Theses Directed:	D.M. Dassler, LT, USN, "Naval Ship Utility: The Soviet Perspective," Master's Thesis, December, 1986.
	K. Briggs, CPT, USAF, "The Analysis of Society Warfare, Master's Thesis, March 1987.
	M.A. Cox, LT, USN and W.P. Quintong, LT, USN, "Soviet Naval Command and Control - A Primer", Master's Thesis, March 1987.
	R.N. Morgan, LT, USN, "Predicting the Design of Soviet Space Sensors," Master's Thesis, September 1987.
	P.A. O'Brien, LT, USN, "Soviet Doctrine and Implications for Strategic Defense," Master's Thesis, September 1987.

Title:	Soviet Control of Air-Defense Missile Systems and Troops
Investigator:	J.G. Taylor, Professor of Operations Research
Sponsor:	U.S. Army Missile Intelligence and Space Center
Objective:	To consolidate and extend available knowledge on the conceptual basis of Soviet control of air-defense missile systems and troops and how such a theory guides Soviet air-defense actions.
Summary:	Considering open-source Russian-language Soviet military materials (mainly books), this research revealed that lack of American understanding of Soviet military (in particular, control) concepts is a major stumbling block to understanding Soviet control of air-defense missile systems and troops. Consequently, it focused on developing a basic understanding of Soviet concepts for air defense and control of air-defense systems. Additionally, ITEAMS meetings were attended and some inputs given directly to the sponsor.
Publication:	J.G. Taylor, "Cybernetic Concepts and Troop Control," NPS Letter Report, September 1987 (124 pages).
Conference Presentation:	J.G. Taylor, "Soviet Air-Defense Concepts," ITEAMS Meeting, Huntsville, Alabama, June 1987.
Theses Directed:	M. Guilfoil, Civilian, National Security Agency, "Bridging the Gap Between Soviet and American Languages and Cultures: A Basic Introduction to TROOP CONTROL for the Russian-Language Translator." Master's Thesis, March 1987. E.J. Apgar, CPT, USA, "An Initial Space-Related Personnel Plan for the U.S. Army Military Intelligence Corps," Master's Thesis, September 1987. R.M. Schmidt, CPT, USA, "An Examination of the Use of Tactical-Satellite Communications as an Architecture to Counter Soviet Radioelectronic Combat," Master's Thesis, September 1987.

Title:	Mission Analysis of Transatlantic RE/RE Shipping Protection by Advanced ASW Search Concepts
Investigators:	A.R. Washburn, Professor of Operations Research, L.C. Thomas, Department of Business Studies
Sponsor:	Admiralty Research Establishment
Objective:	To develop a means of quickly assessing the suitability of various ASW platforms for conducting ASW against diesel submarines near Britain.
Summary:	A model where patrolling ASW platforms react to submarines caused "flaming datums" is considered, and the potential effectiveness of each platform is assessed using a new type of search game. For each type of platform, a computer program calculates the optimal strategies of both sides and outputs "effective area controlled per platform" as a measure of effectiveness.
Publications:	L.C. Thomas and A.R. Washburn, Final Report to the Admiralty Research Establishment, April 1987. L.C. Thomas and A.R. Washburn, "Dynamic Search Games," submitted to Operations Research.
Conference Presentations:	A.R. Washburn, "A Dynamic Search Game," 23rd Gregynog Statistical Conference, Gregynog, Wales, April 1987. A.R. Washburn, "Dynamic Search Games," Scottish and Northambrian Academic Statisticians Meeting, Aberdeen, Scotland, May 1987.

Title: Reliability Growth Model Development

Investigator: W.M. Woods, Professor of Operations Research

Sponsor: NPS Foundation Research Program

Objective: Develop reliability growth models that have a procedure for discounting failures which have resulted in design changes to remove the cause of the failures and for which subsequent testing on the modified hardware has not produced failures for the same causes. Also evaluate these models for their accuracy; i.e. their ability to track specific types of growth patterns.

Summary: A reliability growth model, known to be accurate relative to the accuracy of other well known models, was modified to include a means for discounting failures for which subsequent testing does not result in repeated failures for the same cause. Corrections to discounted failures are also provided for when failures for the same cause occur after discounting has been allowed. Several discounting schemes were developed each being specified by assigning values to parameters in the model; specifically to the fraction of failure to be removed and the number of successful tests required between successive discounts. Special values of these parameters correspond to no discounting. A special discounting procedure was also used which is currently being used by a major defense contractor. Discounting failures, or something like it is necessary when large improvements are made in reliability due to changes in design or other factors and the amount of subsequent testing will be small. Without such features, reliability growth models cannot track rapid change in reliability growth. A computer program was developed to simulate testing of hardware in phases where reliability changes (usually improves) in each phase and which computes reliability estimates in each phase for the randomly generated data in each phase. For each set of input parameters, i.e. each case, the simulation is replicated 100 times and the average of the 100 reliability estimates in each phase is compared with the actual reliabilities for each phase which was used to generate the data. Only attributes data models were used. The results show that one reliability growth model is more accurate than others for a large variety of growth and non-growth patterns. The results also indicate that a discounting procedure currently being used by a major DOD contractor is overly optimistic for same growth patterns.

Thesis Directed: J.E. Drake, CPT, USA, "Discrete Reliability Growth Models Using Failure Discounting," Master's Thesis, September 1987.

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. This computer laboratory came on line this year.

The department's involvement in advanced quantitative methodologies and techniques increased with the installation of the Rand Strategy Assessment System (RSAS). The RSAS allows NPS to operate at the cutting edge of politico-military gaming in the United States. The RSAS is being used for original research as well as to support thesis students and classroom instruction.

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 compliance and naval warfare.

Three additional research projects were supported by the Office of the Secretary of Defense. One involved an analysis of the early formulation of American nuclear strategy while another deals with structural factors involved in the long-term competitive relationship between the two world superpowers. A third on-going project is investigating current issues in the multi-faceted Jordanian-Palestinian relationship.

The Deputy Under Secretary of the Navy (Policy) sponsored a major two-day conference on the Navy in the Pacific. A technical report of all conference papers and discussions is being prepared. A one-hour video-tape of conference highlights will be prepared and made available to the sponsor.

Two faculty members completed research for non-U.S. governmental agencies. The Earhart Foundation and the Woodrow Wilson International Center for Scholars sponsored research into security and political issues facing Europe. The Social Sciences and Humanities Research Council of Canada and the Fullbright Commission supported an analysis of Brazilian politics in the 1980s.

The Naval Postgraduate School Foundation supported research by one faculty member who was concurrently awarded a Fullbright Fellowship to study political regimes in Argentina and Brazil. The Foundation also supported research into Bundeswehr.

Title:	Strategy and the Operational Level of Warfare in the West German Navy
Investigator:	D. Abenheim, Assistant Professor of National Security Affairs
Sponsor:	NPS Foundation Research Program
Objective:	Examine the evolution of West German maritime strategy from the close of World War II until the present. The West German perspective is notable due to the unique geographical area of operations, the necessity to uphold the principle of joint-operations, and because of specific political constraints on the character of the German armed forces. No work in the English language exists on these issues.
Summary:	Preliminary findings highlight the political constraints on the operation of the German armed forces, the attempt to learn from past errors and fashion an image of the soldier suited to a modern, democratic and industrial state. These insights are essential to any further discussion of West German operations and strategy in the context of NATO.
Conference Presentation:	Paper presented at Institute of Contemporary German Studies, Washington, D.C., "Bundeswehr and Future of the Defense of the West," 31 October 1987.
Publication:	Chapter forthcoming in volume compiled from the above conference. Research ongoing. Technical Report NPS-56-88-008, "The Citizen in Uniform: Reform and Its Critics in the Bundeswehr," February 1988.

Title: The Brazilian Political Transition in the 1980s

Investigator: T. C. Bruneau, Professor of National Security Affairs

Sponsor: Social Sciences and Humanities Research Council of Canada and the Fulbright Commission

Objective: To analyze the dynamics and prospects of the transition from military rule to civilian rule in Brazil following twenty one years of military government. The Constituent Assembly is the specific focus of this research which is done in a comparative perspective.

Summary: Research was conducted in Brazil in 1985 and 1986. This involved a thorough review of relevant literature in Portuguese, utilization of survey data, and my interviews with some three dozen members of the political elite. As the process of formulating the constitution continues into early 1988 it is necessary to complete the field research before definitive conclusions can be reached.

Publications: "Constituicao: O Caso de Portugal," Lua Nova, (Sao Paulo), March 1987.

"O Papel da Igreja na Transicao Brasileira," Dados: Revista de Ciencias Sociais (Rio de Janeiro), Vol. 30, No. 1, 1987.

Title:	Religion and Politics
Investigators:	T. C. Bruneau, Professor of National Security Affairs and M. Mooney, Research Assistant at McGill University, Montreal
Sponsor:	Social Sciences and Humanities Research Council of Canada
Objective:	To analyze the changing role of the Catholic laity in the institutional Church in Chile, France, and the United States. Of particular concern are the political implications of these changes in the religious sphere.
Summary:	Research involved a thorough review of the literature on religion and politics in these three countries, three months of interviewing by the research assistant in each, and we are currently at the stage of writing after having analyzed the data.
Publication:	"A Political Transition in Chile?" Problems and Prospects on the Long Road to Democracy" submitted as a Technical Report in November 1987.

Title: Regime Change and State Structure in Latin America

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

Sponsor: NPS Foundation Research Program

Objective: To determine whether and how regime type has an impact on the structure and functions of the national state apparatus, what organizational changes are promoted by which types of regime, in what core functional areas these changes are most evident, and how the reforms translate into organizational traits classifiable by regime type.

Summary: This effort is a follow-up to a first-stage research project funded by NPS Research Foundation that has produced several preliminary articles. For the policy-making community, these studies offer a micro-analytical framework with which to analyze institutional reforms in relation to regime type and regime change. For the Department of Defense, this allows more precise and faster analytic projections of foreign regime character, objectives and capabilities.

Publications: NPS Technical Report NPS56-87-004 "State Terror, Economic Policy, and Social Rupture During the Argentine 'Proceso,' 1976-1981."

NPS Technical Report NPS56-87-005 "State, Labor, Capital: Institutionalizing Democratic Class Compromise in the Southern Cone."

NPS Technical Report NPS56-87-006 "National Labor Administration and Democracy in Brazil, 1985-87."

NPS Technical Report NPS56-87-007 "National Labor Administration and Democracy in Argentina."

NPS Technical Report NPS56-87-008 "State Organization as a Political Indicator."

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

Investigators: R. H. Magnus, Associate Professor of National Security Affairs; J. H. Amos III, 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. This relationship will have a crucial impact on any prospects for a negotiated settlement of the Arab-Israeli conflict, as some form of linkage of Jordan with parts of Palestine is the only negotiated settlement acceptable to both major Arab and Israeli actors.

Summary: The processes of data gathering have been completed as of December 1987 and the writing of the findings is currently underway. There are no publications, conference presentations, or theses directed to date. It is anticipated that at least one thesis relating to this topic will be directed during the coming year (Renee J. Simpson, LT, USN).

Title:	Maritime Strategy in the Asia-Pacific-Indian Ocean Region
Investigator:	E. A. Olsen, Associate Professor of National Security Affairs
Sponsor:	Chief of Naval Research
Objective:	To hold a conference on the role of The Maritime Strategy in the Pacific.
Summary:	A two-day conference was organized and held, examining the evolution and role of The Maritime Strategy, maritime strategy in the Pacific, Asian-Pacific naval issues and contemporary strategy, Asian views of U.S. naval strategy in the Pacific, and the future of the U.S. Navy in the Pacific. Prominent individuals participated in the conference.
Publication:	A technical Report is being prepared based on the papers presented. A condensed videotape version of the conference is being prepared for educational purposes.

Title: Analysis of the Formulation and Implementation of American Nuclear Strategy

Investigators: P. J. Parker, Professor of National Security Affairs (Principal Investigator), and B. D. Dailey, Adjunct Professor of National Security Affairs

Sponsor: Office of the Secretary of Defense/Net Assessment

Objective: The objectives of this study are (1) to identify the specific disparities between doctrine and capability and their evolution (2) to evaluate their importance, and (3) to understand their persistence.

Summary: This project is still in its early stages. A number of military officers who were involved in the formulation and implementation of nuclear strategy are being interviewed. Particular attention is being given to analysis of the decision and organizational process of the military elements responsible for procuring, deploying, and operating strategic systems.

Title: Research Program in Arms Control and Naval Warfare

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

Sponsor: Defense Nuclear Agency

Objective: To provide a series of specific papers on key issues in arms control and a quick response capability to address new issues as they arise. The work is expected to benefit DNA by making available the unique research capability of the Naval Postgraduate School and will indirectly benefit DNA by promoting and further developing on-going faculty research and educating serving officers on nuclear matters.

Title: Research Program in Arms Control (Phase II)

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

Sponsor: Defense Nuclear Agency

Objective: To establish a conceptual basis for understanding, evaluating and predicting Soviet negotiating/compliance patterns. This conceptual basis will enhance our understanding of the Soviet weapon system development process and evolution of the Soviet strategic force postures.

Summary: A systematic understanding of Soviet attitudes toward diplomacy and arms control was applied to identify patterns in Soviet noncompliance. Also included was a thorough review of the negotiating record and SCC deliberations to identify Soviet strategic force objectives and priorities. Initial findings were briefed to sponsors.

Title: Analysis of War Games

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

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 next 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, and to create overall lessons.

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, "Final Report NSDG Game 13," 18 November 1986, 21 pp.

J.J. Tritten, "Creative Use of Scenarios," NPS-56-87-001 Technical Report, 16 pp., April 1987.

J.J. Tritten and K.S. Masterson, "New Concepts in Global Wargaming," U.S. Naval Institute Proceedings, Vol. 113, No. 7, July 1987, pp. 117-119, also as NPS-56-87-002 Technical Report, 15 pp., May 1987.
.PA

N.R. Palumbo, "Strategic Planning for Counterforce Options," NPS-56-87-003 Technical Report, 42 pp., June 1987.

Publications: (cont.)

J.J. Tritten and K.S. Masterson, "New Concepts in Global Wargaming," U.S. Naval Institute Proceedings, Vol. 113, No. 7, July 1987, pp. 117-119, also as NPS-56-87-002 Technical Report, 15 pp., May 1987.

N.R. Palumbo, "Strategic Planning for Counterforce Options," NPS-56-87-003 Technical Report, 42 pp., June 1987.

J.J. Tritten, "Are Nuclear and Nonnuclear War Related?" NPS-56-87-009 Technical Report, 16 pp., August 1987.

J.J. Tritten, "Soviet Naval Strategy," Naval Forces, Vol. VIII, No. IV/1987, pp. 56-60, also as NPS-56-87-010 Technical Report, 12 pp., August 1987.

LT Arthur Scott Mobley Jr., "Unlocking the Potential of War Games: A Look Beyond the Black Box," NPS 56-88-008 Technical Report, 16 pp. February 1988.

Conference Presentations:

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

"New Concepts in Global Wargaming" presented to 54th Military Operations Research Society (MORS) Symposium, June 1986 and to 28th Annual International Studies Association Convention, April 1987.

"Creative Use of Scenarios" presented to 28th Annual International Studies Association Convention, April 1987 and to conference at Rand Corporation on scenario planning, Washington, D.C., June 1986.

Thesis Directed:

"Beyond the Black Box: An Assessment of Strategic War Gaming," LT Arthur Scott Mobley, Jr., December 1987.

Title:	Application of the Rand Strategy Assessment System (RSAS) at the Naval Postgraduate School
Investigators:	J.J. Tritten, Assistant Professor and Chairman of National Security Affairs Department and R.N. Channell, Adjunct Professor, National Security Affairs
Sponsor:	NPS Foundation Research Program
Objective:	Analysis of capabilities of RSAS to support teaching and research at NPS. Installation of RSAS in War Lab. Training on use of models and experimental analysis.
Summary:	Investigation of RSAS and ability of system to support teaching and research at NPS. System was obtained and installed at NPS War Lab. Faculty were trained on use of models to evaluate alternative political-military strategies and force levels. Experimental simulations were conducted and results presented to students and faculty.
Publications:	J. J. Tritten and R. N. Channell, "The Rand Strategy Assessment System at the Naval Postgraduate School," NPS Technical Report (forthcoming March 1988).

Title: Alternative Structures of European Security

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

Sponsor: Earhart Foundation and Woodrow Wilson International Center for Scholars, Smithsonian Institution

Objective: Advance understanding of alternative structures of European security -- that is, configurations of military power and political alignment affecting security in Europe.

Summary: Research to date has focused on Soviet concepts for political change in Europe, Western policies for long-term change in peacetime, prospects for East-West disengagement, and West European defense cooperation.

Publications: D. S. Yost, Alternative Structures of European Security, Working Paper No. 81 (Washington, D.C.: International Security Studies Program, Woodrow Wilson International Center for Scholars, Smithsonian Institution, 1987).

D. S. Yost, "Soviet Aims in Europe," Society, 24 (July-August 1987), pp. 72-79.

D. S. Yost, "The Reykjavik Summit and European Security," SAIS Review, 7 (Summer/ Fall 1987), pp. 1-22.

Title:	Structural Factors in the Long-Term Competition
Investigator:	D. S. Yost, Associate Professor of National Security Affairs
Sponsor:	Under Secretary of Defense for Policy
Objective:	Advance understanding of structural asymmetries -- particularly political, social, and cultural factors -- in the U.S.-Soviet (and East-West) long-term competition.
Summary:	Project results pending.

DEPARTMENT

OF

PHYSICS

DEPARTMENT OF PHYSICS

During FY87 the research activities in the Physics department consisted of 22 sponsored and one unsponsored individual projects.

Of these 22 projects, 17 (77%) were funded by the Navy, including ONR, NUWES, NEPRF, NSWC, NRL, NAVSEASYSCOM, SPAWARS, NCSC, JDL, and the NPS-Foundation. Three projects were funded by the Air Force, AFWL, MIT-LINCOLN, and USAF Space Division; and one each by DARPA, and DNA.

These projects fall naturally into seven groups. They are:

(1) Acoustics/Underwater Acoustics,
(2) Atmospheric Physics,
(3) Directed Energy Beams/Radiation Physics,
(4) Infrared Technology,
(5) Applications of Non-Equilibrium Statistical Mechanics to C3 Theory,
(6) Surface Science, and
(7) Space Physics, which is a newly developed area of effort.

Although broadly based, this research program is the result of a long term carefully orchestrated evolution, designed to explore the physics of areas where modern technology, particularly Naval weapons technology, is limited by our understanding of the natural environment. As a group, the department specializes in the physics of the interface between weapons systems and the environment.

The nature of the research in each area is outlined here.

Acoustics/Underwater Acoustics

The work in this area falls naturally into three categories: propagation related issues, transducer/sonar systems topics, and thermoacoustic processes, including cavitation. In the propagation area, mechanisms of generation of infrasonic ambient ocean noise (Prof. Nichols), time evolution of acoustic cavitation by short pulses of ultrasound, and interactions of sound and ocean bubble swarms (Prof. Atchley) were investigated. In the transducers/sonar area, sonar location of objects buried in sediment, (Prof. Baker); modeling of sonar transducers, in-service performance monitoring of submarine sonar transducers (Profs. Baker and Wilson), and range studies in conjunction with NUWES (Profs. Esary and Wilson); and absolute calibration of electroacoustic transducers using the reciprocity method, fiber optic directional hydrophone system were vigorously pursued by Prof. Garrett. thermoacoustic heat transport was investigated by Prof. Atchley.

Atmospheric Physics

Our atmospheric physics effort is in two complementary areas: In conjunction with the meteorology department, Prof. Schacher develops models used to investigate the transport and diffusion of atmospheric contaminants over complex terrain at Vandenberg AFB. Prof. Walters studies the properties of laser beams propagating in atmospheric turbulence and the development of techniques for the remote sensing of atmospheric turbulence.

Directed Energy Beams/Radiation Physics

Profs. Buskirk and Neighbours participated in a field experiment to investigate the effects of firing a relativistic, high current electron beam in air. They also studied transition radiation at dielectric interfaces and radiation effects on two types of high temperature superconductors, using the NPS 60 MeV electron facility. Gamma, neutron, and electron damage experiments were also performed on other materials, including operational amplifiers.

Infrared Technology

Our academic Center for Infrared Technology, consisting of Profs. Cooper, Crittenden, Rodeback and Milne, has continued its work on FLIR systems performance assessment. This program includes the development of a low cost laser altimeter (Prof. Crittenden), modification of the prototype AN/SAR-8 for use as a data acquisition system, feasibility studies for the integration of infrared data with that of other combat system sensors, and the evaluation and possible upgrading of performance prediction computer codes (Profs. Milne and Cooper).

Applications of Non-Equilibrium Statistical Mechanics

Large complex non-linear systems, such as a C3 system, have common features which can be theoretically represented by the most general language of statistical mechanics. Prof. Ingber has begun the aggregate modeling of combat system's C3 data into a form suitable for analysis by statistical mechanical techniques. Preliminary studies are being performed on JANUS, a war game.

Surface Science

Prof. Harrison's investigations of the interactions of energetic atomic particles with surfaces are at a more fundamental level than much of the department's research, but they contribute directly to more applied efforts. Understanding of these processes has applications in the fabrication and radiation hardening of electronic chips, and the damage produced on satellite surfaces by the solar wind.

Space Physics

This year, Prof. Olsen initiated an experimental and theoretical research program in satellite charge control using electron and ion sources.

Title: Interaction of Sound and Ocean Bubble Swarms

Investigator: A. A. Atchley, Assistant Professor of Physics

Sponsor: Naval Coastal Systems Center

Objective: To investigate the interaction of sound and ocean bubble swarms in order to understand the role of bubbles in sound attenuation. An end result will be the development of a new acoustic method of measuring bubble densities.

Summary: The long term goal of this project is to supply NCSC with experimental data with which to verify their computer model of attenuation of sound propagating in bubbly ocean water. A necessary part of this goal is to measure the density of bubbles in the water. A method, based on the nonlinear properties of bubble dynamics, was adapted for making these measurements and an apparatus for performing proof of concept experiments was designed and built. The results of these measurements are encouraging. We were able to detect the presence of bubbles ranging in size from approximately 10 to 100 m in radius. The next phase of the project is to work on the data acquisition aspects of the problem. The emphasis will be not only detecting but also counting the bubbles. Once the bubbles can be counted, the density can be inferred. The project will continue under direct funding.

Thesis Directed: S. Hampton, LT, USN, "An Acoustic Bubble Density Measurement Technique for Surface Ship Wakes," Master's Thesis, September 1987.

Title: Investigation of Thermoacoustic Heat Transport

Investigator: A. A. Atchley, Assistant Professor of Physics

Sponsor: NPS Foundation Research Program

Objective: To investigate the fundamental processes involved with thermoacoustic heat transport.

Summary: An experimental investigation of the temperature difference generated across a stack of short plates by an acoustic field was carried out in order to test the validity of the theory of thermoacoustic heat transport. The results of this experiment indicate that the theory is valid only for relatively low acoustic pressure amplitudes. There is a serious discrepancy between theory and experiment when higher acoustic pressures are used. The results indicate that the discrepancy is related to the acoustic particle velocity. Future plans are to perform more extensive measurements in order to investigate the nature of the discrepancy. Another aspect of this research is to study the reverse of the above mentioned experiment - the generation of sound by a plate having a temperature difference across it. The apparatus for this project has been constructed and the measurements are underway. This research project will continue under direct funding as a collaboration with Professor S. L. Garrett. The work is sponsored by ONR.

Conference Presentation: M. Muzzerall, A. A. Atchley and T. J. Hofler, "Acoustically Generated Temperature Gradients in Plates," 114th Meeting of the Acoustical Society of America, Anaheim, CA. November 10-20, 1987.

Thesis Directed: M. L. Muzzerall, CAPT, Canadian Forces, "Investigation of Thermoacoustic Heat Transport Using a Thermoacoustic Couple," Master's Thesis, September 1987.

Title: Time Evolution of Acoustic Cavitation Produced by Short Pulses of Ultrasound

Investigator: A. A. Atchley, Assistant Professor of Physics

Sponsor: NPS Foundation Research Program

Objective: To investigate the time evolution of cavitation events produced by short pulses of ultrasound in order to determine the fundamental mechanisms which govern the phenomenom.

Summary: An experimental apparatus consisting of three major subsystems (sample preparation, ultrasound generation and cavitation detection) was designed, constructed and tested. The apparatus allows for the use of three different detection techniques. All three techniques were tested but extensive measurements were performed with only one. These measurements consisted of measuring the cavitation threshold as a function of the characteristics of the ultrasound pulse used to generate the cavitation. The results of these measurements indicate that the product repetition frequency is an important factor in the time evolution of the cavitation events. This hypothesis will be investigated further using the other two detection techniques. Another aspect of the project is the theoretical investigation of cavitation nucleation mechanisms. This work resulted in a set of general criteria for the activation of cavitation nuclei. Future plans are to relate the above mentioned measurements to this theoretical aspect of the project in order to infer the nature of cavitation nuclei.

Conference Presentation: A. A. Atchley, "General Criteria for Cavitation Nuclei," The Conference for Ultrasonics in Biophysics and Bioengineering, University of Illinois, May 26-29, 1987.

Thesis Directed: R. Bruce, LCDR, USN, and R. Middleton, LT, USN, "Experimental Investigation of Cavitation Produced by Pulsed Ultrasound," Master's Thesis, December 1987.

Title: Feasibility Study of the Use of a Buried Sonar for Echo-Location of Objects in Sediment

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

Sponsor: Naval Undersea Warfare Engineering Station

Objective: The objective of this work was to determine the feasibility of using a buried sonar transducer or array of transducers to echo-locate objects such as torpedos buried in the type of soft sediment characterstic of the test-firing ranges operated by Naval Undersea Warfare Engineering Station (NUWES), Keyport, WA.

Summary: Representative values for the various terms in the Active Sonar Equation, e.g., source level, transmission loss, noise level, target strength, detection threshold, were estimated for the type of sediment found on the test ranges at NUWES. Assuming noise-limited performance, maximum detection range was calculated as a function of transmission frequency from 1 to 20 kHz. It was found that the transmission loss through the sediment limits the useful range of the proposed system to approximately ten meters, rendering it impractical for its intended use. Three alternative systems are proposed for further consideration.

Thesis Directed: R. D. Malmberg, LT, USN, "A Study of the Feasibility of Using a Buried Sonar Transducer to Echo-Locate Objects Buried in Sediment," Master's Thesis, September 1987.

Title: Basic Research in Physical Acoustics and Its Applications

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

Sponsor: Office of Naval Research

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 VI of a continuing program in physical acoustics research.

Summary: During this period we initiated an experiment to test an extension of the reciprocity calibration technique to a magnetohydrodynamic (MHD) transducer in a Helmholtz resonator filled with salted water and to the flexural modes of a resonant bar. We also constructed and tested our first thermoacoustic refrigerator using both helium and a helium/xenon mixture as the working fluid. The experimental test of this refrigerator for space applications passed its first hurdle by being assigned top priority for U.S. Navy Quick Response Shuttle Payload (QSRP) experiments by the Navy Space Test Program (STP).

Publications: G. W. Swift and S. L. Garrett. "Resonance Reciprocity Calibration of an Ultracompliant Transducer," J. Acoust. Soc. Am., 81 (5), pp. 1619-23, 1987.

S. L. Garrett, "Resonant Reciprocity Calibration of Conventional, Magnetohydrodynamic, and Quantumfluidic Transducers," J. Acoust. Soc. Am. 80, p. S46, Fall 1986.

G. W. Swift and S. L. Garrett, "Resonant Reciprocity Calibration of an Ultracompliant Transducer," J. Acoust. Soc. Am., 80, p. S25, Fall 1986.

Conference Presentations: S. L. Garrett, "Resonant Reciprocity Calibration of Conventional, Magnetohydrodynamic, and Quantumfluidic Transducers," 112th Meeting, J. Acoust. Soc. Am. 80, p. S46. Anaheim, CA, 8-12 December 1986.

Conference Presentations: (cont.)

G. W. Swift and S. L. Garrett, "Resonant Reciprocity Calibration of an Ultracompliant Transducer," 112th Meeting, J. Acoust. Soc. Am., 80, p. S25, Anaheim, CA, 8-12 December 1986.

S. L. Garrett, T. Holfer, and A. A. Atchley. "Space Thermo-acoustic Refrigerator," Navy Annual Space Test Program (STP) Experiments Conference, Monterey, CA, 18-19 March 1987.

Title: Fiber Optic Directional Hydrophone System

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

Sponsor: Space and Naval Warfare Systems 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: This was the third year of support for a program to develop an all optical equivalent of a DIFAR-like compact directional hydrophone system. The system consists of a pair of seismometer style, neutrally bouyant, fiber optic interferometric bi-directional hydrophones and an interferometric omnidirectional hydrophone. The three hydrophone signals can be combined to steer a cardiod array pattern throughout all azimuth. The system also includes a fiber optically read magnetic compass to relate heading information to the array beam axis. Sufficient progress was made during this period that further details are now classified.

Publications:

D. L. Gardner, T. Holfer, S. R. Baker, R. K. Yarber, and S. L. Garrett, "A Fiber-Optic Interferometric Seismometer," J. Lightwave Tech, LT-5(7), 1987, pp. 953-960.

J. T. Newmaster, M. R. Brininstool, T. Holfer, and S. L. Garrett, "Channel Reduction Schemes for Fiber Optic Angle Encoders," Fiber and Integrated Optics, 7(2), Forthcoming.

D. L. Gardner, R. K. Yarber, E. F. Carome, and S. L. Garrett, "A Fiber Optic Interferomeric Geophone," J. Acoust. Soc. Am., 80, p. S7, Fall 1986.

D. L. Gardner and S. L. Garrett, "Fiber Optic Seismic Sensor," Fiber Optic and Laser Sensors V, R. P. DePaula and E. Udd, editors, Proc. Soc. Photo-Optical Inst. Eng.: SPIE 838, Forthcoming.

J. T. Newmaster, M. R. Brininstool, T. Holfer, and S. L. Garrett, "Remote Fiber Optic Sensors for Angular Orientation," Fiber Optic and Laser Sensors V, R. P. DePaula and E. Udd, editors, Proc. Soc. Photo-Optical Inst. Eng.: SPIE 838, Forthcoming.

Publications: (cont.)

C. M. Crooker and S. L. Garrett, "Fringe Rate Demodulator for Fiber Optic Interferometric Sensors," Fiber Optic and Laser Sensors V, R. P. DePaula and E. Udd, editors, Proc. Soc. Photo-Optical Inst. Eng.: SPIE 838, Forthcoming.

Conference Presentations:

S. L. Garrett, "Fiber Optic Seismic Sensors for Battlefield Surveillance," 14th Meeting of NATO AC/243, Panel III, Research Study Group 11 (RSG. 11), 28-30 October 1986.

D. L. Gardner, R. K. Yarber, E. F. Carome, and S. L. Garrett, "A Fiber-Optic Interferometric Geophone," J. Acoust. Soc. Am., 80, p. S7, Anaheim, CA, 8-12 December 1986.

C. M. Crooker and S. L. Garrett, "Fringe Counting Demodulator for Fiber Optic Interferometric Sensors," J. Acoust. Soc. Am., 80, p. S26, Anaheim, Ca, 8-12 December 1986.

D. L. Gardner, R. K. Yarber, E. F. Carome, and S. L. Garrett, "Fiber Optic Interferometric Geophone with Hydrophone Applications," 6th International Conference with Integrated Optics and Optical Fiber Communications, Reno, NV. 19-22 January 1987.

S. L. Garrett, D. L. Gardner, R. K. Yarber, C. M. Crooker, J. T. Newmaster, M. R. Brininstool, and E. F. Carome, "Toward an Entirely Fiber Optical Compact Directional Hydrophone System," Integrated Undersea Surveillance System (IUSS) Tech. Review, Naval Ocean Systems Center, San Diego, 2-6 February 1987.

Theses Directed:

D. L. Gardner, LCDR, NOAA. "A Fiber-Optic Interferometric Seismic Sensor with Hydrophone Applications," Doctoral Thesis in Engineering Acoustics, September 1987.

J. T. Newmaster, LT, USN, "Remote Fiber Optic Angular Orientation Sensor with Compass Applications," Master's Thesis, September 1987.

Patent Application:

S. L. Garrett and D. L. Gardner, "Multiple Axis, Fiber Optic Seismic Sensor," Navy Case No. 70625

Title: Classical Trajectory Simulation Studies of the Ion Bombardment of Rh(111) Surfaces Using Embedded Atom Model Potential Functions

Investigator: D. E. Harrison, Jr., Professor of Physics

Sponsor: None

Objective: To develop an Embedded Atom Model (EAM) version of QDYN, the existing Ion Bombardment computer model used at NPS. To use this program to validate other EAM model programs developed at Cal. Tech. and Penn. State University. To compare the results from this model with previous research results based on the pair-potential model.

This program, EDYN, is to be used as the basis for a third generation program designed to study the ion bombardment of semiconductor surfaces.

Summary: Classical trajectory simulations based on EAM potential functions were used to investigate the sputtering of Rh(111) surfaces by Ar+ ions in the energy range between 500 eV and 5.0 keV. Two potentials were examined in detail.

Publications: B. J. Garrison, N. Winograd, D. Lo, T. A. Tombrello, M. H. Shapiro, and D. E. Harrison, Jr., "Energy Cost to Sputter an Atom from a Surface in keV Ion Bombardment Processes," Surface Science 80, pp. L129-133, 1987.

B. J. Garrison, C. T. Reimann, N. Winograd, and D. E. Harrison, Jr., " Energy and Angular Distributions of Rh Atoms Ejected due to Ion Bombardment from Rh(111): A Theoretical Study," Physical Review B1 36(7), pp. 3516-3521, 1987.

Conference Presentation: B. J. Garrison*, N. Winograd, D. M. Deavens, C. T. Reimann, D. Y. Lo, T. A. Tombrello, D. E. Harrison, Jr., and M. H. Shapiro, "Many Body Interactions for Theoretical Studies of keV Particle Bombardment, Secondary Ion Mass Spectrometry," SIMS VI, Versailles, France, 14-18 September 1987. (*presented paper).

Title: Modeling C3 of Combat Systems Statistical Mechanics Application of Biological Intelligence

Investigator: L. Ingber, Professor of Physics

Sponsor: Joint Directors of Laboratories

Objective: To develop approach to model aggregate data from large scale combat simulation.

Summary: A new method, "two temperature fast simulated annealing" was developed to fit data from combat simulations to short-time probability distributions of Gaussian-Markovian functional form. The Lagrangian of such a distribution is used as a "cost function" to fit parameters of the theory, e.g., as they typically enter as coefficients of polynomicals of the underlying (attrition or force) variables. These methods were tested and validated to known solutions, then used to fit data from JANUS simulation.

Publications:

J. Connell, L. Ingber, and C. Yost, "Statistical Mechanical Virtual Neural Computer," 1987 Symposium on C3 Research, Forthcoming.

L. Ingber, "Applications of Biological Intelligence to Command, Control, and Communications," in Computer Simulation in Brain Science, edited by R. Cotterill, Forthcoming.

L. Ingber and T. R. Moore, "Proposal for Real-Time Use of C3 Models Using Optical Associative Memories." NPS Report NPS-61-87-006, 1987.

L. Ingber, "C3 Decision Aids: Statistical Mechanics Application of Biological Intelligence," 1987 Symposium on C3, Forthcoming.

L. Ingber, "Mesoscales in Neocortex and in Command, Control and Communications (C3) Systems," Systems with Learning and Memory Abilities, edited by J. Delacour, Forthcoming.

L. Ingber, "Statistical Mechanics of Mesoscales in Neocortex and in Command, Control and Communications (C3) Systems," Sixth International Conference on Mathematical Modeling, Forthcoming.

Conference Presentations:

L. Ingber, "C3 Aids Decision Aids: Statistical Mechanics Application of Biological Intelligence," 1987 C3 Symposium on C3 Research, National Defense University, Washington, DC, 16-18 June 1987.

L. Ingber, "Mesoscales in Neocortex and in Command, Control and Communications (C3) Systems," Systems with Learning and Memory Abilities, Laboratorie de Psychphysiologie, University of Paris, Paris, France, 15-19 June 1987.

L. Ingber, "Statistical Mechanics of Mesoscales in Neocortex and in Command, Control and Communications (C3) Systems," Statistical Mechanics of Mesoscales in Large Systems, NPS, Monterey, CA, 27-29 July 1987.

L. Ingber, "Statistical Mechanics of Mesoscales in Neocortex and in Command, Control and Communications (C3) Systems," Sixth International Conference on Mathematical Modeling, Washington University, St. Louis, Missouri, 4-7 August 1987.

Theses Directed:

S. Upton, CAPT, USMC, "A Statistical Mechanics Model of Combat," Master's Thesis, March 1987.

J. C. Connell, Jr., CDR, USN, "Virtual Statistical Mechanical Neural Computer: Large Systems Scaling Algorithm and C3 Applications," Master's Thesis, December 1987.

C. P. Yost, LCDR, USN, "Statistical Mechanical Neural Computer: C3 Applications," Master's Thesis, December 1987.

W. Bogan, LT, USN, "Statistical Mechanics Model of IBGTT Outer-Air Battle," Master's Thesis, December 1988.

Title: Satellite Charge Control with Electron and Ion Sources

Investigator: R. C. Olsen, Associate Professor of Physics

Sponsor: NPS Foundation Research Program

Objective: To establish a program in satellite charge control, for low altitude (shuttle/space station) and high altitude (geosynchronous) satellites. In particular to establish the data analysis system, and laboratory system needed for such work. This was the initial year of a two year program.

Summary: The study of a satellite charge control requires an understanding of previously acquired data, the development of new hardware, and ultimately new flight experiments. The analysis of data from previous experiments requires computational facilities similar to those used elsewhere in the space physics community, and networking with those facilities. Towards that end, a MicroVax II GPX graphics workstation has been installed. The computer arrived late in the reporting period (August), and did not see extensive use. Laboratory hardware was ordered, but not received during the reporting period. Analysis of previously reduced data was begun.

Title: Vandenberg AFB Range Safety Handbook

Investigators: G. Schacher, Professor of Physics, R. Kamada, Adjunct Research Professor of Physics, C. Skupniewicz, Meteorologist, T. Mikkelson, RISO, Denmark, Ib Troen, and E. Takle, Iowa State University

Sponsor: U.S. Air Force Space Division

Objective: To develop a handbook to assess the impact of accidental releases of hazardous materials.

Summary: Vandenberg AFB is an area of very complex meteorology, in particular the low marine inversion and complex terrain. There are no models which can adequately predict atmospheric transport and diffusion in this area. The purpose of this work is to develop an empirical flow model and a puff diffusion model for the area and to use these models to produce the basis for a hazard assessment handbook. The models have been developed, the prevalent meteorological scenarios for the area determined, and hazardous situations identified. The composition of the handbook is nearly complete. This project involves NPS, RISO National Laboratory, Denmark, and Iowa State University.

Publications:

J. D. Foot and E. C. Takle, "Evaluation of an Alternative Method for Numerically Modeling Nonhydrostatic Flows over Irregular Terrain," Boundary Layer Meteorology, 1988.

C. E. Skupniewicz and G. E. Schacher, "Modification of Sea Breeze Surface Layer Flows Above the Marine Boundary Layers," Proceedings of the 4th Conference on Meteorology and Oceanography of the Coastal Zone, American Meteorological Society, 1988.

C. E. Skupniewicz and G. E. Schacher, "Turbulence Intensity through the Energy Producing Frequencies of the Horizontal Velocity Spectra," Forthcoming.

S. Thykier-Nielsen, T. Mikkelson, S. E. Larsen, I. Troen, A. de Baas, R. Kamada, C. Skupniewicz and G. E. Schacher, "A Model for Accidental Releases in Complex Terrain," 7th International Technical Meeting on Air Pollution Modeling and its Applications, Cambridge, England.

Title: Optical Communication Link Atmospheric Measurements

Investigator: D. L. Walters, Associate Professor of Physics

Sponsor: MIT Lincoln Laboratory (USAF)

Objective: To perform site evaluation measurements of the atmospheric isoplanatic angle and modulation transfer function that will permit the characterization and selection of a geosynchronous to ground laser communication link experiment.

Summary: This is an ongoing effort where we perform atmospheric modulation transfer function, isoplanatic angle, and acoustic echosounder measurements of the atmospheric degradations above mountain sites on a seasonal basis. We have found that the surface based turbulence can be very low at sites near the Pacific coastal mountain ranges. In addition the upper atmospheric isoplanatic angles can by very high between major cold fronts. Exceptionally high atmospheric modulation transfer function measurements have been collected that track with the upper atmospheric isoplanatic angle measurements. This is the first time this has been observed.

Theses Directed: M. R. Wroblewski, LT, USCG, "Development of a Data Analysis System for the Detection of Lower Level Atmospheric Turbulence with an Acoustic Sounder," Master's Thesis, June 1987.

F. J. Weingartner, LT, USN, "Development of an Acoustic Echosounder for Detection of Lower Level Atmospheric Turbulence," Master's Thesis, June 1987.

Title: Remote Atmospheric Optical Turbulence Systems

Investigator: D. L. Walters, Associate Professor of Physics

Sponsor: Air Force Weapons Laboratory

Objective: To develop and deliver remote sensor equipment for use at a classified test range.

Summary: This has been a continuing project since 1985. I have been developing and refining remote atmospheric optical equipment for characterizing the turbulent degradations induced by the atmosphere on laser propagation. I have developed standardized atmospheric isoplanatic angle and modulation transfer function instrument as well as acoustic sounder techniques for quantifying these degradations. Three of these systems have been delivered to the Air Force during FY87 for use when we are unable to provide direct support.

Publications: T. R. Moore and D. L. Walters, "Observations on Centrosymmetric and Asymmetric Scattering in Barium Titanate," Journal of the Optical Society of America, 1986.

T. R. Moore and D. L. Walters, "Characterization of Asymmetric Self-Defocusing and Centrosymmetric Scattering in Barium Titanate," Society of Photo-Optics Instrumentation Engineers, Forthcoming.

Theses Directed: T. R. Moore, LT, USN, "Determination of the Origin of Self-Pumped Phase Conjugation in Barium Titanate," Master's Thesis, June 1987.

G. Unal, LTJG, Turkish Navy, "Measurements of the Microscopic Properties Contributing to Photorefraction in Barium Titanate," Master's Thesis, December 1986.

Title: In-Service Performance Monitoring of Submarine Sonar Transducers

Investigators: O. B. Wilson, Professor of Physics and S.R. Baker, Assistant Professor of Physics

Sponsor: Naval Sea Systems Command (PMS 390-E-57 and -58) and Naval Research Laboratory, Underwater Sound Reference Detachment

Objective: The primary objectives are (1) to take advantage of state-of-the-art computer-controlled measuring instruments to help improve the quality of the in-service measurements conducted in the field on fleet sonar transducers by Navy technicians as an aid in making of maintenance decisions, and (2) to use the power of small computers to provide the technician in the field the capability to estimate sonar transducer array performance. This is a continuing program.

Summary: With significant efforts of our students, there has been significant progress towards both objectives:

-- The work on the Complex Immittance Measuring system done in FY86 has led to its adoption as a NAVSEA-approved procedure for the DT-276 hydrophone and the development of a specialized portable instrument package for carrying out the procedure.

-- In-situ reciprocity calibration.

-- Applications of these procedures to other transducers in submarine sonars are ready for field-tresing by fleet personnel.

-- Array performance algorithms developed and are being field-tested.

-- Inboard phasing techniques developed and are being field-tested.

Publication: G. B. Kerr, P. M. O'Neill, O. B. Wilson and S. R. Baker, "Automated In-Situ Measurement of Hydrophone Sensitivity for Hull-Mounted Submarine Sonar Arrays Using a Reciprocity Method," 112th Meeting of the Acoustical Society of America, J. Acoust. Soc. Am. 80 S1, p. S27, December 1986.

Conference Presentation: G. B. Kerr, P. M. O'Neill, O. B. Wilson and S. R. Baker, "Automated In-Situ Measurement of Hydrophone Sensitivity for Hull-Mounted Submarine Sonar Arrays Using a Reciprocity Method," 112th Meeting of the Acoustical Society of America, Anaheim, CA, 8-12 December 1986.

Theses Directed: G. B. Kerr, LT, USN and P. M. O'Neill, LT, USN, "Automated In-Service Sonar Array Performance Monitoring," Master's Thesis, December 1986.

S. A. Taylor, LCDR, Royal Australian Navy, "In-Service Sensitivity Measurement of the Mulloka Sonar Transducer," Master's Thesis, March 1987.

D. E. Westbrook, LT, USN, "Application of Automated In-Service Monitoring Techniques to the AN/BQQ-5 Spherical Array Transducers," Master's Thesis, June 1987.

Title: Modeling of Sonar Transducers

Investigators: O. B. Wilson, Professor of Physics, S. R. Baker, Assistant Professor of Physics, J. -N. Decarpigny, Adjunct Research Professor of Physics, J. -C. Debus, Adjunct Research Professor of Physics

Sponsor: Naval Research Laboratory, Underwater Sound Reference Detachment and Naval Sea Systems Command (PMS 390-E-57 and -58)

Objective: The objectives were to adapt the finite-element computer code ATILA, developed by Decarpigny and Debus at the Institut Superieur Electronique du Nord, for running on NPS VAX computers, prepare an American version of a user manual for the use of the ATILA in sonar transducer analysis and design, and run a workshop on use of ATILA. A secondary objective was to apply ATILA to the analysis of the effects of rubber debonding on the vibrational modes of the DT-276 hydrophone.

Summary: During the summer of 1987 ATILA was installed on the Computer Science Department's VMS VAX. A four-day workshop was run in August which was attended by about ten persons. Several were from NPS, three from the Naval Undersea Systems Center, New London, two from the Naval Research Laboratory, Orlando, and one from the Naval Ocean Systems Center. A user manual in English was prepared, published and distributed. In addition, NPS played the role of host for a one-day workshop on another transducer modeling method, TEA, which was attended by those here for the ATILA workshop and about ten others from industry and Naval laboratories. Some initial progress was made in studying the effects of the delamination of the rubber coatings on the vibrational modes of the DT-276 hydrophone.

Publication: J. -N. Decarpigny and J. -C. Debus, "User Manual for ATILA, a Finite-Element Code for Modeling Piezoelectric Transducers," NPS Report NPS61-87-007, August 1987.

Title:	The Range Studies Program
Investigators:	O.B. Wilson, Professor of Physics, and J.D. Esary, Professor of Operations Research
Sponsor:	Naval Undersea Warfare Engineering Station
Objective:	The objectives of this continuing program are to help support the long-term development problems of the Undersea Warfare Engineering Station in its work on the testing of underwater weapons.
Summary:	This has involved both faculty members and students from a number of academic disciplines and curricula. The investigators named play two roles, one as a coordinator of activities of individual task investigators and second as task investigators.
Publication:	O. B. Wilson and J. D. Esary, "Annual Summary Report, Range Studies Program," NPS Report NPS-61-87-002, December 1986.

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, systems and controls, electromagnetics, radar and electronic warfare, communications and computer engineering. Most projects involve the efforts of thesis students, as is indicated by the number of theses published in support of each project.

SIGNAL PROCESSING

Spectral parameter estimation methods were developed by Professor R.D. Hippenstiel using extensions to the autoregressive moving average (ARMA) model. The goal is to estimate either the poles and zeros of signals or the equivalent network transfer function.

Professor Murali Tummala continued his investigation of adaptive algorithms for normalized lattice filters. His new approach assures stability of the filter by forcing the system poles to reside within the unit circle in the z-plane. Initial simulations have shown improvement in convergence speed.

Professor John Powers continued a joint project with the Aeronautics Department to develop techniques for obtaining quantitative particle size data within the combuster and across the exhaust nozzle of solid propellent rocket motors. Various methods are being considered such as holography and forward scattered light measurements.

Professor M.A. Morgan continued research in the development of optimized signal processing algorithms for identifying radar targets using their aspect independent natural resonances. Using transient scattering signatures from scale model aircraft, classifications versus signal fidelity and bandwidth were found.

The development of a time-invariant, space-variant, random transfer function of the ocean volume was investigated by Professor Lawrence Ziomek. This development uses 3-D ray acoustics coupled with its associated coherence function to yield the electrical signal at each point-source element of a planar array.

Various digital image processing techniques were considered in the work of Professor C.W. Therrien, as directed towards enhancing video images of underwater objects during recovery in turbid water. This has included adaptive filtering, histogram equalization and noise removal methods. Analysis of computations and other considerations was initiated.

SYSTEMS AND CONTROLS

Professors Roberto Cristi and Sherif Michael began the development of a parallel processor for adaptive control applications. A recursive least squares identification algorithm was devised for parallel processor implementation. Results pertaining to the stability and convergence of adaptive controllers was formulated.

Professor R. Panholzer headed the continuation of a multi-disciplinary project directed towards design refinement and concept assessment for a small, low cost, full capability general purpose satellite.

ELECTROMAGNETICS

A new generalized potential formulation for electromagnetic fields in inhomogeneous media was developed by Professor Morgan. This formulation has been tested and is being implemented via the numerical finite element method to solve for scattering from complex material objects.

The efficiency of energy transmission via a slowly decaying pulse was investigated by Professor H.M. Lee. Fields generated by a switched uniform circular current distribution were computed and it was confirmed that energy decay is slower than the inverse square of the distance along the broadside axis.

Professor Powers continued work on a linear systems approach to the modeling of propagation of pulsed and transient ultrasound waves in lossless and lossy media. The technique, which employs spatial frequency domain techniques, allows the application of computer-efficient FFT algorithms in lieu of methods involving complicated line integral evaluations.

RADAR AND ELECTRONIC WARFARE

Professors Jeffrey Knorr and Glen Myers investigated the feasibility of frequency hopping as an ECCM technique with analog messages. An advantage over the use of digital messages is the lack of a periodic clock signal thus allowing analog messages to have random frequency hopping. Currently a prototype system is being constructed as an M.S. Thesis.

Professor M.A. Morgan is investigating the viability of obtaining narrow pulse signatures radar targets using measured random noise scattering. This has the potential of providing a low-cost broad-band laboratory tool for scattering experiments as well as offering high resolution, but passive, radar sensors for use in hostile situations.

RADAR AND ELECTRONIC WARFARE (cont.)

Professor C.W. Therrien developed digital signal processing models for the radar cross section (RCS) of certain types of range-extended targets. A 2-D stochastic model was used to describe the space-time dependence of the the measured RCS and dual-polarized coherent RCS data was analyzed.

Professor H.M. Lee investigated the Navy's capability in defending against skimmer missiles. Propagation of radar signals along the spherical ocean surface was studied and an engineering design of digital signal processing aids to SRAWW was commenced.

COMMUNICATIONS

Professor Paul Moose developed adaptive algorithms for obtaining high quality uninterrupted telemetry data at PMTC from its distributed network of telemetry receivers. This algorithm automatically selects the best source or combination of sources. Initial simulations have been made to confirm the theory.

Professor Daniel Bukofzer considered the effectiveness of jamming techniques in spread spectrum communications systems. The emphasis of this work has been on frequency hopping methods and will, to some extent, influence the direction the U.S. Navy takes in enhancing its ability to jam communications at the battle group level.

An investigation of cyclic spectral analysis algorithms and computational structures was conducted by Professor H.H. Loomis for the purposes of detection and classification of spread spectrum signals in noise and interference.

Another project carried out by Professor Loomis considered algorithms for the detection of communications signals in noise and interference with the discovery of detector performance bounds being made.

A fiber optic telemetry unit was designed, built and successfully deployed by Professor J.P. Powers in monitoring the operating voltage of a long-life seawater battery in Monterey Bay. This is an interdisciplinary effort, in conjunction with the Oceanography Department.

COMPUTER ENGINEERING

A knowledge based expert system for image identification was developed by Professor Chin-Hwa Lee. This prototype system has been used to compare digitized aerial photographs with 3-D geometric models of a building. Differences are reported by way of an artificial intelligence (AI) inference mechanism.

COMPUTER ENGINEERING (cont.)

A microprocessor controlled experiment for the evaluation of silicon and gallium arsenide (GaAs) solar cells was developed by Professors Michael and Fuhs. This experimental device was very effective in recording solar cell data at a remote location.

Professor C.H. Lee continued his work in the use of highspeed and high-density VHSIC chips in tactical image processing systems. Inherent in the task was the development of a gate array design to solve timing problems.

Professor J.T. Butler developed new synthesis techniques for multi-valued CCD logic circuits which can provide specified functions as a computer-aided design (CAD) tool. In a separate project with NSF, Professor Butler investigated the development of CAD tools using multi-valued circuits.

Professor H.H. Loomis investigated computer algorithms and architectures for the production, distribution and analysis of tactical information. This included architectures of spaceborne computer systems.

Title: Effectiveness of Jamming Techniques in Spread Spectrum Communication Systems

Investigator: Daniel Bukofzer, Assistant Professor of Electrical and Computer Engineering

Sponsor: Naval Ocean Systems Center

Summary: The focus has been on frequency hopped spread spectrum systems due to sponsor requirements and the fact that such systems are of greatest tactical interest. Jamming approaches were considered and effects evaluated. Additionally the feasibility of frequency hopped analog modulated signal transmission was investigated and operational problems discovered. The activities carried out will influence to some extent the direction the U.S. Navy takes in building up its ability to provide communications jamming capabilities with each battle group. Previous work on jamming has been to a limited extent incorporated in our EC4560 (ECCM) course.

Title: On the Design of Multiple-Valued CCD VLSI Circuits

Investigators: J. T. Butler, Professor of Electrical and Computer Engineering and Hans G. Kerkhoff, Dr. Ir., University of Twente, The Netherlands

Sponsor: NATO

Objective: Development of synthesis techniques for the new multiple-valued CCD logic circuits.

Summary: My contribution is the development of synthesis techniques for the new multiple-valued CCD logic circuits. These will be used to produce circuits with specified functions, and will become part of a computer-aided design tool. The circuits are fabricated at the University of Twente under the direction of H. G. Kerkhoff.

Title:	Development of CAD Tools for Multiple-Valued Circuits
Investigators:	J. T. Butler, Professor of Electrical and Computer Engineering
Sponsor:	NSF
Objective:	To develop computer-aided design tools.
Summary:	This is a new project in which CAD tools due to be developed for the multiple-valued CCD programmable logic-arrays designed under a previous NATO grant. This effort is intended to help bring to the U.S. a technology in which Dutch researchers are much further ahead.

Title: A VLSI Application to Adaptive Control

Investigator: Roberto Cristi, Sherif Michael, Assistant Professors of Electrical and Computer Engineering

Sponsor: NPS Foundation Research Program

Objective: This project aims at the study of a parallel processor dedicated to Adaptive Control applications.

Summary: As a first stage in this study we devised a Recursive Least Squares identification algorithm in a form suitable to the implementation on a parallel processor. In particular mathematical techniques (such as QR factorization and Givens Rotation) have been applied to achieve the desired form of the algorithm. Furthermore, the identification algorithm mentioned above has been combined into the controller structure in order to achieve the desired control actions.

Meanwhile some results pertaining to the stability and convergence of Adaptive Controllers have been formulated. In particular, the problem of concern was the convergence of the estimated parameters to their correct values, and the behavior of the adaptive algorithm in the vicinity of unstabilizable plant estimates.

Publications:

R. Cristi, S. Michael, "An Adaptive Algorithm for Control of a DC Motor on Systolic Arrays," Proc. Asilomar Conference on Circuits, Systems and Computers, Pacific Grove, CA, November 1986.

R. Cristi, "Parallel Processing in the Adaptive Control of Linear Systems," in Linear Algebra in Signals, Systems and Control, B. Nath Datta Editor, SIAM (to appear).

R. Cristi, "A Note on Indirect Adaptive Control with Stabilizable Plant Estimates," IEEE Transactions on Automatic Control, Vol. AC-31, November 1987.

R. Cristi, "Internal Persistency of Excitation in Indirect Adaptive Control," IEEE Transactions on Automatic Control, Vol AC-32, December 1987.

Title: Fixed Distributed Systems: Environmental Acoustics and Fiber Optic Communications

Investigators: Calvin Dunlap, Adjunct Research Professor of Oceanography, and John Powers, Professor of Electrical and Computer Engineering

Sponsor: 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 cables for transmitting the data. This report is on the fiber optic telemetry portion of this project.

Summary: A fiber optic telemetry unit used to monitor the operating voltage of a long-life seawater battery was designed and successfully deployed for a short-time test in Monterey Bay.

Design efforts continued on a multi-channel fiber optic data link from undersea experiments to shore. Three approaches were 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 active filters separate and detect the channels. The second approach uses a high-speed A/D converter 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. The third approach studied the use of code division multiplexing to all several channels of information to be transmitted simultaneously.

Theses Directed: "Implementation of an IBM/AT as a GPIB controller", LT G.H. Self, Jr., USCG, MSEE, Dec. 1986.

"Fiber optic implementation of MIL STD-1553: a serial bus protocol," CAPT R.S. Wester, USAF, MSEE, Dec. 1986.

"An underwater seawater battery monitor and telemetry recording system," LCDR E.R. Gibson, USN, MSEE, Dec. 1986.

"The design and testing of an analog optical communication link capable of simultaneous transmission of four frequency division multiplexed signals," LT M.S. Silvers, USN, MSEE, June 1987.

Theses Directed: (cont.)

"Code division multiple access applied to fiber optic data transmission," LT T.A. Fischer, USN, MSEE, Sep. 1987.

"Design and implementation of a fiber optic RS232 link," LT J.W. Ryan, USN, MSEE, Sep. 1987.

Title: Photovoltaic Power Technology

Investigators: A. Fuhs, Distinguished Professor of Electrical and Computer Engineering and Sherif Michael, Assistant Professor of Electrical and Computer Engineering

Sponsor: SPAWAR

Objective: To develop Microprocessor controlled experiment for the evaluation of Silicon and Gallium Arsenide solar cells. To investigate the novel approach of forward biased current annealing of radiation damaged GaAs cells, and to investigate the spectral response of damaged cells in solar concentrators.

Summary: All objectives of the project were met successfully. The microprocessor based experiment has proven to be a very effective method to record remotely and accurately solar cell data. The approach was demonstrated earlier in a publication by S. Michael. The results of the investigation of current annealing of radiation damaged GaAs cells were very promising. This could lead to a novel technique to extend the end of life of orbiting satellites, by annealing their solar power panels in orbit. A GaAs solar concentrator and currently a Fresnel lens demonstrated the advantage of using concentrators to improve cells efficiencies and radiation protection. The project resulted in several theses and it was extended to the end of 1987. A publication in a national conference is also expected.

Thesis Directed: "Forward Biased Current Annealing of Radiation Damaged Gallium Arsenide and Silicon Solar Cells," by Lt. Richard Staats, M.S.E.E., Sept. 1987.

Title: Propagation of Scalar Acoustic Waves

Investigators: Daniel Guyomar (former NRC Research Associate) and John Powers, Professor of Electrical and Computer Engineering

Sponsor: Unsponsored

Objective: To apply spatial frequency domain techniques to modeling the propagation of pulsed and transient ultrasound waves in lossless and lossy media. The technique would allow the application of computer-efficient FFT algorithms to problems that have previously used complicated line integrals for evaluation.

Summary: A linear systems approach has been identified which provides a simplified explanation of the work of the prior years. This approach relates the Green's function and the total impulse response and identifies the transfer propagation function (in the spatial frequency domain) as the two-dimensional spatial transform of the Green's function.

Publications: D. Guyomar and J. Powers, "A Fourier approach to diffraction of pulsed ultrasonic waves in lossless media", Journal of the Acoustical Society of America, 82(1), pp. 354-359, 1987.

D. Guyomar and J. Powers, "A transfer function model for propagation in homogeneous media," Pattern Recognition and Acoustic Imaging, Vol. 768, Society of Photo-optical Instrumentation Engineers, Bellingham WA), pp. 253-258, 1987.

Conference Presentations: D. Guyomar and J. Powers, "A transfer function approach to transient propagation in media with a quadratic frequency dependence of attenuation coefficient," presented at the 112th meeting of the Acoustical Society of America, Anaheim CA, 8-12 December 1986.

D. Guyomar and J. Powers, "Transfer function model for propagation in homogeneous media," presented at the International Symposium on pattern Recognition and Acoustical Imaging, Newport Beach CA, 1-6 February 1987.

Thesis Directed: "A transfer function approach to scalar wave propagation in lossy and lossless media," LT T.D. Merrill, USN, MSEE, Mar. 1987.

Title:	Spectral Estimation Via a Parametric Approach
Investigator:	R.D. Hippenstiel, Assistant Professor of Electrical and Computer Engineering
Sponsor:	NPS Foundation Research Program
Objective:	To estimate spectral parameters or equivalently the network transfer function when both poles and zeros are present.
Summary:	Coefficients of an Autoregressive-Moving Average (AR-MA) model are obtained using a sequential technique. AR and MA coefficients are estimated separately using correlation estimate refinements as the estimation progresses. The AR coefficients are obtained via an extended Yule-Wallser equation approach in which as the estimation progresses correlation estimates closer to the origin are used. In addition the correlation coefficients are filtered pending the previous computation of coefficients. The MA coefficients are obtained using matrix properties. The order of the MA network is restricted to 3 or less with extensions under consideration. If the extension to an arbitrary order "g" is not possible, cascaded (repeated) application of low order networks is suggested.
Conference Presentation:	21st Annual Asilomar Conference on Signals, Systems and Computers, Nov. 2-4, 1987

Title: Advanced Electronic Warfare Systems

Investigators: Jeffrey Knorr, Professor of Electrical and Computer Engineering and Glen Myers, Associate Professor of Electrical and Computer Engineering

Sponsor: Naval Space Warfare Systems Command

Objective: The investigation concerned frequency hopping (FH) with analog messages. Feasibility was established and modulation format defined. This communication ECCM technique is of interest to DoD. All previously known FH systems transmit digital messages. A shortcoming of those is the required clock (periodic). With analog messages, the hopping can be random. A student is presently building such a FH system as part of his MSEE thesis requirement. The material will be incorporated into ECE 4560.

Title: Knowledge Based Expert System for Image Understanding

Investigator: C. H. Lee, Associate Professor of Electrical and Computer Engineering

Sponsor: Defense Mapping Agency

Objective: Apply knowledge-based AI techniques to Image Understanding. Implement a prototype photo-interpretation assistant system to process aerial photographs.

Summary: A knowledge-based expert system for photo-interpretation is prototyped in this project. This system will compare input aerial photographs with a 3-D geometric model of a building and report changes to the user. The PROLOG interpreter is used to build the knowledge-base and the inference mechanism. Image processing operators were written in FORTRAN and PASCAL. These modules work in cooperation to accomplish the image understanding task. A number of inference rules and image processing rules are used in this system to draw conclusions about the input images. Experience of testing these rules leads to insight into worthwhile further studies.

Publication: C. H. Lee, "Model-based Building Verification in Aerial Photographs," Proceedings of the Workshop on Computer Vision, Nov. 30, 1987

Theses Directed: Diego L. Rueda, "Image Interpretation Using an Expert System," M. S. Thesis, Dec. 1986.

James, Chauncy McDougall, "An Application of a Gradient Relaxation Method to Noisy Infrared Images," M. S. Thesis, June 1987.

Title:	VHSIC Design Methodology and System Applications
Investigator:	C. H. Lee, Associate Professor, Department of Electrical and Computer Engineering
Sponsor:	Naval Ocean Systems Center
Objective:	Demonstrate the insertion of high speed and high density VHSIC chips in tactical image processing systems.
Summary:	Most Phase I VHSIC chips work at a 25 MHz clock rate, and many of the VHSIC processors are highly pipelined internally. To develop a prototype using these chips requires solving more timing problems than in non-VHSIC designs. Specifically, to provide setup data and take the results away from these chips turns out to be quite involved. A gate array design can solve the speed problem mentioned previously. It should be able to generate fast control signals and reduce the delay time to a minimum. The study of the gate array approach reveals that a large volume initial requirement is difficult to satisfy. The CAD tools for gate array design are also very expensive.
Conference Presentations:	C. H. Lee, "An Image Processing Algorithm Design for the TRW Content Addressable Memory (CAM)," VHSIC Insertion Workshop, Nov. 4, 1986.
Thesis Directed:	Darrel W. Purdy, "Implementation of an FIR Band Pass Filter Using a Bit-slice Processor," M.S. Thesis, June 1987.

Title: Directed, Slowly Decaying Pulses

Investigator: Hung Mou Lee, Associate Professor of Electrical and Computer Engineering

Sponsor: Office of Naval Research

Objective: To determine the efficiency of energy transmission via a slowly decaying pulse called on "electromagnetic missile" and to determine the conditions required to generate such pulses. This project is of interest to the SDI Office.

Summary: The fields of the pulse generated by switching on and off a uniform distribution of current over a circular disk was studied. The theoretical finding indicating that the energy carried by such a pulse decayed at a rate slower than the inverse square of the distance along the axis of the disk was confirmed. Under the assumption that this propagation and spreading of their fields were studied analytically. Their Poynting vectors were also investigated. The efficiency of energy transmission via such a pulse was determined. The conditions for generating such pulses were also formulated.

Publications:

"Electromagnetic scattering of tubular cylindrical structure-double series formulation and some results," H.M. Lee, IEEE Transactions on Antennas and Propagation, AP-35, (4), April 1987, pp. 384-390.

"Transient front and initial conditions in Maxwell's theory," S.C. Lee and H. M. Lee, Journal of Applied Physics, 62(2), Jan. 1987, pp. 804-805.

"Rise and fall of directed transient - use of Mellin transformation in time domain problems," H. M. Lee, accepted for publication in Radio Science.

"Focus wave mode and moving source at complex locations," submitted to the Journal of Mathematical Physics.

Conference Presentations:

"A class of pulses whose strengths decrease more slowly than 1/r," H.M. Lee, Proceedings of ICAP'87, Vol. I, York, UK, April 1987, pp. 512-515.

"The Mellin transform: a scale transformation for problems of simple geometries," H.M. Lee, Abstracts of the National Radio Science Meeting, Blacksburg, VA, June 1987, p. 99.

Conference Presentations: (cont.)

"Time domain studies of slowly decaying pulses," H.M. Lee, (invited paper for presentation at the special session in honor of Brittingham) Abstracts of the National Radio Science Meeting, Blacksburg, VA, June 1987, p. 174.

Title: SRAAW Radar Performance Studies

Investigator: Hung-Mou Lee, Associate Professor of Electrical and Computer Engineering

Sponsor: Office of the Chief of Naval Operations

Objective: To study the Navy's capability in defending against the skimmer missiles.

To aid NAVSEA and the NATO AAW Program Office in developing radars for detecting and tracking the skimmer missiles.

Continued in the following year as "Navy anti-air warfare studies."

Summary: Propagation of radar signals along the spherical ocean surface was studied. Emphasis was placed on examining the fields near and beyond the optical horizon. Engineering design for implementing digital signal processing techniques to aid SRAAW was commenced.

Publication: "Analysis of the angular error of amplitude comparison monopulse tracking of a two-element target," submitted to IEE Proceedings.

Thesis Directed: L. T. Scalzitti, "Engineering design of a digital MTI system for Short Range AAW," Master's Thesis, March 1988.

Title: Project GUSTY ORIOLE, Research and Development of Computer Architectures and Algorithms for Navy Space Systems

Investigator: H. H. Loomis, Jr., Professor of Electrical and Computer Engineering

Sponsor: To apply the expertise of the faculty and NPS students through their thesis research to the computer architecture and algorithm relate problems of the Navy Space Program, and secondarily to provide the opportunity for the injection of real problems and systems from the Navy Space Program into the Space Operations and Space Engineering Curricula at NPS.

Summary: Investigated algorithms and architectures of systems for the production, distribution and analysis of tactical information. Investigated architectures of spaceborne computer systems. Investigated operational problems concerned with the employment of tactical information for decision making and targetting. As a result of the research in this area, a formulation of the global multisource correlation problem has been made and work is under way to demonstrate the feasibility of a system which can keep track of all seagoing surface ships of larger than a certain size and provide that information to deployed commanders.

The necessary secure computing facilities have been developed to be able to work with real contact data using state of the art Navy systems such as the HP9020C running the PAWS (Prototype Analyst WorkStation) software for contact tracking as well as the secure VAX discussed above or secure IBM PC/AT systems. This research has resulted primarily in thesis output to this point, although publishable work should be forthcoming. This project has also provided a substantial infusion of current and future space technology into the course SS3001, "Military Applications of Space."

Theses Directed: "TADIXS-B for P-3 Targeting Support," Tracy Hennings, LT USN, Master of Science in Systems Technology (Telecommunications Systems Management), March 1987.

Theses Directed: (cont.)

"The Use of Augmented POST as an Interim Afloat Correlation system," Douglas Beauvais, LCDR, USN, Master of Science in Electrical and Computer Engineering (Space Engineering), June 1987.

"Battle Group Surveillance Requirements for the 1990's: A Requirements Analysis for Space Based Bistatic Radars" Daniel Gildea, LT, USN, Master of Science in Systems Technology (Space Systems Operations), September 1987, (Co-advisor with M. Melich, Electronic Warfare).

"Space Support to Long Range War-at-Sea: An Over-the-Horizon Targeting Concept," Bobby Goodman, LT USN, Master of Science in Systems Technology (Space Systems Operations), September 1987.

"A Fleet Oriented User Manual for the NEST System," Michael Mulcahy, LT, USN, Master of Science in Systems Technology (Space Systems Operations), September 1987.

"A Proposal for Hull-to-Emitter Correlation," Debra Paulson, LT, USN, Master of Science in Systems Technology (Space Systems Operations), September 1987.

Title: Optimal Processing of Signals from Distributed Telemetry Receivers

Investigator: P. H. Moose, Associate Professor of Electrical and Computer Engineering

Sponsor: Pacific Missile Test Center

Objective: The objective of this research is to develop adaptive algorithms for automatically selecting the best signal source, or for combining several signal sources, in order to obtain high quality uninterrupted telemetry data at PMTC from its distributed network of telemetry receivers.

Summary: During this period we developed a digital simulation of the Microdyne 1200 PCM/FM telemetry receiver using the IBM mainframe computer system at NPS. We used this simulation to verify our theoretical predictions for an algorithm to estimate the telemetry receiver signal-to-noise ratio. The algorithm uses short term estimates of the video power spectral density and is capable of estimating SNR within about 2 dB using only 100 msecs of data. This allows rapid changes in SNR to be accurately followed so that low SNR source can be replaced with a high SNR source.

We have also suggested a system design for bringing two bit streams into time registration to prevent loss of synchronozation when sources are switched and made theoretical calculations of its performance.

Theses Directed: "Signal-to-Noise Ratio Estimates of FSK Telemetry Signals," John M. Senyard, MSEE, Sept. 1987.

"Estimation and Modeling of Signal-to-Noise Performance in a Telemetry Reception System," Michael J. Quinn, MSEE, March 1987.

Title:	Finite Element Computation of Electromagnetic Scattering
Investigator:	M.A. Morgan, Associate Professor of Electrical and Computer Engineering
Sponsor:	Office of Naval Technology
Objective:	To develop CAD type computer programs for use in the analysis and design of complex electromagnetic scattering structures.
Summary:	A new generalized coupled azimuthal potential formulation is being developed and applied using the finite element method to compute scattering by complex objects. The scattering solution is effected by partitioning the physical structure into solution modules. The complete solution is then assembled using flow-diagram based matrix feedback control theory, where the individual modules are represented using matix transfer functions.
Publications:	M.A. Morgan and B.E. Welch, "Field Feedback Formulation for Electromagnetic Scattering," IEEE Transactions on Antennas and Propagation, December 1986, pp. 1377-1382. M.A. Morgan, "Generalized Coupled Azimuthal Potentials for Electromagnetic Fields in Inhomogeneous Media," Submitted to IEEE Transactions on Antennas and Propagation.
Conference Presentations:	M.A. Morgan, "Stability Considerations in the Field Feedback Formulation," 1987 URSI Radio Science Meeting, Virginia Tech University, June 1987. M.A. Morgan, "Generalized Coupled Azimuthal Potentials for Electromagnetic Fields in Inhomogeneous Media," 1988 URSI National Radio Science Meeting, University of Colorado, December 1988.
Thesis Directed:	E. Connolly, "Finite Element Electromagnetic Scattering: An Interactive Microcomputer Program," Masters Thesis, June 1988.

Title:	High-Resolution Transient Scattering Measurements Using a Broadband Noise Source
Investigator:	M.A. Morgan, Associate Professor of Electrical and Computer Engineering
Sponsor:	DARPA Aerospace Technology Office
Objective:	To investigate the viability of synthesizing narrow pulse signatures of radar targets using measured random noise scattering.
Summary:	In this unique effort, narrow pulse responses of scattering targets are synthesized from experimental measurements of the cross-correlation of broadband random noise incident upon and scattered from objects. A dual-channel coherent sampling oscilloscope is used as a correlation receiver.
Publication:	M.A. Morgan and B.W. McDaniel, "Transient Electromagnetic Scattering: Data Acquisition and Signal Processing," IEEE Transactions on Instrumentation and Measurement, Accepted for Publication.
Theses Directed:	S. Somapee, "A Computer Algorithm for Automated Transient Scattering Measurements," M.S. Thesis, June 1988. D.I. Lee, "Impulse Scattering Responses Using Noise Illumination," M.S. Thesis, March 1988.

Title: Target Identification Using Resonance Annihilation Filtering

Investigator: M.A. Morgan, Associate Professor of Electrical and Computer Engineering

Sponsor: DARPA Tactical Technology Office

Objective: To develop optimized algorithms for utilizing natural resonances of radar targets for aspect independent identification in the real world.

Summary: Aspect invariant natural resonant cancellation is being investigated using specially designed resonance annihilation digital filters. Considerations are given to classification accuracy versus signal to noise ratio and signal bandwidth for scale model tactical aircraft models.

Publication: M.A. Morgan, "Scatterer Discrimination Based Upon Natural Resonance Annihilation," Journal of Electromagnetic Waves and Applications, Accepted For Publication.

Conference Presentations: M.A. Morgan, "Pulse Shaping for Target Interrogation," 22nd General Assembly of the International Union of Radio Science, Tel Aviv, Israel, August 1987.

M.A. Morgan and P.J. Moser, "Finite Element Evaluation of Complex Natural Resonant Frequencies," 1988 National Radio Science Meeting, University of Colorado, Jan., 1988.

Theses Directed: L. Cheeks, "Comparison of K-Pulse and E-Pulse Methods for Aspect Independent Radar Target Identification," M.S. Thesis, Extension until December 1988.

S.A. Norton, "Identification of Radar Targets from the Poles of their System Function," Electrical Engineers Thesis, March 1988.

Title: Continuing Satellite Design Studies

Investigators: R. Panholzer, Professor and Chairman of the Space Systems Engineering Academic Group, R. Adler, L. W. Chang, M. Cotton, A. Fuhs, Y. Joshi, R. Kolar, A. Kraus, S. Michael, M. Morgan, G. Myers, F. Terman, and H. Titus.

Sponsors: Strategic Defense Initiative Office, Innovative Science and Technology, Washington, D.C. and Air Force Technical Applications Center, Patrick AFB, Florida.

Objective: Refine design and prove concept feasibility for a small, low cost, full capability, general purpose satellite.

Summary: Preliminary design of a full capability, reconfigurable, low cost satellite has been funded by AFTAC in the past. The research effort in FY87 is a continuation of this design effort.

Publications:

A. E. Fuhs and M. R. Mosier, "ORION: A Small, General Purpose, Low Earth Orbit Satellite Bus Design," Proceedings of the First Annual Utah State University Conference on Small Satellites, (USU, Utah), October 1987.

A. E. Fuhs and J. Sanders, "Lightsats . . . Moving to the Mainstream," Aerospace America, Vol. 25, No. 11, pp. 48-50, November 1987.

A. W. Boyd, Brian P. Kosinski, Richard L. Weston, "Autonomous Measurement of Space Shuttle Payload Bay Acoustics During Launch," Naval Research Reviews, Office of Naval Research, One/1987, Vol XXXIX.

A. W. Boyd Jr., A. E. Fuhs and M. R. Mosier, "ORION: A General Purpose, Low Cost Satellite," Proceedings of the 1987 AIAA/DARPA Meeting on Lightweight Satellite Systems, (AIAA, Washington D.C.), Forthcoming.

A. E. Fuhs and M. R. Mosier, "Lightsats . . . A Perspective", Aerospace America, Forthcoming.

Conference Presentations:

A. W. Boyd Jr., A. E. Fuhs and M. R. Mosier, "ORION: A General Purpose, Low Cost Satellite," AIAA/DARPA Meeting on Lightweight Satellite Systems, Monterey, California, August 1987.

A. E. Fuhs and M. R. Mosier, "ORION: A Small, General Purpose, Low Earth Orbit Satellite Bus Design," First Annual USU Conference on Small Satellites, Logan, Utah, October 1987.

Theses Directed:

T. Keeble, MAJ, USA, "Fault Tree Reliability Analysis of the Naval Postgraduate School Mini-Satellite (ORION)," Master's Thesis, September 1987. (Advisors: J. Esary and A. Fuhs).

T. Light, CAPT, USA, "Relating Service Doctrine to Space System Requirements," Master's Thesis, June 1987. Advisors: (A. Fuhs and C. Jones).

D. L. Peters, CAPT, USA, "Investigation of Design Considerations for Telemetry, Tracking, and Command (TT&C) Antenna System on Naval Postgraduate School ORION Minisatellite," Master's Thesis, September 1987. (Advisors: R. Adler and G. Myers).

S. E. Petersen, LT, USN, "Autonomous Satellite Navigation System Using the Global Positioning System," Master's Thesis, March 1987. (Advisors: F. Terman and H. Titus).

W. J. Welsh, LT, USN, and M. Landers, LT, USN, "Project SKYLITE, A Design Exploration," Master's Thesis, September 1987. (Advisors: R. Olsen and P. Durkee).

Title: Analysis and Modeling of Extended Radar Cross Section Data

Investigator: C. W. Therrien, Associate Professor of Electrical and Computer Engineering

Sponsor: M.I.T. Lincoln Laboratory

Objective: To develop digital signal processing models for the radar cross section of certain types of range-extended targets.

Summary: Certain types of extended targets when viewed by a wideband radar exhibit a radar cross section (RCS) that is a function of both time and relative range. When the RCS is correlated in both space and time a two-dimensional (2-D) stochastic signal model must be used to describe the time and space dependence. This research performed a statistical analysis of the dual polarized coherent RCS data and suggested some alternative practical 2-D models for the RCS that would match the statistical characteristics of the observed radar data.

Publication: "Modeling of Lincoln Wideband Radar Cross Section Data," C. W. Therrien, Naval Postgraduate School Report, October 1987.

Thesis Directed: "Analysis and Modeling of Coherent Space-Time Dependent RCS for Extended Radar Targets," R. Eric Reinke (Engineer's degree thesis in progress to be completed in September 1988).

Title: Digital Processing for Enhancement of Images of Underwater Objects (Task 87-4 of proposal entitled "Range Studies Program," J. Esary and O. B. Wilson, coordinators)

Investigators: C. W. Therrien, Associate Professor of Electrical and Computer Engineering and J.S. Lim, Visiting Consultant

Sponsor: Naval Undersea Warfare Engineering Station

Objective: To determine if digital image processing methods can prove useful in enhancing video images during underwater object recovery operations.

Summary: Various image processing techniques were applied to a few frames of video images of objects in turbid water to enhance these images. Methods explored were adaptive filtering for local contrast enhancement, histogram equalization, linear filtering, and various noise removal methods. Some noticable improvement in the intelligibility of the images was made. A new method was developed that is less prone to increasing video noise. An analysis of computations and other considerations related to real time implementation of the algorithms was begun.

Publication: "Study on Image Processing for Turbid Water Viewing," J. Lim and C.W. Therrien, Naval Postgraduate School Report NPS62-87-013, June 1987.

Thesis Directed: "Enhancement of Video Images Degraded by Turbid Water," J. Franco, MS Thesis (December 1986).

Title: Adaptive Algorithms for Normalized IIR Lattice Filters

Investigator: Murali Tummala, Adjunct Teaching Professor of Electrical and Computer Engineering

Sponsor: NPS Foundation Research Program

Summary:

This is a continuing research effort of the work done earlier on a National Research Council Postdoctoral fellowhip. This project is the first phase of a bigger project that continues into AY88. In this first phase, we have undertaken the development of an adaptive algorithm for the Gray-Markel normalized IIR lattice. The algorithm is based on the least mean square criterion. It involves updating a trigonometric function as against a reflection coefficient. This new approach assures the stability of the filter by restricting the poles of the transfer function to be with in the unit circle. Some preliminary simulation runs have been carried out which showed some improvement in the speed of convergence. More simulation runs are being carried out and the algorithm is being modified to obtain further convergence speed improvements, and some theroetical analysis of the convergence performance is undertaken.

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: Office of Naval Research

Objective: To derive a time-invariant, space-variant, random transfer function of the ocean volume based on three-dimensional ray acoustics, the corresponding coherence function, and the expression for the random output electrical signal at each element in a receive planar array of point sources. Also, the relationship between transfer function and coherence function derivations and the method of moments and ray-path integrals shall be studied.

Summary: Both a random, time-invariant, space-variant transfer function of the ocean volume and its corresponding coherence function were derived based on three-dimensional ray acoustics. New expressions for the amplitude, eikonal, and phase along a ray path were derived. Comparisons between the transfer function approach and both the path-integral technique and the Rytov method for weak fluctuations were made. It was shown that the transfer function approach was analogous in concept with the path integral technique, although the transfer function approach is more general. The transfer function approach was also shown to be in agreement with the Rytov method for weak fluctuations.

Publication: L. J. Ziomek, "Linear Time-Invariant space-Variant Filters and Three-Dimensional Ray Acoustics," in review.

DEPARTMENT

OF

METEOROLOGY

DEPARTMENT OF METEOROLOGY

The research program in the Department of Meteorology continues in several areas: (I) 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) regional weather studies and (6) 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 also applying the techniques to the prediction of air flow near mountains and to tropical cyclones. Further, he is 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 and M. S. Peng are investigating the "Mei-Yu" front over eastern Asia with a dynamical front 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 surface 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 Systems are used to evaluate physical processes that occur during rapid cyclogenesis.

Other modeling efforts include (1) 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 (2) a numerical investigation of the dynamics and prediction of synoptic-scale variability in the coastal ocean off California, led by R. L. Haney.

DYNAMICS OF FLOW OVER AND AROUND MOUNTAINS

R. T. Williams is 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. T. Williams, C.-S. Liou and M. S. Peng continue to investigate various aspects of the dynamics of tropical weather systems, 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, C. S. Liou 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.

A multi-year basic research program to understand the dynamics of tropical cyclone motion has begun. R. L. Elsberry serves as the Technical Director of the overall research initiative at the Office of Naval Research. R. T. Williams and M. S. Peng are developing analytical and numerical models of tropical cyclone motion, and Research Chair incumbent, G. J. Holland, is also involved in this research program. R. L. Elsberry and associates continue applied research efforts to improve tropical cyclone prediction via statistical evaluations and expert systems.

Other modeling efforts include (1) 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 (2) a numerical investigation of the dynamics and prediction of synoptic-scale variability in the coastal ocean off California, led by R. L. Haney.

DYNAMICS OF FLOW OVER AND AROUND MOUNTAINS

R. T. Williams is 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. T. Williams, C.-S. Liou and M. S. Peng continue to investigate various aspects of the dynamics of tropical weather systems, 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, C. S. Liou 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.

A multi-year basic research program to understand the dynamics of tropical cyclone motion has begun. R. L. Elsberry serves as the Technical Director of the overall research initiative at the Office of Naval Research. R. T. Williams and M. S. Peng are developing analytical and numerical models of tropical cyclone motion, and Research Chair incumbent, G. J. Holland, is also involved in this research program. R. L. Elsberry and associates continue applied research efforts to improve tropical cyclone prediction via statistical evaluations and expert systems.

MARINE ATMOSPHERIC BOUNDARY LAYERS OVER THE SEA AND ICE

Research in this 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 and across an ocean front in the northwest North Atlantic Ocean. The marginal ice zone experiment was conducted in March and April 1987, and included measurements from three ships. The ocean front experiment was performed in February 1986 and analyses are being performed on the multi-platform data set. 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 distributions, (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. W. J. Shaw, K. L. Davidson and P. A. Durkee executed a measurements program with NEPRF and NOAA,s Wave Propagation Laboratory in the sea breeze circulation in the Salinas Valley. This study involved acoustic sounders, surface measurements, rawinsondes, and doppler lidar in one of the most extensive sea breeze measurement experiments that has been undertaken.

REGIONAL WEATHER STUDIES

F. R. Williams and R. J. Renard are continuing the development of a Forecaster,s Handbook for the Central American land and adjacent ocean areas, which will include sections on climatology, and air/ocean circulation 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 aperature radar (SAR) images of the ocean surfaces. Analyses are being performed on surface stress data from a tower off the California Coast, near San Diego. The data were collected in conjunction with aircraft and Space Shuttle (Shuttle Imaging Radar) overflights. An experiment is being planned for an area off the coast of Norway which will relate surface stress to information gathered by airborne SAR and scatterometers. This will be a high wind and high sea-state experiment. 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, Adj. Professor of Meteorology, C.-P. Chang, Professor of Meteorology and C. H. Wash, Associate 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: The calculation of Q-vectors (Huskins et al, 1978) was used at 700 mb as a diagnostic tool to assess how well the forecasts preserved the character of the large scale forcing of the ageostrophic flow. The Q fields at i = 72 is very similar to the i = 00 analysis, thus it appears that the sense of the error is to consistently underestimate the strength of the ageostrophic flow. There are also significant errors through the storm tracks of the north Pacific and north Atlantic oceans.

Using spherical harmonics, with triangular truncation, an attempt was also made to try to ascertain the scale dependence of the NOGAPS forecast error. For January 1987, the thickness field shows a warm bias over the north Pacific and north Atlantic and a cold bias over Asia, Africa and Australia. The analysis and 120 h forecast are similar. There are decided differences but nothing egregiously at in error. The error fields indicate that some of the largest problems are at the largest zonal scales.

Publications: Chen, G. T. J., Y. J. Wang and C.-P. Chang, 1987: "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," Mon. Wea. Rev., 115, 25-250.

Curtis, J., J. Boyle and C. Wash, 1987: "Variability in Skill in 120 h FNOC 500 mb Height Forecasts," Mon. Wea. Rev., (accepted subject to revision).

Title: Analysis of Surface Winds over Tropical Oceans during TOGA

Investigators: C.-P. Chang, Professor of Meteorology, M. S. Peng, Adjunct Research Professor of Meteorology

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 Ocean Global Atmosphere Experiment. The enhancement is based on the incorporation of low-level cloud drift winds using a vertical shear determined by operational numerical analysis and prediction models. Experiments for the daily and monthly mean analysis during April 1984 were conducted, resulting in an improvement of estimated surface wind errors between 1-2 m/s depending on geographical regions of the Pacific.

Thesis Directed: R. Weinheimer, "Reanalysis of Surface Marine Winds over the Tropical Pacific Using Satellite Data," Master's Thesis, September 1987.

Title: Tropical Monsoon Studies

Investigators: C.-P. Chang, Professor of Meteorology, R. T. Williams, Professor of Meteorology

Sponsor: National Science Foundation

Summary: This project studies a variety of large-scale motions in the tropics and subtropics, particularly those associated with the Asian monsoon circulations. It consisted of four parts:

1. Theoretical studies of planetary scale motion forced by tropical heating. The effects of vertical shear, vertical differential damping and planetary boundary layer were found to influence the forcing of midlatutude motions by tropical heat sources. In addition, the vertical interaction of simple modes may be responsible for the maintenance of the eastward propagating 30-50 day oscillations.

2. Observational studies of planetary scale motions. The day-to-day variation of the East Asian Jet was found to correlate positively with that of the tropical divergent flow to the south of it, suggesting the transient forcing of time-mean planetary scale circulation was also studied using a nine-year data set.

3. Theoretical studies of zonal symmetry. Several differences between parallel flow and non-parallel flow instabilities in terms of spatial and time growth rates were found using the two-scale technique.

4. Studies of the Mei-Yu system of the East Asian summer monsoon. A numerical experiment suggested that the Low-Level Jet associated with intense Mei-Yu fronts receives energy through an equatorward, convection-driven secondary circulation which is quite different from the cross-frontal circulation associated with dry fronts.

Publications:

Boyle, J. and G.T. Chen, 1987: "Synoptic Aspects of the Asian Winter Monsoon," Monsoon Meteorology, Oxford University Press (forthcoming).

Chan, C.-S. Liou and R.T. Williams, 1987: "Analytical and Numerical Studies of the Beta-effect in Tropical Cyclone Motion, Part I: Zero Mean Flow," J. Atmos. Sci., 44, 1257-1265.

Chang, C.-P. and H. Lim, 1986: "Kelvin Wave CISK: A Possible Mechanism for the 30-50 Day Oscillations," Preprints, Int. Conf. Monsoon and Mesoscale Meteorology, November 1986, Taipei, 236-245.

Chen, G.T.J., T.E. Gerish and C.-P. Chang, 1986: "Structure Variations of the Synoptic-Scale Cyclonic Disturbances near Borneo during the MONEX Period," Papers Met. Res., 9, 117-135.

Chen, G. T. J., Y. J. Wang and C.-P. Chang, 1987: "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," Mon. Wea. Rev., 115, 235-250.

Chou, L.C., 1986: "A Numerical Simulation of a Mei-Yu Front and the Associated Lowlevel Jet," Ph.D. Dissertation, Naval Postgraduate School, 153 pp.

Lau, K. M. and C.-P. Chang, 1987: "Planetary Scale of the Winter Monsoon and Atmospheric Teleconnections," Monsoon Meteorology, Oxford University Press, (forthcoming).

Lim, H. and C.-P. Chang, 1987: "On the Dynamics of Midlatitude-tropical Interactions and the Winter Monsoon," Monsoon Meteorology, Oxford University Press, (forthcoming).

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," J. Atmos. Sci., 43, 1681-1695.

Peng, M.S. and R.T. Williams, 1987b: "Spatial Instability of a Baroclinic Current with Slow Streamwise Variation," J. Atmos. Sci., 44, 2668-2773.

Title: Atmospheric Forcing on Ocean-Atmosphere Mixed-Layer Processes

Investigators: K. L. Davidson, Professor of Meteorology, G. E. Schacher, Dean of Science and Engineering and W. J. Shaw, Assistant Professor of Meteorology

Sponsor: Office of Naval Research (ONR-1122PO)

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 complete analyses Gulf of Alaska (STREX) and an Eastern Pacific data set (MILDEX) and to perform analyses on data from 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. (Boyle et al, DAO, 1987). 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 OCEANUS) 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: 86-P Geernaert, G.L. and K.B. Katsaros, "Incorporation of Stratification Effects on the Oceanic Roughness Length in the Derivation of the Neutral Drag Coefficient," JPO, 16 (1986), 1580.

87-P Boyle, P.J., K.L. Davidson and D.E. Spiel, "Characteristics of Overwater Surface Stress During STREX," DOA 4 (1987) 343.

87-P Geernaert, G.L., "On the Importance of the Drag Coefficient in Air-Sea Interaction," DOA 11 (1987).

Conference Presentation:

86-C Davidson K.L, S.H. Borrmann and C.A. Vaucher, "Atmospheric Boundary Layer Properties Observed in FASINEX," Fall AGU Meeting (FASINEX Session), San Francisco, CA, December 1986.

Theses Directed:

Higgins, J.P., "Equilibrium Atmospheric Boundary Layer Features Over a Subtropical Ocean Front," NPS MS Thesis, (1987).

87-R Dotson, M.E., "An Evaluation of the Impact of Variable Temporal and Spatial Data Resolution Observed in FASINEX Upon IREPS," NPS MS Thesis, (1987).

87-R Mundy, J., "Variation of the Wind Stress Related to Frontal Passages During FASINEX 1987," NPS MS Thesis, 1987.

Title: Atmospheric Measurements in the MIZ

Investigators: K. L. Davidson, Professor of Meteorology, G. E. Schacher, Dean of Science and Engineering and P. S. Guest, Meteorologist

Sponsor: Office of Naval Research (ONR-1125AR)

Objective: The objective of these MIZ meteorology measurements is to obtain microscale, mesoscale and synoptic scale descriptions of atmospheric properties in the ice edge region. These descriptions will be used to relate atmospheric forcing to acoustic signals and changes in the upper ocean and ice morphology.

Summary: Measurements were made during the summer (June-July) marginal ice zone experiments (MIZEX) in 1983 and 1984 and during spring (March-April) in 1987. Of primary interest are characterizations which can be related to future data obtained from polar orbiting satellites and buoys. In order to interpret the information from these future available platforms, in situ measurements of surface wind stress and near surface thermodynamic parameter are required under a wide variety of conditions.

The FY87 effort includes analyses/interpretation of data collected during summer (June-July) experiments and during the winter (March-April) experiments. Procedures adapted for shipboard and ice flow collection of the surface stress data have proven successful (Guest and Davidson, JGR, 1987). Past experiment shipboard data are being matched with aircraft and satellite data. The winter experiment will include data from 3 ships, aircraft remote sensing and satellites.

Publications: Borrmann, S.H., K.L. Davidson and M.E. Miller, 1987: "Surface of Aerosol Size Distributions in the Marginal Ice Zone during the 1983 Marginal IceZone Experiment," Journal of Geophysical Research, 92, 6971-6976.

Guest, P.S. and K.L. Davidson, 1987: "The Effect of Observed Ice Conditions on the Drag Coefficient in the Summer East Greenland Sea Marginal Ice Zone," Journal of Geophysical Research, 92, 6943-6954.

Publications: (cont.)

Campbell, W.J., P. Gloersen, E.G. Josberger, O.M. Johannenssen, P.S. Guest, N. Lannelongue and K.L. Davidson, 1987: "Mesoscale and Large-Scale Sea Ice Morphology in MIZEX-84," Journal of Geophysical Research, 92, 6805-6824.

Johannessen, J.A., O.M. Jahannessen, E. Svendsen, R. Shuchman, T. Manley, W. Campbell, E. Josberger, S. Sandben, J. Gascard,T. Olaussen, K. Davidson, and J. Van Leer, 1987: "Mesoscale Eddies in the Fram Strait Marginal Ice Zone during MIZEX 1983 and 1984," Journal of Geophysical Research, 92, 6754-6772.

Davidson, K.L. and P.S. Guest, 1987: "NPS Meteorology Studies of the Marginal Ice Zone," Naval Research Reviews, XXXIX, 2835.

Geernaert, G.L. K.L. Davidson and P.S. Guest, 1987: "Observed Short-term Characteristics of the Marginal Ice Zone Planetary BoundaryLayer and its Impact on Elevated EM Ducting," Radio Science (in preparation).

Conference Presentations:

K. L. Davidson, S. H. Borrmann, C. A. Vaucher, "Atmospheric Boundary Layer Properties Observed in FASINEX," AGU Fall Meeting, California, 8 December 1986.

K. L. Davidson, and P. S. Guest, "Factors Affecting the Atmospheric Boundary Layer Over a Summertime Marginal Ice Zone - An Observational Study," IUGG General Assembly, Canada, August 1987.

K. L. Davidson, and J. E. Overland, "MIZEX Meterorology: Winter and Spring," IUGG General Assembly, Canada, August 1987.

Theses Directed: Willis, Z., "Spatial and Temporal Variation of the Arctic Marine Atmospheric Boundary Layer with Application to Refractivity," December 1987.

Schultz, R. R., "Meteorological Features During the Marginal Ice Zone Experiment (20 March - 10 April) of 1987," December 1987.

Barron, J., "A Multispectral Technique to Discriminate Clouds From Snow and Sea Ice in the Arctic," December 1987.

Title: Droplet Contributions to Humidity Exchanges Over the Sea (HEXOS)

Investigator: K. L. Davidson, Professor of Meteorology

Sponsor: Office of Naval Research (ONR-1122MM)

Objective: The long term objective of laboratory and field experiments is to understand the transfer and effects of water vapor adjacent to the ocean surface. A series of laboratory and field experiments on the production of droplets and turbulent transport of vapor at the sea surface have been conducted. Near termobjectives were to perform a coordinated shipboard/tower experiment under high wind condition and to analyze results from windwave laboratory facilities.

Summary: The laboratory data were collected in the wind-wave tunnel at the Institute de la Macanque Statistique de la Turbulence (IMST) in Marseille, France (HEXIST) in 1985 and provided information on droplet fluxes over simulated whitecaps with varying values of turbulence and humidity in the overlying airflow. The field data were collected from the RRS FREDERICK RUSSELL and from the Meetpost Noordwijk Tower near the coast of The Netherlands (HEMAX) in October and November 1986, under varying wind and wave condition.

Continuing analyses/interpretation are designed to scale the laboratory results to the larger scale field results. Interpretations of both sets of data will yield improved humidity exchange coefficients which include both vapor and droplet contributions to the humidity flux from the sea surface. Emphasis is placed on the exchange coefficients during extreme wind and wave conditions.

Publications: Fairall C.W. and K.L. Davidson, 1986: "Dynamics and Modeling of Aerosol in the Marine Atmospheric Boundary Layer," in Oceanic Whitecaps and their Role in Air-Sea Exchange Processes, edited by E.C. Monahan and G. MacNicocial1, D. Reidel Publishing, 195-208.

Monahan, E.C., D.E. Spiel and K.L. Davidson, 1986: "Model for Aerosol Production via Whitecaps and Wave Disruption," in Oceanic Whitecaps and their Role in Air-Sea Exchange Processes, edited by E.C. Monahan and G. MacNiocial1, D. Reidel Publishing, 167-174.

Publications: (cont.)

Davidson, K.L., and C.W. Fairall, 1986: "Optical Properties of the Marine Atmospheric Boundary Layer: Aerosol Profiles," in Proceedings of SPIE, Vol. 637, Ocean Optics VIII, 18-24.

Borrmann, S.H., K.L. Davidson and M.E. Miller, 1987: "Surface of Aerosol Size Distributions in the Marginal Ice Zone during the 1983 Marginal Ice Zone Experiment," Journal of Geophysical Research, 92 6971-6976.

Davidson, K.L. and P.S. Guest, 1987: "NPS Meteorology Studies of the Marginal Ice Zone," Naval Research Reviews, XXXIX, 2835.

Mestayer, P.G., C.W. Fairall, S. E. Larsen, and D. E. Spiel, 1987: "Turbulent Transport and Evaporation of Droplets Generated at an Air-water Interface," Atmospheric Research (Submitted).

Conference Presentation:

Mestayer, P.G., C.W. Fairall, S. E. Larsen, D. E. Spiel and J. Edson, 1987: "Turbulent Transport and Evaporation of Droplets Generated at an Air-water Interface," VI Turbulent Shear Flow Symposium, Toulouse, France, September 1987.

Title: Observational studies of MIZ Boundary Layer Processes

Investigators: K. L. Davidson, Professor of Meteorology, G. E. Schacher, Dean of Science and Engineering and P. S. Guest, Meteorologist

Sponsor: Office of Naval Research (ONR-1244)

Objective: The long term objective of the MIZ meteorology measurements is to obtain understandings of physical features and processes responsible for arctic low formation and boundary layer evolutions. These understandings will be necessary in the development of prediction models for high wind events and anomalous EM/EO propagation phenomena in the MIZ region. Of particular interest is the formulation of procedures to utilize information from polar orbiting satellites, buoys and the existing observation network in prediction/analyses for the East Greenland Sea MIZ region.

Summary: The FY87 studies include analyses/interpretation of multi-ship (up to 5) rawinsonde data collected during MIE-84 (June-July 1984) and the collection of rawinsonde data from three ships during MIZEX-87 (March-April 1987). Analyses on existing and planned data will be directed toward determining the relative roles of surface diabatic heating, boundary layer gradients and advection and upper level flows in generation of disturbance at and adjacent to the MIZ.

Meteorological satellite derived precursor condition for arctic low formation will be related to surface layer and boundary layer gradients of vector wind, temperature and humidity. Regional prediction models being formulated by the Norwegian meteorological services and the US Navy Environmental Prediction Research Facility (NEPREF) will be evaluated on the basis of past and planned date sets. Evaluation of recently proposed physical models for intense cyclogenesis in the cold region is also possible from the subject data.

Publications:

Borrmann, S.H., K.L. Davidson and M.E. Miller, 1987: "Surface of Aerosol Size Distributions in the Marginal Ice Zone during the 1983 Marginal Ice Zone Experiment," Journal of Geophysical Research, 92, 6971-6976.

Guest, P.S. and K.L. Davidson, 1987: "The Effect of Observed Ice Conditions on the Drag Coefficient in the Summer East Greenland Sea Marginal Ice Zone," Journal of Geophysical Research, 92, 6943-6954.

Campbell, W.J., P. Gloersen, E.G. Josberger, O.M. Johannenssen, P.S. Guest, N. Lannelongue and K.L. Davidson, 1987: "Mesoscale and Large-Scale Sea Ice Morphology in MIZEX-84," Journal of Geophysical Research, 92, 6805-6824.

Johannessen, J.A., O.M. Jahannessen, E. Svendsen, R. Shuchman, T. Manley, W. Campbell, E. Josberger, S. Sandben, J. Gascard,T. Olaussen, K. Davidson, and J. Van Leer, 1987: "Mesoscale Eddies in the Fram Strait Marginal Ice Zone during MIZEX 1983 and 1984," Journal of Geophysical Research, 92, 6754-6772.

Davidson, K.L. and P.S. Guest, 1987: "NPS Meteorology Studies of the Marginal Ice Zone," Naval Research Reviews, XXXIX, 28-35.

Geernaert, G.L. K.L. Davidson and P.S. Guest, 1987: "Observed Short-term Characteristics of the Marginal Ice Zone Planetary BoundaryLayer and its Impact on Elevated EM Ducting," Radio Science (in preparation).

Conference Presentations:

K. L. Davidson, S. H. Borrmann, C. A. Vaucher, "Atmospheric Boundary Layer Properties Observed in FASINEX," AGU Fall Meeting, California, 8 December 1986.

K. L. Davidson, and P. S. Guest, "Factors Affecting the Atmospheric Boundary Layer Over a Summertime Marginal Ice Zone - An Observational Study," IUGG General Assembly, Canada, August 1987.

K. L. Davidson, and J. E. Overland, "MIZEX Meterorology: Winter and Spring," IUGG General Assembly, Canada, August 1987.

Theses Directed: Willis, Z., "Spatial and Temporal Variation of the Arctic Marine Atmospheric Boundary Layer with Application to Refractivity," December 1987.

Schultz, R. "Meteorological Features During the Marginal Ice Zone Experiment (20 March - 10 April) of 1987," December 1987.

Barron, J., "A Multispectral Technique to Discriminate Clouds From Snow and Sea Ice in the Arctic," December 1987.

Title: Surface Wind Stress and Radar Measurements of the Sea Surface

Investigator: K. L. Davidson, Professor of Meteorology

Sponsor: Office of Naval Research (ONR-112D1)

Objective: The objective of this effort is to relate observed surface layer wind stress and radar data collected during the Tower Ocean Wave and Radar Dependence (TOWARD) experiment and during the Frontal Air-Sea Interaction Experiment (FASINEX).

Summary: TOWARD and FASINEX yielded unique in situ radar (L,X and Ku band) measurements of the sea surface in conjunction with surface wind stress measurements. High resolution time and space correlation between the observated wind stress and radar signatures will yield information on relation between radar signatures and physical properties of the sea surface.

Continuing analyses/interpretation of the TOWARD data will relate surface stress co-sprectra to the direction of the vector difference of the wind and tower based/radar sensed waves. Continuing analyses/interpretation of the FASINEX data will relate the surface stress to aircraft and ship borne radar (X,S and Ku band) images of the surface.

Publications: 87-S Geernaert, G.L., K.L. Davidson, S.E. Larsen and T. Mikkelsen, "Wind Stress Measurements During the Tower Ocean Wave and Radar Dependence Experiment," JGR (1988).

87-S Li, F., W. Large, W.J. Shaw, E. Walsh and K.L. Davidson, "Ocean Radar Backscatter Relationship With Near Surface Winds : A Case Study during FASINEX," JPO (1988).

Title: Electronic Weapon System Satellite Support

Investigator: P. 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:

Durkee, P. A., and D. E. Burks, 1988: "Meteorological Range Estimation from Satellite-Detected Radiance," NEPRF Technical Report in preparation.

Durkee, P. A., and M. Garcia de Quevedo, 1988: "Estimation of Infrared Extinction by Aerosols from Multispectral Satellite-Detected Radiance." In preparation for submission to Applied Optics.

Theses Directed: Pfeil, F. R., "Developing a Physical Basis for an Aerosol Climatology of the Pacific Basin," MS Thesis, September 1986.

M. García de Quevedo, "Estimation of Extinction Coefficients at 3.75 and 11.00 Micrometers from Satellite Measurements at 0.63 and 0.86 Micrometers," MS Thesis, March 1987.

Title: Radiometric Detection of Marine Atmospheric Boundary Layer (MABL) Characteristics

Investigator: Philip A. Durkee, Assistant 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 that began in FY85. 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 on 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: Durkee, P.A., 1987: "Aerosol Characteristics Inferred from Dual-Wavelength Radiance Measurements," Submitted to J. Geophys. Res. (in revision).

Coakley, J. A., Jr., R. L. Bernstein and P. A. Durkee, 1987: "Effect of Ship-Stack Effluents on Cloud Reflectivity," Science, 237, 1020-1022.

Theses Directed: R. J. Kren, "Marine Boundary Layer Depth and Relative Humidity from Multispectral Satellite-Detected Radiance," MS Thesis, June 1987.

F. M. Tettelbach, "Stratocumulus and Cloud-Free Reflectance from Multispectral Satellite Measurements," MS Thesis, December 1987.

Title: Ocean Response to Atmospheric Forcing

Investigator: R. L. Elsberry, Professor of Meteorology

Sponsor: Office of Naval Research (Physical Oceanography Program)

Objective: To improve understanding of the physical mechanisms that lead to significant changes in upper ocean properties in response to strong atmospheric forcing events, especially tropical cyclones. A combination of observations, analytical models and numerical simulations has been used in the continuing project.

Summary: Seven moored current meter arrays in the Gulf of Mexico during hurricane Frederic (1979) have been examined in detail (Shay and Elsberry, 1987). An immediate nearinertial current response at all depths detected in hurricane Allen is found at each site. The depth-averaged current response was 5-10 cm/s at the array sites. The first baroclinic mode was the most energetic mode and 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, respectively.

A unique data set of Airborne eXpendable Current Profilers (AXCP) observations in Hurricane Norbert provides more detailed profiles for determining the vertical structure of the ocean current response. Since these measurements were made directly under the hurricane, the theory is extended to calculate the forced dynamical modes (Shay et al., 1987). The vertical structure in the AXCP data compares rather well with the 3-dimensional velocity structure obtained from the theory. A sum of the first three or four forced modes explains over 70% of the observed current variance on the right side of the storm in the direct forcing regime. Most of the forced response is associated with the wind stress curl treated by Geisler. However, the stress divergence and Ekman-type terms also contribute 10-15% to the near inertial currents directly under the hurricane.

Summary: (cont.)

The depth-averaged currents, which are not resolved well in the moored current meter observations, are simulated with a 17-level primitive equation model (Chang, 1985) that includes a free surface. Many aspects of the ocean observations seem to be represented well by the model when it is forced with a storm circulation similar to Frederic. Significant clockwise rotating amplitudes in the near-inertial wave band are simulated throughout the water column (depth = 600 m). The free-surface slope induces a barotropic current of 4-7 cm/s in the near-inertial wave band, which agrees with the estimates from the Frederic observations. These simulations provide a more complete picture of the near-inertial response to hurricanes than can be inferred only from the observations.

Publications:

L. K. Shay and R. L. Elsberry, "Near-Inertial Ocean Current Response to Hurricane Frederic," J. Phys. Oceanogr., 17, (August 1987), 1249-1269.

P. G. Black, R. L. Elsberry, L. K. Shay and R. Partridge, "Hurricane Josephine Surface Winds and Ocean Response Determined from Air-Deployed Drifting Buoys and Concurrent Research Aircraft Data," J. of Atmos. and Ocean Tech. (accepted).

L. K. Shay, R. L. Elsberry and P. G. Black, "Mesoscale Ocean Current Response to Hurricanes," Extended Abstracts, 17th Conf. on Hurricanes and Tropical Meteorology, American Meteorological Society, 388-392.

Conference Presentation:

L. K. Shay, R. L. Elsberry and P. G. Black, "Near-Inertial Ocean Current Response to Hurricane Josephine," Abstract in EOS, Vol. 67(44), p. 1033, American Geophysical Union, Fall 1986.

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 using data from the Genesis of Atlantic Lows Experiment (GALE) and Experiment on Rapidly Developing Cyclones over the Atlantic (ERICA).

Summary: Preliminary diagnostic studies of three GALE Intense Operation Periods were completed. These investigations primarily used operational analyses. The creation of new analyses incorporating GALE data and using 6 h data assimilation cycle was started. The theoretical, numerical and synoptic study of the role of superposition on cyclogenesis was completed by LCDR Warrenfeltz for his Ph.D.

Publications: W.A. Nuss, R.A. Anthes, "A Numerical Investigation of Low-Level Processes in Rapid Cyclogenesis," Mon. Wea. Rev., November, 1987.

W.A. Nuss, "Air-Sea Interaction Influence on the Structure and Intensification of Marine Cyclones," In review, Mon. Wea. Rev.

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," To be submitted to Journal Atmos. Sciences.

Theses Directed: Warrenfeltz, L.L., 1987: "Superposition Effects in Rapid Cyclogenesis," Ph.D. Dissertation, Department of Meteorology, Naval Postgraduate School, Monterey, CA, 173 pp.

Soper, D.J., 1987: "Diagnostic Study of a Genesis Atlantic Lows Experiment (GALE) Cyclogenesis Event," M.S. Thesis, Naval Postgraduate School, Monterey, CA, 108 pp.

Pertle, W.E., 1987: "A Synoptic Investigation of Maritime Cyclogenesis during GALE," M.S. Thesis, Naval Postgraduate School, Monterey, CA, 103 pp.

Conference Presentations:

Nuss, W. and C. Wash, 1987: "GALE IOP-9: Upper-level Forcing and Air-Sea Interaction," Sixth Extratropical Cyclone and GALE Project Workshop, Pacific Grove, CA, 16-20 February 1987.

Liou, C.-S., D. Soper and R. Elsberry, 1987: "Preliminary Analysis and Prediction Studies of a Cyclogenesis Event (GALE IOP-2)," Sixth Extratropical Cyclone and GALE Project Workshop, Pacific Grove, CA, 16-20 February 1987.

Title: Tropical Cyclone Motion Studies

Investigator: Russell L. Elsberry, Professor of Meteorology

Sponsor: Office of Naval Research

Objective: To improve basic understanding of the tropical cyclone. The primary focus is on understanding the role of tropical cyclone structure. The ultimate goal in this five-year program is the development of improved methods of forecasting the track of tropical cyclones, which pose one of the primary peace-time threats to the safety of fleet operating units.

Summary: A variety of initially symmetric vortices have been studied with a non-divergent, barotropic vorticity model that does not include an initial background flow (Fiorino and Elsberry, 1987). Increasing the inner core speed from 20 m/s to 50 m/s with identical profiles outside 300 km produces only about 5% increase in speed along essentially the same track. However, a 50% increase in storm translation (especially westward displacements) results if the outer region (300-800 km) winds are increased by several m/s. These tracks are associated with the production of largescale (600 km from storm) gyres that are cyclonic to the left and anticyclonic to the right of the storm. The flow between these gyres accounts for about 95% of the storm displacement in the absence of any initial background flow. These gyres are rotated cyclonically when the outer region winds are stronger so that a larger translation toward the west is produced. Some observations in Typhoon Abby support the existence and rotation of the gyres to keep the flow between the gyres oriented along the track.

Three technical reports on the ONR Accelerated Research Initiative on Tropical Cyclone Motion have been produced. First, Elsberry (1987a) reports on the observational systems that potentially could be used in tropical cyclone research. Second, Elsberry (1987e) discusses the potential effects and new strategy required because of the termination of operational tropical cyclone reconnaissance in the western North Pacific. Finally, Sandgathe (1987) has described the tropical cyclone forecast problems that require improved understanding.

Publications:

R. L. Elsberry, "Some Issues Related to the Theory of Tropical Cyclone Motion," Tech. Rep. NPS63-86-005, Naval Postgraduate School, 1986.

R. L. Elsberry, "Potential Observing Systems for Tropical Cyclone Motion Studies," Tech. Rep. NPS 63-87-003, Naval Postgraduate School, 1987a.

R. L. Elsberry, "Some Reflections on the Present Status of Tropical Cyclone Track Prediction," Extended abstracts, 17th Tech. Conf. on Hurricanes and Tropical Meteor., American Meteor. Soc., Boston, 259-261, 1987b.

R. L. Elsberry, "Analysis of Tropical Cyclones," Chapter 1, A Global View of Cyclones, (R. L. Elsberry, Ed.), University of Chicago Printing Dept., 185 pp., 1987c.

R. L. Elsberry, "Tropical Cyclone Motion," Chapter 4, Global View of Tropical Cyclones, (R. L. Elsberry, Ed.), University of Chicago Printing Dept., 185 pp., 1987d.

R. L. Elsberry, "Interim Review of the Possibilities and Opportunities for the ONR Tropical Cyclone Research Initiative," Tech. Rep. NPS 63-87-007, Naval Postgraduate School, 1987e.

M. Fiorino and R. L. Elsberry, "The Role of Vortex Structure in Barotropic Tropical Cyclone Motion," Extended abstracts, 17th Tech. Conf. on Hurricanes and Tropical Meteor., American Meteor. Soc., Boston, 5559, 1987.

S. A. Sandgathe, "Opportunities for Tropical Cyclone Motion Research in the Northwest Pacific Region," Tech. Rep. NPS 63-87-006, Naval Postgraduate School, 1987.

Conference Presentation:

R. L. Elsberry, "The Navy (ONR) Initiative on Understanding Tropical Cyclone Motion," Proc. 41st Annual Interdepartmental Hurricane Conference, January 6-9, 1987.

Title: Tropical Cyclone Prediction

Investigator: R. L. Elsberry, Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To improve the accuracy of the tropical cyclone forecast guidance to the fleet. One goal of this continuing project is to produce a more objective approach to the tropical cyclone prediction. New technology such as decision-tree algorithms and expert systems offer potential for future improvements in forecasts.

Summary: A technique (Curry, Elsberry and Chan, 1987) for estimating objectively the location of a tropical cyclone from a variety of fixes has been provided to NEPRF for inclusion in the automated tropical cyclone forecast system. The procedures for evaluating the Nested Tropical Cyclone Model in terms of five storm-related factors (Chan, Williams and Elsberry, 1987) has been extended to four other objective aids used by the Joint Typhoon Warning Center (Jones, 1986; Jones and Elsberry, 1987). Only the OTCM has forecast skill at 72 h, and this skill is only in the along-track component. None of the four aids has cross-track prediction skill at 72 h relative to a CLImatology-PERsistence (CLIPER) forecast.

Empirical orthogonal function (EOF) analysis has been shown to be useful in depicting efficiently the synoptic flow surrounding tropical cyclones (Peak, Wilson, Elsberry and Chan, 1986). 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, 1987). A similar approach (Meanor, 1987; Meanor, Elsberry and Peak, 1987) has been successfully used to demonstrate significant differences in the vertical shear components in the 700-400, 400-250, and 700-250 mb layers. Both the EOF coefficients representing these shear fields and the wind fields at the individual levels have been used as predictors in a statistical post-processing of the OTCM track forecasts. The 72 h forecast errors were reduced to 435 km from 593 km for

Summary: (cont.)

the unmodified OTCM and 631 km for the JTWC official forecasts. These algorithms have been supplied to NEPRF for operational testing. The EOF coefficients also have been used to develop a prototype intensity forecast scheme (Weniger, Elsberry and Peak, 1987; Weniger, 1987).

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, 1987). This decision-tree approach has been extended to include shear-related EOFs (Meanor, 1987). Based on this research, the number of objective aids should be reduced as several aids provide information that is not significantly different from the CLIPER forecast.

Publications:

J.C.-L. Chan, B. J. Williams and R. L. Elsberry, "Performance of the Nested Tropical Cyclone Model as a Function of Five-Storm Related Parameters," Monthly Weather Review, 115, (July 1987), 1238-1252.

Curry, W. T., R. L. Elsberry and J. C.-L. Chan, "An Objective Technique for Estimating Tropical Cyclone Warning Positions," Monthly Weather Review, 115, (June 1987), 1073-1082.

H. Jones and R. L. Elsberry, "Evaluation of Four Objective Track Forecast Aids for Western North Pacific Tropical Cyclones," Extended abstracts, 17th Tech. Conf. on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA, 153-156, 1987.

D. H. Meanor, R. L. Elsberry and J. E. Peak, "Environmental Vertical Wind Shear as a Predictor of Tropical Cyclone Track Error," Extended abstracts, 17th Tech. Conf. on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA, 223-226, 1987.

J. E. Peak, W. E. Wilson, R. L. Elsberry and J. C.-L. Chan, "Forecasting Tropical Cyclone Motion Using Empirical Orthogonal Function Representations of the Environmental Wind Fields," Monthly Weather Review, 114, (December 1986), 2466-2477.

Publications: (cont.)

J. E. Peak and R. L. Elsberry, "Selection of Optimal Tropical Cyclone Motion Guidance Using an Objective Classification Tree Methodology," Monthly Weather Review, 115, (September 1987), 1851-1863.

T. B. Schott, J. C.-L. Chan and R. L. Elsberry, "Further Applications of Empirical Orthogonal Functions of Wind Fields for Tropical Cyclone Motion Studies," Monthly Weather Review, (July 1987), 1225-1237.

E. L. Weniger, R. L. Elsberry and J. E. Peak, "Tropical Cyclone Intensity Prediction Based on Empirical Orthogonal Function Representation of Wind and Shear Fields," Extended abstracts, 17th Tech. Conf. on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA, 1987, 297-298.

Theses Directed:

H. Jones, "Comparisons of Western North Pacific Tropical Cyclone Aids Using Storm-Related and Synoptic Parameters," Master's Thesis, December 1986.

D. H. Meanor, "Vertical Wind Shear as a Predictor of Tropical Cyclone Motion," Master's Thesis, March 1987.

E. L. Weniger, "Tropical Cyclone Intensity Prediction Based on Empirical Orthogonal Function Representation of Wind and Shear Fields," Master's Thesis, June 1987.

Title: Eddy Generation Mechanisms in Eastern Boundary Current Regions

Investigator: Robert L. Haney, Professor of Meteorology

Sponsor: Office of Naval Research

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 three 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 third type of study is an oceanic hindcast using observed data (oceanic and atmospheric). 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.

Publication: Mettlach, T.R., 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," Journal of Geophysical Research, 92, February 1987, 1967-1974.

Theses Directed: "Topographic Influences in the California Current System," C.Y. Chen, M.S., December 1986.

"Wind Forcing Experiments in the California Current System," P. G. Renaud, M.S., December 1986 (co-advisor).

Title: Large-Scale Atmosphere-Ocean Coupling

Sponsor: National Science Foundation

Investigators: R. L. Haney, Professor of Meteorology, M.A. Rennick, Adjunct Research Professor of Meteorology

Objective: To improve our understanding of the physical basis of El Nino-Southern Oscillation (ENSO).

Summary: An analytic investigation of unstable air-sea interactions in a coupled reduced-gravity ocean-atmosphere model of the equatorial region has been completed. The results demonstrate the extreme sensitivity of the coupled air-ocean system to processes that effect the ocean surface temperature. Numerical calculations using the nonlinear version of our model can substantiate the basic conclusions of the analytic study, and provide further insight into processes that effect the sea surface temperature during the early phase of an ENSO event. Finally a comment was made on a previous model study by Anderson and McCreary (J. Atmos. Sci., 1985) which was based on an improper formulation of upper ocean physics.

Publication: Rennick, M. A. and R. L. Haney, "Stable and Unstable Air Sea Interaction in the Equatorial Region," Journal of the Atmospheric Sciences, 43, December 1986, 2937-2943.

Conference Presentation: Haney, R. L., "Coupled Models of ENSO," Proceedings, WMO Symposium on Ocean Atmosphere Interaction Relevant to Long Range Forecasting, Toulouse, France, 15-19 June 1987.

Title: G. J. Haltiner Research Chair in Meteorology

Investigators: R. J. Renard, Professor of Meteorology, T. H. Vonder Haar, Professor, Department of Atmospheric Sciences, and Director, Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO

Sponsor: Naval Air Systems Command

Objective: The Chair has been established to provide a strong interaction between the Navy's research community 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: Dr. Vonder Haar contributed significantly to the orderly development of the new NPS Interactive Digital Environmental Analysis (IDEA) Laboratory, now being used extensively for classroom/laboratory course instruction and student thesis research in the Air/Ocean Sciences area by providing advice and ideas, software and special satellite data sets. He began research on several new areas, including new estimates of poleward energy transport by the ocean; variations of energy output from the sun; and use of new marine atmospheric boundary layer high resolution models to explore the impact of diurnal variations of solar heating/infrared cooling on cloud conditions. He completed a publication dealing with use of spectral radiance observations from aircraft, together with Monte Carlo estimates, regarding the feasibility of theory showing that such spectral data can be used to estimate the effective optical depth and effective drop size of marine stratus and stratocumulus. He developed, in collaboration with FORD Aerospace and NASA engineers, the concept and conceptual design for earth science measurements from the geostationary platform (circa, 2001). He completed a multi-year, multi-million dollar research proposal to NASA (in collaboration with Professor Durkee, NPS faculty member, and others) for earth/ocean/atmospheric measurements from a spectral radiometer to be flown on the Shuttle Earth Observation Mission pallet. He also advised a number of the Navy's graduate students at NPS regarding their ongoing course interests and/or

Summary: (cont.) thesis topics related to various environmental satellite problems (e.g., three Space Science students w.r.t. *Orion satellite; one Space* Operations student regarding concept and structure of her thesis on NROSS payload selections; several Air/Ocean Sciences students regarding details of their use of civil and military weather satellite data).

Publications:

A. E. Lipton and T. H. Vonder Haar, 1987: "Retrieval of Water Vapor via Principal Components: Options and their Implications," J. Climate Appl. Meteor., (accepted).

T. H. Vonder Haar, A. C. Meade, R. J. Craig, and D. L. Reinke, 1988: "Four-Dimensional Imaging for Meteorological Applications," J. Atmos. Ocean. Tech., (accepted).

F. P. Kelly, C.-F. Shih, D. L. Reinke, and T. H. Vonder Haar, "Metric Statistical Comparison of Objective Cloud Detectors," Proceedings, Digital Image Processing and Visual Communications Technologies in Meteorology, 26-29 October 1987, Cambridge, MA, SPIE.

T. H. Vonder Haar, D. L. Reinke, and S. Naqvi, "A System for Rapid 4-Dimensional Display of Combined Satellite and Radar Observations," Preprints, Fourth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography and Hydrology, January 31 - February 5, 1988, Anaheim, CA, American Meteorological Society, Boston, MA.

D. W. Hillger, A. S. Jones, J. F. W. Purdom, and T. H. Vonder Haar, "Spatial and Temporal Variability of VAS Radiance Measurements by Structure and Correlation Analysis," Preprints, Third Conference on Satellite Meteorology and Oceanography, January 31-February 5, 1988, Anaheim, CA, American Meteorological Society, Boston, MA.

D. L. Randel, and T. H. Vonder Haar, "NIMBUS-7 Earth Radiation Budget Measurements and their Relationship to the Energetics of the General Circulation." Preprints, Third Conference on Satellite Meteorology and Oceanography, January 31-February 5, 1988, Anaheim, CA, American Meteorological Society, Boston, MA.

Publications: (cont.)

C.-F. Shih, M. Wentzel, and T. H. Vonder Haar, "Effects of Data Resolution on Marine Stratiform Cloud Detection Using AVHRR and VISSR Satellite Data." Preprints, Third Conference on Satellite Meteorology and Oceanography, January 31-February 5, 1988, Anaheim, CA, American Meteorological Society, Boston, MA.

T. H. Vonder Haar, J. L. Behunek, and C.-F. Shih, "Estimation of Meteorological Parameters Over Mesoscale Regions from Satellite and In Situ Data." Preprints, Third Conference on Satellite Meteorology and Oceanography, January 31-February 5, 1988, Anaheim, CA, American Meteorological Society, Boston, MA.

D. W. Hillger and T. H. Vonder Haar, "Estimating Noise Levels of Remotely-Sensed Measurements from Satellites Using Spatial Structure Analysis." J. Atmos. Ocean. Tech., 5, 9 pp.

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 data base of McMurdo and Williams Field surface, McMurdo upper-air and Ross Sea area Automatic Weather Station (AWS) observations was extended to December 1985. Using a linear discriminant method, new equations for forecasting visibility in three categories (< 3 mi, < 2 mi, < 0.5 mi) at McMurdo and Williams Field were developed, as a function of surface, upper air and AWS prediction parameters. A test operational visibility forecast program was sent to McMurdo.

A comparability test of visibility forecasts for McMurdo and Williams Field was accomplished using a homogeneous data set of surface data from the two stations. The AWS data set (especially Stations 8906 (Marble Point, 8907 (Ferrell), 8913 (Whitlock) and 8905 (Manning)) were investigated for their use in yielding precursor information on low visibility events at McMurdo and Williams Field. The Naval Postgraduate School hosted the Antarctic Automatic Weather Station Conference in Monterey on 17 March 1987, attended by about 25 scientists and operational meteorologists (two from NSFA). The NSFA was assisted in final revisions and review of Forecaster's Handbook for Antarctica.

Publications: R. A. Hale and R. J. Renard, "Statistical Predictions of Restricted Visibility at McMurdo and Williams Field, Antarctica," Antarctic Journal of the United States: 1987 review issue, Vol. XXIII, No. 5.

R. J. Renard, "The Naval Postgraduate School Antarctic Weather Data/Analysis Archive," Workshop on U. S. Antarctic Meteorological Data Delivery Systems, Boulder, CO, 10-11 September, 1987.

Conference Presentation:	R. A. Hale and R. J. Renard, "Review of NPS Research on Forecasting Visibility for McMurdo and Williams Field, Antarctica," Antarctic Automatic Weather Station Conference, Naval Postgraduate School, 17 March 1987, Monterey, CA.

Title: Regional Synoptic Forecasting: Central America and Adjacent Caribbean Sea/North Pacific Ocean Areas

Investigators: R. J. Renard, Professor of Meteorology and F. R. Williams, Adjunct Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To produce a handbook describing the analyses and forecasting of atmospheric and oceanic conditions important to air/sea operations over and near Central America.

Summary: The project commenced during FY 1986 with both investigators traveling to various US/Central American sites to gather climatological, analytical and forecast information on air/ocean parameters of operational importance to the Central American area weather analysis and forecasting. During the FY87 reporting period the oceanographic section of the handbook was contracted out to Dr. G. H. Jung, with the first draft received. Meteorological data gathering has continued with compilation of daily streamline analyses from both the National Weather Service and naval centers; satellite imagery and sea level pressure analyses from the National Hurricane Center in Miami; and observations and forecasts from stations in Central America. Tropical meteorology literature has been searched and the first draft commenced. The handbook will be published in FY 1988.

Title: Aircraft Measurements in the Frontal Air-Sea Interaction Experiment

Investigator: W.J. Shaw, Assistant Professor of Meteorology

Sponsor: National Science Foundation (NSF)(CY86-88; 11K)

Objective: To collect data during FASINEX using the NCAR Electra aircraft and to use them to deduce the atmospheric boundary layer's response to an ocean front.

Summary: The NCAR Electra flew six missions near 70W and 28 N in February 1986. Meteorological data were received from NCAR in July 1986. The first year of analysis was spent in determining necessary standard corrections to the Electra's mean wind velocity measurements, humidity measurements, and sea-surface temperature measurements and in developing a preliminary assessment of the atmospheric boundary layer's mesoscale variability in relation to the ocean front. These have been completed. Emerging scientific results, which are still preliminary, indicate that the front does indeed leave a substantial imprint in the flux fields of the ABL. Surface stresses change by as much as a factor of 3 from one side of the front to the other. Additionally, cooperative work with other scientists, who made scatterometer measurements coordinated with the turbulence measurements of the Electra, indicates that the scatterometer reflects surface stress rather than neutral surface wind. This result addresses what has been a controversial question in the surface stress measurement community for many years. The final year of the project will be devoted to developing the physical balances necessary to explain the atmosphere-ocean interaction near the front.

Publications:

Li, F., Large, W., E. Walsh and K. Davidson, 1987: "Ocean Radar Backscatter Relationship with Near Surface Winds: A Case Study during FASINEX," (Submitted to the Journal of Physical Oceanography).

Shaw, W. and G. T. Vaucher, 1987: "Correction of the Wind Field Measured by the NCAR Electra during FASINEX for Inertial Navigation System Drifts," NPS Tech. Rep. NPS 63-87-008, 43 pp.

Title: Measurements of the Coastal Boundary Layer and Sea Breeze

Investigators: W. J. Shaw, Assistant Professor of Meteorology, K. L. Davidson, Professor of Meteorology and P. A. Durkee, Assistant Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To obtain intensive measurements of the sea breeze circulation and the sea breeze front in order to provide a detailed description of their dynamics and thermodynamics and of their relation to the spatial distribution of marine aerosol particles. Such observations have substantial application in the evaluation of sea breeze models and in the interpretation of coastal satellite imagery.

Summary: The Land/Sea Breeze Experiment (LASBEX) jointly sponsored by NEPRF and NOAA, occurred September 15-30, 1987 on Monterey Bay and in the Salinas Valley. NPS participated with rawinsonde launches and surface meteorological measurements including aerosol distributions in Monterey Bay and with surface meteorology and a pair of doppler sodar systems in the Salinas Valley. Additional measurements included a lidar operated by NOAA's Wave propagation Laboratory, an additional sodar and surface meteorology from NEPRF, and shore-based radiosonde launches by Louisiana State University. Except for the hindrance of more than the average amount of fog during the measurement period, LASBEX observations appear to have been quite successful. Because the opportunity for LASBEX developed after last January, direct funding of research at NPS prevents NEPRF support for the analysis of the data until FY89.

Title: Temporal and Spatial Variability of the Marine Atmospheric Boundary Layer for EM Propagaton

Investigator: W. J. Shaw, Assistant Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To use rawinsonde data from several recent field measurement programs in the atmospheric boundary layer to document temporal and spatial variability of the ABL in primarily undisturbed conditions. The purpose is to examine the effects of this variability on the integrated Refractive Effects Prediction System (IREPS) assessment of mean refractive conditions.

Summary: Two separate studies were accomplished. The first used rawinsonde data from the Frontal Air-sea Interaction Experiment (FASINEX) in the Sargasso Sea and from the Cross-Appalachian Tracer Experiment (CAPTEX) in central Pennsylvania. The second study used data collected from several ships near 80N latitude as part of the Marginal Ice Zone Experiment (MIZEX84). The data were unique because they included nearly simultaneous atmospheric profiles from multiple ships and because there were generally several launches per day over several weeks. The analyses showed conclusively that even under ideal fairweather conditions, the atmosphere shows considerably more temporal and spatial refractive variability that had previously been assumed. The analysis of the Arctic data also revealed humidity measurement difficulties in Arctic stratus clouds that had not been previously noted and which may require improved sensors for use in that region.

Theses Directed: "An Evaluation of the Impact of Variable Temporal and Spatial Data Resolution upon IREPS," M. E. Dotson, M.S., June 1987.

"The Spatial and Temporal Variability of the Arctic Atmospheric Boundary Layer and its Effect on Electromagnetic (EM) Propagation," Z. S. Willis, M.S., December 1987.

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.

Publication: 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: Pind, M. "Evaluation of Satellite-derived Precipitation along the West Coast of the United States," M.S. Thesis, June, 1987.

Scanlon, R. "Mesoscale Applications of High Resolution Imagery," M.S. Thesis, September, 1987.

Title: Observational-Numerical Study of Maritime Extratropical Cyclones using FGGE Data

Investigators: C.H. Wash, Associate Professor of Meteorology, R.L. Elsberry, 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, 1987: "Diagnostic Study of Explosive Cyclogenesis during FGGE," Mon. Wea. Rev., 109, December 1987.

Elsberry, R.L. and M. Sinclair, 1986: "A Diagnostic Study of Baroclinic Disturbances in a Polar Air System," Mon. Wea. Rev., November 1986.

Liou, C.-S. and R. Elsberry, 1987: "Heat Budgets of a Rapidly Developing Cyclone," Mon. Wea. Rev., September 1987.

Elsberry, R.L. and P.J. Kirchoffer, 1987: "Studies of Explosive Cyclogenesis over the Ocean Based on Operationally Analyzed Fields," Weather and Forecasting, (in review).

Title: Satellite Applications for TESS

Investigators: C.H. Wash, Associate Professor of Meteorology
Philip A. Durkee, Assistant Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To provide NEPRF with satellite applications for the TESS 3.0 system. 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.

Thesis Directed: Allen, R., 1987: "Automated Satellite Cloud Analysis: A Multi-Spectral Approach to the Problem of Now/Cloud Discrimination," M.S. Thesis, June 1987.

Title: Air Flow over Large Scale Topography

Investigators: R.T. Williams, Professor of Meteorology, M.A. Rennick, Adjunct 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. This is a continuing project.

Summary: The formation of cyclones in the lee of a mountain range was studied with analytic and numerical models. The principal mechanisms were isolated. The problem of flow over or around a long mountain range was investigated with two and three dimensional finite difference models. The interaction of fronts with topography was investigated with a two-dimensional model. The fronts were driven by confluence and also by shearing deformation. Baroclinic instability in a zonally varying basic current was treated with the two-scale method.

Publications:

Gall, R. L., R. T. Williams and T. L. Clark, 1987: "On the Minimum Scale of Surface Fronts," Journal of the Atmospheric Sciences, 44, 2562-2574.

Gall, R. L., R. T. Williams and T. L. Clark, 1987: "Gravity Waves Generated during Frontogenesis," Submitted to the Journal of the Atmospheric Sciences.

Hayes, J. L., R. T. Williams and M. A. Rennick, 1987: "Lee Cyclogenesis Part I: Analytic studies," Journal of the Atmospheric Sciences, 44, 432-442.

Peng, M. and R. T. Williams, 1987: "Spatial Instability of a Baroclinic Current with Slow Streamwise Variation," Journal of the Atmospheric Sciences, 44, 1681-1695.

Publications: (cont.)

Peng, M. S., and R. T. Williams, 1987: "On the Transformation between Temporal and Spatial Growth Rates," Journal of the Atmospheric Sciences, 44, 2668-2673.

Williams, R.T., M.S. Peng and D.A. Zankofsky, 1987: "Interaction of Fronts with Topography." In preparation.

Conference Presentations:

Williams, R. T. and M. A. Rennick: "Lee Cyclogenesis in a Baroclinic Current," Sixth Extratropical Cyclone Workshop, Pacific Grove, CA, 16-20 February 1987.

Williams, R.T., M.S. Peng and D.A. Zankofsky: "Interaction of Fronts with Surface Topography," Sixth Extratropical Cyclone Workshop, Pacific Grove, CA, 16-20 February 1987.

Williams, R.T., M.S. Peng and D.A. Zankofsky: "Interaction of Fronts with Topography," IUGG General Assembly, Vancouver, British Columbia, 10-21 August 1987.

Rennick, M.A. and R. T. Williams: "Lee Cyclogenesis in a Baroclinic Current," Fourth Conference on Mountain Meteorology of the American Meteorological Society, Seattle, WA, 25-28 August 1987.

Williams, R.T., M.S. Peng and D.A. Zankofsky: "Breakdown of Semi-Geostrophic Flow Over a Two Dimensional Mountain," Fourth Conference of the American Meteorological Society, Seattle, WA 25-28 August 1987.

Thesis Directed:

Byrne, G.T., "Numerical Investigation of Orographically Enhanced Instability," Master's Thesis, September 1987.

Title:	Development of Finite Element Prediction Model
Investigators:	R.T. Williams, Professor Meteorology, A.L. Schoenstadt, Professor of Mathematics B. Neta, Associate Professor of Mathematics R. Newton, Professor of Mechanical Engineering
Sponsor:	NAVAIRSYSCOM
Objective:	Develop and test finite element regional prediction model.
Summary:	The Canadian baroclinic finite element program was modified to include time dependent boundary conditions. Three vertical finite element schemes were developed (Jordan) and compared with the corresponding finite difference schemes. An analytic study of the finite element advection equation was carried out by Neta and Williams with four types of triangular elements and the usual rectangular elements.
Thesis Directed:	B.G. Shapiro, LTJG, USAF, "A Study of Finite Difference and Finite Element Vertical Discretization Schemes for Baroclinic Prediction Equations," Master's Thesis, June 1987.

Title:	Development of a Finite Element Prediction Model
Investigators:	R. T. Williams, Professor of Meteorology A. L. Schoenstadt, Professor of Mathematics B. Neta, Professor of Mathematics R. E. Newton, Professor of Mechanical Engineering
Sponsor:	Office of Naval Research
Objective:	To develop and test a finite element atmospheric prediction model. This is a continuing project.
Summary:	A linearized Boussinesq model was used to investigate vertical descritization in baroclinic prediction models. Two finite element and two finite difference schemes were compared for barotropic and baroclinic conditions. Special attention was paid to the finite element boundary conditions. Finite element and finite difference schemes were evaluated for Rossby waves.
Publications:	Neta, B. and R. T. Williams, Rossby Wave Freqencies and group velocities for finite element and finite difference approximations to the vorticity-divergence and primitive forms of the shallow water equations. In preparation.
Conference Presentations:	Neta, B. and R. T. Williams, Finite elements versus finite difference for fluid flow problems. Numeta 87, Swansea, United Kingdom, July 6-10, 1987.
Thesis Directed:	Shapiro, B. G., A Study of Finite Difference and Finite Element Vertical Discretization Schemes for Baroclinic Prediction Equations, Master's Thesis, June 1987.

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

Objective: Develop and test better numerical techniques for use in Navy weather forecasting models. This is a continuing project.

Summary: The interaction of planetary waves with synoptic waves was carried out with the normal model technique developed by Errico. The NOGAPS model was used with Fleet Numerical Oceanography Center initial data, and it was shown that the interaction between planetary and synoptic waves could be important. Flow over steep mountains was simulated with two and three-dimensional finite difference models and a spectral model. Frontal effects were included in the two dimensional finite difference simulations.

Publications: Hayes, J. L., R. T. Williams and M.A. Rennick, 1987: "Lee Cyclogenesis Part I: Analytic Studies," Journal of the Atmospheric Sciences, 44. 432-442.

Williams, R. T., M. S. Peng and D. A. Zankofsky, 1987: "Interaction of Fronts with Topography." In preparation.

Conference Presentations: Williams, R. T., M. S. Peng and D. A. Zankofsky: "Interaction of Fronts with Surface Topography." Sixth extratropical Cyclone Workshop, Pacific Grove, CA, 16-20 February 1987.

Williams, R. T., M. S. Peng and D. A. Zankofsky: "Interaction of Fronts with Topography." IUGG General Assembly, Vancouver, British Columbia, 10-21 August 1987.

Williams, R. T., M. S. Peng and D. A. Zankofsky: "Breakdown of SemiGeostrophic Flow Over a Two Dimensional Mountain," Fourth Conference of the American Meteorological Society, Seattle, WA 25-28 August 1987.

Title: Theory of Tropical Cyclone Motion

Investigator: R.T. Williams, Professor of Meteorology

Sponsor: Office of Naval Research

Objective: To understand the physical processes which control the motion of tropical cyclones.

Summary: This study of tropical cyclone motion uses the non-diverent barotropic model to represent the vertically averaged flow. The beta effect on cyclone motion is isolated by excluding the basic durrent. The analytic solutions with the linearized equation show that an initial vortex is stretched to the west with time, but the movement of the vortex center is negligible. An east-west asymmetry in the meridional wind is created with the strongest speeds to the east of the vortex. The finite difference solutions for the same problem show essentially the same solutions, which demonstrates the accuracy of the numerical procedures. The inclusion of the nonlinear term in the numerical model produces a northwestward drift of the vortex of a few hundred kilometers over 72 hours. This northwestward movement increases with both the maximum wind speed and the movement increases with both the maximum wind speed and the radius of maximum wind in a constant-shape vortex. A wind maximum is found to the northeast of the vortex, which appears to be consistent with observational findings. This asymmetry plays an important role in vortex motion.

These results strongly suggest that the initial vortex structure should be important in tropical cyclone prediction models. Most current models use a fixed structure for all tropical cyclones.

Publication: Chan, Johnny C.-L. and R. T. Williams, 1987: "Analytical and Numerical Studies of the Beta-effect in Tropical Cyclone Motion, Part I: Zero Mean Flow," Journal of the Atmospheric Sciences, 44, 1257-1265.

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 (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); Performance and Absenteeism in Public Organizations (Associate Professor James Morris); DoD Manpower Issues (Professor James Blandin).

Title: FORECASTS System

Investigators: R. von Pagenhardt, T. Adler, J. Blandin, N. Choucri, J. Dawson, H. Guetzkow, O. Helmer, O.J. LaCivita, E. Laurance, R. Looney, D. Meadows, D. Meadows, F. Melese, R. North, R. Pirog, K. Wall, LTC D. Bonsper, USMO (Ret), COL J. Channon, USA (Ret), CAPT W. Eskridge, USA (Ret), LCDR L. Vaughan, USN, and LCDR T. Wray, USN.

Sponsor: OJCS; JDSSC/DCA

Objectives: To update, enhance, and make more useful the FORECASTS System of the Joint Staff in order that J-5 and others, including the Policy Planning Staff of State, 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 System on to a micro-computer and create FORECASTS System II by updating a validated database through 1985, while developing PO DOS compatible software for JCS desktop computers as well as those at service colleges and the NPS. The new system will require the FORECASTS team to create an international relations forecasting module, and to provide documentation meeting high standards of science and exposition.

Publications: This project calls for a book based upon the use of the FORECASTS System for anticipating global challenges and evaluating alternative policies for the United States.

Conference Presentation: Two conferences were held among the Representatives of the OJCS, JDSSC and NPS/DRMEO, each for two days.

DEPARTMENT

OF

AERONAUTICS

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

During the reporting period, Aero/Astronautics faculty have been active in the following major research areas:

Aircraft Combat Survivability

Professor Ball continued his studies of aircraft combat survivability. This year's effort involved eight thesis students.

High Angle of Attack Aerodynamics

Professors Bodapati and Platzer devoted their efforts to the establishment of a center for high angle of attack unsteady aerodynamics to support the Navy's next generation super-maneuverability fighter aircraft program. Also, research programs sponsored by the Army Research Office and the Air Force Office of Scientific Research on the investigation of the compressibility effects on airfoil dynamic stall are part of this effort.

Helicopter-Ship Interface

Professor Healey continued his experimental investigations of the helicopter-ship interface problem. The objective of this work is to map in detail the airflow in the vicinity of models of specified ships for use in simulation work.

Boundary Layer Studies

Professor Howard initiated a research program to study the Remotely Piloted Vehicle (RPV) airfoil behavior in a turbulent environment. The boundary layer characteristics of a Wortmann airfoil will be obtained in a wind tunnel by means of surface pressure, wake and boundary layer hot wire measurements.

Finite Element Analysis of Shell Structures

Professor Kolar investigated the behavior of thin shell structures using various plate and shell finite elements. The effects of various integration schemes were studied and an extension to analyze thick composite plates was made.

Thermal Efficiency Models for Steam Distribution Systems

Professor Miller investigated the applicability of several pressure-flow models to steam distribution systems. He found that the model developed by Oak Ridge National Laboratories is the most suitable one for naval shore installations. The model was field tested at the Naval Supply School, Athens, Georgia.

Solid Fuel Ramjet Propulsion

Professor Netzer is continuing his investigation of solid fuel ramjets by experimentally determining the effects of operating conditions and fuel composition on the combustion characteristics of metallized fuels and by determining the relationships between ignition and flammability limits. He also initiated an investigation into the feasibility of using dual-combustion mode solid-fuel ramjets (supersonic/subsonic) for high Mach number tactical missiles.

Gas Turbine Combustors

Professor Netzer is also continuing the experimental investigation of the effects of fuel composition, smoke suppressant additives and combustor operating conditions on the sooting characteristics of gas turbine combustors and engine exhaust augmentor tubes.

Unsteady Flows in Aircraft Propulsion Systems

Professor Platzer continued the analysis of the steady and unsteady blade performance in axial-flow turbomachinery. A numerical method based on Cebeci's viscous/inviscid interaction procedure was developed to analyze viscous incompressible flows through turbomachinery cascades. Also, he performed an experimental investigation of the mixing effectiveness of a new jet excitation scheme for use in thrust augmenting aircraft ejectors.

Turbine Blade Heat Transfer

Professor Platzer continued the development of a general method for the analysis of heat transfer on turbine blades exposed to unsteady flow effects.

Aeroelasticity in Turbomachines

Professor Platzer completed the editing of a two-volume AGARD Manual on Aeroelasticity in Axial-Flow Turbomachines. The first volume contains eleven chapters on unsteady turbomachinery aerodynamics and was published in March 1987. The second volume on structural dynamics and aeroelasticity will be published in 1988.

Compressor Aerodynamics

Professor Shreeve continued experimental investigations of compressor cascade flows and of the tip clearance effects in a three-stage low-speed axial flow compressor.

Composite Materials Research

Professor Wu continued research on the aging characterization of composite materials. He is establishing a stress aging facility for fibers and for composites to provide an independent and uninterrupted data base for DOD needs. Also, he is developing a proof-test methodology for advanced composites.

Title: NSP Survivability Support

Investigator: Robert E. Ball, Professor, Department of Aeronautics

Sponsor: Naval Weapons Center

Objective: To conduct studies in Aircraft Combat Survivability (ACS)

Summary: Studies in ACS have been conducted at NPS for the past 13 years. This year's effort involved eight theses and one report. The following topics are included:

1. Development of an interaction computer program for the simulation of engagements at sea between a ship and attacking aircraft.

2. Development of a computer program for assessing the survivability of a helicopter in the conceptual design phase.

3. Vulnerability reduction of spacecraft.

4. High energy laser effects in aircraft.

5. Evaluation of several pieces of electronic warfare equipment for a particular Navy aircraft.

6. The state of the art in IR countermeasures.

7. Helicopter susceptibility in air-to-air combat.

Publication: R. E. Ball and J. N. Williams, Helicopter Susceptibility in Air-to-Air Combat, Naval Air Systems Command, July 1987.

Theses Directed: D. D. Antonio, "A Missile Flyout Model for ISEAS," M.S., Dec 86.

R. W. Baker, "The Implementation and Modification of BLUEMAX II: A Flight Path Generator for Use at the Naval Postgraduate School," M.S., Dec 86.

S. R. Laabs, "Requirements for an Interactive Computer Program for Evaluating the Survivability of Helicopter Conceptual Designs (HISAP)," M.S., Dec 86.

J. Mamau, "Computer Simulation of an Anti-Air Operation in the Combat Information Center," M.S., Dec 86.

Title: Compressibility Effects on the Dynamic Stall of Airfoils Undergoing Ramp-Type Motion

Investigators: S. Bodapati, Associate Director and Adjunct Professor of Aeronautics; M.F. Platzer, Professor and Chairman of Aeronautics; M.S. Chandrasekhara, Adjunct Research Professor of Aeronautics

Sponsor: Air Force Office of Scientific Research

Objective: The objective of this investigation is to qualitatively and quantitatively determine the effects of compressibility on dynamic lift when the airfoil is undergoing ramp-type motion, and to determine the effects on dynamic stall vortices, transition, separation, reattachment, type of stall, and stall development as the Mach number is increased progressively from 0.2 to 0.5. This is a new multiyear program related to the supermaneuverability of fighter aircraft.

Summary: Much of the expected improvement in maneuvering that is sought in the Maneuverability Initiative that was introduced by AFOSR will depend on the attainment of high lift, especially through use of unsteady aerodynamic effects. However, it has been observed that the dynamic stall phenomenon which is the primary source of this high unsteady lift, is significantly affected by compressibility effects - to the extent of being completely eliminated under certain conditions. Our proposed program will supply the basic quantitative information about this developing compressible flow field which is needed to permit rational development of techniques to allow application of concepts developed at low speed to aircraft flying at speeds which induce compressibility effects. A mechanism to pitch an airfoil at a constant pitch rate of up to 3600 degrees per second using a hydraulic actuation was designed. The details of the hydraulic system, the mechanical linkage system, servovalve, and the control system are being finalized. A model is attached between a pair of Schlieren quality windows and the windows are rotated dynamically; the view of the flow near the surface of the airfoil will be completely unobstructed. While the design is in progress exploratory tests were carried out under simulated conditions to develop the flow visualization and LDV data acquisition and analysis techniques which will be required for tests in the new facility. This program is being carried out in conjunction with the program being carried out for the Army Research Office, making use of certain common facilities, instrumentation, and experimental techniques.

Thesis Directed: R. R. Ryles, "Investigation of Dynamic Stall Using LDV: Mean Flow Studies," Master's Thesis, September 1987.

Title: Compressibility Effects on the Dynamic Stall of Oscillating Airfoils

Investigators: S. Bodapati, Associate Director and Adjunct Professor of Aeronautics; M.F. Platzer, Professor and Chairman of Aeronautics; M.S. Chandrasekhara, Adjunct Research Professor of 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. This is a continuing program related to the dynamic stall of helicopters.

Summary: A 25cm x 35cm wind tunnel test section and an oscillating mechanism was designed and fabricated for the indraft facility at the Fluid Mechanics Laboratory of NASA Ames Research Center. While the actual experimental apparatus is being fabricated, simulated experiments were carried out to develop the techniques to visualize the instantaneous Schlieren pictures throughout the Mach number range using the readily available 25cm x 11cm test section with an oscillating airfoil model. A Vaxlab (Microvax-II) was procured and all the instrumentation (like scanivalve, LDV, traverse mechanism, temperature and pressure transducers, etc.) required for the experiment was interfaced and the computer programs to acquire the data online are being developed. In parallel, efforts are being made to calculate the flow fields using the Navier-Stokes solver under simulated conditions. Detailed flow field characteristics at some typical experimental conditions were evaluated. These investigations are being carried out in cooperation with NASA Ames Research Center, in conjunction with the investigations performed for the AFOSR on supermaneuverability initiative. described under separate project.

Thesis Directed: J. F. Valdes, "Dynamic Stall Calculations Using a Navier-Stokes Solver," Master's Thesis, December 1987.

Title: Ship Airwake Study

Investigator: J. Val Healey, Associate Professor of Aeronautics

Sponsor: Naval Air Systems Command, AIR 53

Objective: To study sheared turbulent flow around ship-like structures. The longer term objective is to map in detail the airflows in the vicinity of models of specified ships for use in simulation work.

Summary: Vast sums of money are currently being spent on helicopter/ship interface testing and a very large backlog of tests currently exists. Simulating this interface would largely eliminate this expenditure, drastically reduce the backlog and aid in training of pilots.

To achieve this, detailed measurements must be made of the mean wind speed, the turbulence intensity and the spectrum function in the wakes of models of specified ships. The longer term aim of the project is to do this using hot-wire anemometry and, because of the complexity of the flow and occasional uncertainty in the flow direction, detailed flow-visualization studies must first be done. Good progress has been made in the past year towards understanding the wakes of ship models in a simulated atmosphere. For example, there appeared to be no shedding of vortices from the ship, and trailing vortices from the major ship elements appeared to feed a strong trailing vortex on the leeward side of the ship. The latter vortex weakened as the ship heading approached the windward direction and ninety degrees to it. It was determined that further studies needed to be made in local areas leeward of the major ship elements and around oscillating models.

Publication: J. Val Healey, "The Prospects for Simulating the Helicopter/Ship Interface," Naval Engineers Journal, Vol 99, No. 2, March 1987.

Thesis Directed: William K. Bollinger, "Visualization of the Flowfield Around a Generic Destroyer Model in a Simulated Turbulent Atmospheric Boundary Layer," Masters Thesis, June 1987.

Title: Boundary Layer Studies of a Wortmann Airfoil in a Turbulent Environment

Investigator: R.M. Howard, Assistant Professor of Aeronautics

Sponsor: NPS Foundation Research Program

Objective: To analyze the behavior of the wing boundary layer in the presence of freestream turbulence. This investigation will be accomplished in a wind tunnel study with surface pressure, wake and boundary-layer hot-wire anemometer measurements.

Summary: Naval Remotely Piloted Vehicles (RPVs) are subject to turbulence in the mean wind and from the superstructure airwake during on-board retrieval. Problems unique to the low Reynolds number flight regime include lift-curve hysteresis and the formation and bursting of laminar separation bubbles. A systematic study of these phenomena under the influence of elevated levels of freestream turbulence has not previously been performed.

A program to study RPV airfoil behavior in a turbulent environment was begun with the design and construction of square-mesh, square-bar biplanar grids to generate near-isotropic turbulence of various intensities and length scales. A hot-wire anemometer longitudinal mapping of the flowfield was performed to establish baseline data for various flow environments using the turbulence grids.

An airfoil model is currently being constructed. The project has been continued into FY 88.

Title: Plate/Shell Element for Nonlinear Finite Element Analysis of Shell Structures

Investigator: R. Kolar, Assistant Professor of Aeronautics

Sponsor: NPS Foundation Research Program

Objectives: To investigate the behavior of thin shell structures using various plate/shell finite elements.

Summary: This research project addresses the issues involved in analyzing thin shell structures. Currently available plate/shell finite elements are evaluated and the advantages and disadvantages are brought out. Effects of different order integration schemes was studied. As an extension of the project, existing approaches to study thick composite plates was undertaken. Various factors, such as plate thickness, fiber orientation, delamination, local buckling etc., are identified for further study.

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: To experimentally determine the effects of fuel composition, smoke suppressant additives and combustor operating conditions on the sooting characteristics of gas turbine combustors and engine exhaust augmentor tubes.

Summary: This is a continuing investigation. In FY 87 the augmentor tube was reduced in diameter in order to reduce the augmentation ratio. A third laser (.5145 microns) was added to provide for three wavelengths for soot size measurements within the combustor, and a three-angle forward light scattering apparatus was designed and operated at the augmentor exhaust. In order to better simulate the exhaust conditions of an actual engine, an air quench ring was added aft of the combustor, before the exhaust nozzle.

This was used to reduce the exhaust product temperature approximately the amount as would be experienced with a turbine present.

A test series was conducted using NAPC-9 fuel (high aromatic JP-5) at fuel-air ratios of .0159 and .0179. D32 decreased with increasing fuel-air ratio in the aft can region (.45 to .35 microns). Within the combustor D32 was between .15 and .17 microns, indicating significant agglomeration occurs aft of the main burner. In addition, D32 was measured to be between 1.50 and 1.55 microns at the exit of the augmentor tube using the three-angle light scattering measurements, indicating that significant agglomeration was also occurring within the exhaust nozzle and/or the augmentor tube. These tests were without quench air. The large particle diameters observed at the augmentor tube exhaust permitted the use of a Malvern 2600 particle sizer as another source for confirming the data. The Malvern 2600 was used both at the exit of the exhaust nozzle and at the exit of the augmentor tube. At the motor exhaust D32 was measured to be 1.2 microns. At the augmentor tube exhaust 80% of the particles were between 1.4 and 1.9 microns, with a D32 of 1.9 microns. These data confirmed the measurements made with the three-angle forward scattering apparatus at the exit of the

Summary: (cont.)

agglomeration occurs both within the exhaust nozzle and within the augmentor tube.

NAPC-2 fuel was used with quench air at a fuel-air ratio of .018. In order to increase the measured intensity of scattered light at the exit of the augmentor tube, the scattering angles were changed to 5, 10 and 20 degrees (vs. 10, 20 and 30). This resulted in some improvement in signal strength, but it remained below desirable levels. D32 within the combustor was between .22 and .25 microns. Repeated tests indicated a D32 of between .77 and .80 microns at the augmentor exit. This was significantly smaller than obtained with the earlier tests. At this point it is not known whether the effect was due to fuel composition or to the quench air. However, the latter is the most probable cause based upon previously observed effects of fuel composition. The lowering of product gas temperature appears to significantly retard soot agglomeration.

Publication:

J. S. Bennett, C. H. Jway, D. J. Urich, and D. W. Netzer, Gas Turbine Combustor and Engine Augmentor Tube Tube Sooting Characteristics, NPS6786-004, Dec 1986.

Theses Directed:

M. F. Young, "Optical Sizing of Soot in Gas Turbine Combustors and Exhaust Augmentor Tubes," MSAE, March 1987.

T. A. Grafton, III, "Measurements of Gas Turbine Combustor and Engine Augmentor Tube Sooting Characteristics," MSAE, Sept, Sept 1987.

Title: Solid Fuel Ramjet Combustion

Investigator: D. W. Netzer, Professor of Aeronautics

Sponsor: Naval Weapons Center

Objectives: (1) To experimentally determine the effects of operating conditions and fuel composition on the combustion characteristics of metallized fuels.

(2) To experimentally determine the relationships between ignition and flammability limits and how these limits are influenced by fuel composition.

(3) To initiate an investigation into the feasibility of using dual-combustion mode solid fuel ramjets (supersonic/subsonic) for high Mach number tactical missiles.

Summary: This is a continuing investigation. An experimental investigation was conducted to study the effects of inlet step height on ignition and flammability limits and recirculation zone and boundary layer combustion phenomena of various metallized and nonmetallized fuels. A windowed, variable inlet geometry, two-dimensional solid fuel ramjet (SFRJ) was utlized. High speed motion pictures of the interior of the combustion chamber at the recirculation zone and the boundary layer development region were obtained. Data was obtained at a mass flux of 0.2 lbm/inz-sec at a nominal air inlet temperature of 1000 R, with pressures ranging from 100 to 150 psia. The flammability limits for nonmetallized fuels were found to be approximately the same or slightly less in step height than the ignition limits. Recirculation zone flame stability was dominant in determining flammability limits for these fuels. Small steps in the fuel surface were found to significantly reduce the inlet step requirements for flame stability.

As the inlet step height was reduced (before ignition limits were reached) chamber pressure/fuel regression rate decreased. This behavior may provide a method for some thrust modulation in the SFRJ.

Metallized fuels were found to require higher pressures to sustain combustion. Fuel composition was found to significantly effect the size, number and trajectories of metallic particles in the gas phase region. Initial holograms were obtained of the combustion process of a boron based fuel in a 2-D windowed motor.

Summary: (cont.) An analytical investigation indicated that a dual mode SFRJ may be able to out perform an SFRJ at Mach 6, 80,000 ft. if supersonic combustion efficiencies greater than 70% can be attained.

Conference Presentations: W. H. Campbell, Jr., B. N. Ko, S. R. Lowe, and D. W. Netzer, "Solid Fuel Ramjet Fuel Regression Rate/Thrust Modulation," 23rd JANNAF Combustion Meeting, Hampton, VA, 1 Oct 1986.

C. K. Scott, III, and D. W. Netzer, "Metallized Fuel Burning Characteristics in the Solid Fuel Ramjet," 23rd JANNAF Combustion Meeting, Hampton, VA, 1 Oct 1986.

Thesis Directed: A. Karadimitris, "The Effects of Metallized Fuel Composition on the Characteristics of Solid Fuel Ramjets," Dec 1986.

C. B. Vaught, "An Investigation into the Feasibility of Using a Dual-Combustion Mode Ramjet in a High Mach Number Tactical Missile," Sept 1987.

C. A. Easterling, III, "A Holographic Investigation of Particulates in Metallized Solid Fuel Ramjet Combustion," Sept 1987.

R. C. Wooldridge, "An Experimental Investigation of the Ignition and Flammability Limits of Various Hydrocarbon Fuels in a Two-Dimensional Solid Fuel Ramjet," June 1987.

Title: Solid Propellant Combustion/Automated Data Retrieval from Holograms

Investigators: D. W. Netzer, Professor of Aeronautics, J. P. Powers, Professor of Electrical and Computer Engineering

Sponsor: Air Force Astronautical Laboratory

Objective: Develop and utilize techniques to obtain particulate size data within the combustor and across the exhaust nozzle of solid propellant rocket motors.

Summary: This is a continuing investigation and consists of two main studies: (1) experimentally measuring particulate sizes using measurements of forward scattered light, holography, high speed motion pictures and SEM evaluation of residue collected in exhaust probes, and (2) development of techniques for computer aided automatic retrieval of particle size data from holograms. The latter effort is summarized in the input from Prof. J. P. Powers.

Holograms have been successfully obtained in both 2-D and 3-D, small solid propellant motors. They have been limited, to data, to pressures below 300 psi and to metal loadings less than 5%.

An NPS designed light scattering measurement apparatus and a Malvern 2600 HSD particle sizer have been used interchangeably on a small, 3-D windowed motor. Particle size distributions have been obtained (1) just off of the end-burning grain, (2) at the entrance to the exhaust nozzle and (3) at the nozzle exhaust for both critical and ambient exhaust pressures. A reduced smoke (1% ZrC) propellant was used to pressures of approximately 450 psi.

Publications: J. Powers and D. W. Netzer, Combustion/Particle Sizing Experiments at the Naval Postgraduate School Combustion Research Laboratory, NASA Conf. 2477, Automated Reduction of Data from Images and Holograms, Aug 1987, pp. 135-136.

D. W. Netzer and J. Powers, Particule Sizing in Rocket Motor Studies Utilizing Hologram Image, Automated Reduction of Data from Images and Holograms, Aug 1987, pp. 589-606.

Conference Presentation: T. Edwards, K. G. Horton, D. Redman, J. S. Rosa, J. B. Rubin, S. C. Youn, J. P. Powers, and D. W. Netzer, "Measurements of Particulates in Solid Propellant Rocket Motors," 23rd JANNAF Combustion Meeting, NASA-Langley Research Center, Hampton, VA, 1 Oct 1986.

Theses Directed: M. G. Keith, "Particle Sizing in a Solid Propellant Rocket Motor Using a Light Scattering Technique," MSAE, Dec 1986.

J. D. Walker, "Holographic Investigation of Metallized Solid Propellant Combustion in Two-Dimensional and Three-Dimensional Rocket Motors," MSAE, Sept 1987.

T. E. Pruitt, "Measurement of Particle Size Distribution in a Solid Propellant Rocket Motor Using Light Scattering MSES," June 1987.

E. D. Youngborg, "Measurement of Operating Environment Effects on ZrC Particulate Size in Solid Propellant Rocket Motors," MSAE, in progress.

Title: Compressor Tip Clearance Effects

Investigators: R. P. Shreeve, Professor and Director, Turbopropulsion Laboratory, Department of Aeronautics, Dr. G. J. Walker and Ian Moyle, 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 has been reassembled with two stages of "symmetrical" blading.

The bearing arrangement was revised and an in-situr blade-tip grinding technique was developed to enable the tip-clearance to be set, and held to + 0.001 inch tolerance. Steady-state and phase-locked data acquisition from hot-wire and buried wire gauges was verified and a device to control the thickness of the inlet case-wall boundary layer was constructed. All preparations for the test program are now completed.

A review and analysis was completed of published data on tip-clearance effects.

Publications: Walker G. J. "Turbulent Skin Friction on Axial Compressor Blading," Proceedings of The 8th International Symposium on Air-Breathing Engines, Cincinatti Ohio 15-19 June 1987.

Moyle, I. N. "Analysis of the Losses Associated with Tip Clearance changes in Axial Flow Compressors," paper to be presented at ASME International Gas Turbine Conference, Amsterdam, Netherlands, June 1988.

Title: Controlled Diffusion Blading Development

Investigators: R. P. Shreeve, Professor and Director, Turbopropulsion Laboratory, Department of Aeronautics and Dr. G. J. Walker, 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,

Summary: Two CD blading designs have been examined experimentally and computationally. A NASA-designed stator cascade designed with a new optimization procedure was compared in its performance with a reference D.A cascade design. The results of the experimental program, including surface pressure distributions, boundary layer transition and separation behavior deduced from china-clay observations, and loss measurements, were compared with design and analysis predictions, and the need for improved viscous flow prediction was demonstrated.

To provide data with which to evaluate developing viscous-viscid interative codes, a program to map the viscous behavior through the NASA CD cascade using a 2 component LDV system was initiated. The boundary layer & wake development was measured successfully at the design point and one off-design air-angle.

Publication: Walker, G. "Transitional Flow on Axial Turbomachine Blading," Paper AIAA-87-0010 presented at AIAA 25th Aerospace Sciences Meeting, Reno, Nevada, Jan 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, 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: A research compressor and test rig designed for 30,460 RPM has been developed & used to examine a transonic rotor flow field during operation. In addition to combination pneumatic-thermocouple probes for time-averaged flow measurements, the "Dual-Probe-Digital Sampling", or "DPDS" technique, using simple Kulite probes, was developed to determine rotor exit flow conditions in the rotor frame. Thus blade-to-blade, hub-to-tip, loss and temperature distributions were resolved. Also, rotor-tip shock structure was measured using Kulite sensors in the compressor case wall and in a cascade model of the relative flow at the tip. The cascade model was used in both a blow-down wind-tunnel and on a water-table. Agreement was found in the end results. Further experiments will await completion of a new rotor design.

Publications: Byrd, A. K. "Transonic Compressor Blade Tip Flow Vizualization on a Water Table," M.S. Thesis, Naval Postgraduate School, Monterey California December 1986.

Title: Wave Rotors and Wave Engines

Investigators: R. P. Shreeve, Professor and Director, Turbopropulsion Laboratory, Department of Aeronautics and Dr. Atul Mathur, (Exotech Inc.)

Sponsor: Naval Air Systems Command 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 Random Choice Method Euler Code for the design of wave rotor cycles was coupled with a gas turbine engine performance code for the purpose of analyzing the benefits of incorporating a wave rotor as a component in an engine cycle. Preliminary calculations were carried out. Realistic projections of the utility of incorporating wave rotor components require the modification of the unsteady flow code to include the effects of friction & heat transfer. In addition, an unsteady 1D Euler oode based on Verhoff's QAZ1D approach was further developed to incorporate wave-rotor boundary conditions.

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, California, September 1986.

Mathur, A. "Estimation of Turbofan Engine Cycle Performance With and Without a Wave Rotor Component," Contractor Report, NPS 67-86-008CR Naval Postgraduate School, Monterey, California, September 1986.

Mathur, A. & Shreeve, R. P., "Calculation of Unsteady Flow Processes in Wave Rotors," Paper AIAA-87-0011 presented at the AIAA 25th Aerospace Sciences Meeting, Reno, Nevada, January 12-15, 1987.

Mathur, A. & Shreeve, R. P., "Outline for a Wave-Rotor Engineering Guide," Technical Report NPS67-87-005PR, Naval Postgraduate School, Monterey, California, March 1987.

Johnston D. T., "Further Development of a One Dimensional Unsteady Euler Code for Wave Rotor Applications," MS Thesis, Naval Postgraduate School, Monterey, California March 1987.

DEPARTMENT

OF

OCEANOGRAPHY

DEPARTMENT OF OCEANOGRAPHY

NEARSHORE STUDIES

Professors E.B. Thornton and C.S. Wu are studying the kinematics of breaking waves within the surf zone and their effect on beach erosion. Data have been acquired through participation in experiments in Southern California and North Carolina. Using these data, a model based on energy flux balance has been developed which describes the transformation of random wave heights and resulting alongshore currents. The research sponsor for these studies is ONR and the State of California.

COASTAL OCEAN STUDIES

Prof. M. L. Batteen is using a primitive equation ocean model to understand the effects of wind forcing on the California Current. Studies have used observational data from NPS cruises. The sponsor for this research has been the NPS Research Foundation.

Prof. S. R. Ramp has been a participant in the "Coastal Transition Zone" project. The purpose of this project is to improve our understanding of the formation of cold filaments which extend offshore from coastal upwelling regions. Prof. Ramp organized several cruises to the study region and supervised the collection of hydrographic data. The sponsors for this research are the Office of Naval Research and the NPS Research Foundation.

Prof. C. R. Dunlap continued his efforts to develop an ocean drifting buoy which samples oceanographic, meteorologic and acoustic parameters and telemeters this information ashore via the ARGOS satellite data relay system. A prototype system was deployed and tested in the California Current. The sponsor for this research was the Office of Naval Research.

OPEN OCEAN STUDIES

Under sponsorship of the National Science Foundation, Prof. A. J. Semtner, Jr., carried out studies of the interannual variability of the Tropical Pacific Ocean. Prof. Semtner used an advanced, primitive equation numerical model with a 15-year record of atmospheric forcing. The goal of this study is to better understand the causes of "El Nino."

Prof. D. C. Smith, IV, carried out a study to understand the circumstances under which rings coalesce with the Gulf Stream. A regional two-layer numerical model of the ocean was used. This study was sponsored by the National Science Foundation.

OPEN OCEAN STUDIES (cont.)

Prof. T. P. Stanton and Prof. E. B. Thornton are studying the properties of velocity shears and density gradients in the upper ocean. A towed package and coherent and incoherent doppler velocimeters have been developed to measure finescale shear and turbulent microstructure. Observations were collected during two cruises. The research is sponsored by the Office of Naval Research.

Prof. R. W. Garwood, Jr., Prof. P. Chu and Prof. Patrick C. Gallacher are sponsored by the NPS Research Foundation, the Office of Naval Research and the National Science Foundation to investigate the thermodynamic and dynamic coupling between the oceanic and atmospheric turbulent boundary layers. These studies not only lead to better predictions of mixed layer depth, but also better characterize atmosphere-ocean exchanges.

ARCTIC STUDIES

Professors R. H. Bourke and R. G. Paquette are involved in studies of the frontal and finestructure phenomena associated with the ice edges of the Atlantic and Pacific Oceans as well as studies of Arctic sea ice. These studies have applications for both environmental acoustics and under-ice submarine operations. The sponsors are the Arctic Submarine Laboratory and NSWC.

Prof. D. C. Smith, IV, completed a numerical study of the interaction of an ocean eddy with the marginal ice zone. This study was sponsored by the Office of Naval Research.

Prof. A. J. Semtner, Jr., completed studies of the atmospheric forcing and sea-ice response in a coupled ice-ocean model. These studies were sponsored by the NPS Foundation.

ENVIRONMENTAL ACOUSTICS

Prof. J. A. Nystuen is developing techniques for measuring rainfall at sea through ambient sound measurements. His research is sponsored by the NPS Foundation.

Prof. C. R. Dunlap and Prof. R. H. Bourke are studying the performance of vertical line arrays. The sponsor is the Naval Avionics Center and the Naval Air Systems Command.

Professors 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.

Title: Chair in Arctic Marine Science

Investigators: R.H. Bourke, Professor of Oceanography and J.E. Walsh, Adjunct Research Professor of Oceanography

Sponsor: Office of Naval Research

Objective: 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 Walsh, an atmospheric scientist and professor in the Department of Atmospheric Science at the University of Illinois, was the Chair incumbent during FY87. He had a productive year providing seminars and lectures, writing papers and attending conferences. He served on the advisory board of several national and international committees. During his year at NPS he advised a Master's student on a statistical study relating 25 years of SST and ice concentration data to formulate a statistical prediction scheme. This should provide insight into the role that thermal advection plays in controlling the position of the ice edge. Prof. Walsh also acquired information and resources so that he could teach a course in Polar Oceanography at U. of Illinois upon his return.

Title: Marginal Sea-Ice Zone Studies 1986

Investigators: R.H. Bourke, 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 FY87 we completed the analysis of the 1985 cruise to Fram Strait. The results of this cruise were presented at two workshops and as a Master's thesis which won the CNOC award for FY87. Editing the 1986 cruise data was extensive due to need to intercalibrate four CTD's. Analysis is nearing completion and results will be published in Dec 1987. Preparations for a summer cruise in FY87 were well along when the cruise was cancelled. A Master's thesis was completed which examined the ambient noise in the Eurasian Basin and Greenland Sea obtained from drifting buoys. Ice thickness data from five ice floes has been examined with the goal of establishing a predictive capability. Results will be published in FY88. Dr. T.O Manley from Lamont Doherty Geophysical Observatory collaborated with Prof. Bourke on a study of the potential energy field in Fram Strait with the objective to characterize the potential for baroclinic and barotropic eddy generation.

Publications: Bourke, R.H., M.D. Tunnicliffe, J.L. Newton. R.G. Paquette, and T.O. Manley, "Eddy Near the Molloy Deep Revisited," Journal of Geophysical Research, 92(C7): 6773-6776, 1987.

Publications: (cont.)

Bourke, R.H., J.L. Newton, R.G. Paquette. and M.D. Tunnicliffe, "Circulation and Water Masses of the East Greenland Shelf," Journal Geophysical Research, 92 (C7): 6729-6740, 1987.

Bourke, R.H. and R.G. Paquette, "Studies of the Marginal Ice Zone Along the East Greenland Coast," Naval Research Reviews, 19-27, 1987.

Bourke, R.H. and R.P. Garrett, "Sea Ice Thickness Distribution in the Arctic Ocean," Cold Regions Science and Technology, 13: 259-280, 1987.

Conference Presentations:

Bourke, R.H. and A.M. Weigel, "On the Baroclinic Circulation of the West Spitsbergen Current," Fram Strait: Exchange and Dynamics Workshop, Seattle, WA, 17-20, Nov 1986.

Bourke, R.H., "The West Spitsbergen Current," Workshop on Poleward Flows on Eastern Ocean Boundaries, Monterey, CA, 5 Dec 1986.

Bourke, R.H. and R.P. Garrett, "Sea Ice Thickness Distribution in the Arctic Ocean," Fall Annual Meeting American Geophysical Union, San Francisco, CA, 8-10 Dec 1986.

Bourke, R.H., "Overview of Programs Which Have or Could Benefit from the Development of an Ice Penetration Technology," Third Ice Penetration Technology Workshop, Washington, DC, 15-19 June 1987.

Theses Directed:

Weigel. A.M., "Mesoscale Variability in the West Spitsbergen Current and Adjacent Waters of the Greenland Sea," Master's thesis, Sept 1986. Also issued as NPS Tech. Report 68-87-002.

Addison. V., "Physical Oceanography of Northern Baffin Bay and Nares Strait," Master's Thesis, expected completion Dec 1987. Will be issued as an NPS Tech. Report.

Poffenberger. D.L., "Analysis of Arctic Ambient Noise Measured from Drifting Buoys," Master's Thesis, expected completion Dec 1987. Also issued as NPS Tech. Report 68-87-005 and 68-87-006.

Title:	Studies in Support of NSWC
Investigators:	R.H. Bourke, Professor of Oceanography, C.R. Dunlap, Adjunct Research Professor of Oceanography
Sponsor:	Naval Surface Warfare 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. During FY87 LT Oard completed her study to establish the source spectrum of the various ambient noise forcing functions prevalent in the Arctic Ocean. This work should be quite beneficial in the development of the Navy's arctic ambient noise model. Prof. Bourke visited NSWC in June to chair a session of the 3rd Ice Penetration Conference hosted by NSWC. He returned in Oct 1987 to act as an environmental specialist for an arctic war game conducted by NSWC.
Publication:	Oard, V.T. "Characteristic Spectral Signatures of Arctic Noise-Generating Mechanisms," Master's Thesis, June 1987.
Conference Presentations:	Bourke, R.H., "Overview of Navy Programs Which Have or Might Benefit from the Development of an Ice Penetration Technology," 3rd Ice Penetration Technology Workshop, NSWC, Washington. D.C., June 16-19, 1987. Bourke. R.H., "Winter Oceanographic and Acoustic Conditions Around Svalbard," Seminar War Game, NSWC, Washington, D.C., Oct 5-6, 1987.

Title: Coupled Oceanic and Atmospheric Boundary Layers

Sponsor: NPS Foundation Research Program

Investigators: R.W. Garwood, Jr., Associate Professor of Oceanography, P. Chu, Adjunct Research Professor of Oceanogrphy

Objective: To understand the feedback mechanisms among three components (air, ice, and ocean) in the marginal ice zone (MIZ). Thermally generated surface wind, blowing from ice to water (ice breeze) with some deflection due to the earth rotation, force the ice drift and ocean currents near the MIZ. By changing the surface temperature gradient, the ice motion and ocean currents feed back on the surface winds. A coupled air-ice-ocean model is developed to predict the ice-drift pattern, the ice divergence/convergence criterion, the ice edge upwelling, ice edge banding, and the polynya formation.

Publications:

Chu, P.C., 1986a. "An Instability Theory of Ice-Air Interaction for the Migration of the Marginal Ice Zone," Geophys. J. Roy. Astron. Soc., 86, 863-883.

Chu, P.C., 1986b. "An Ice-Air Feedback Mechanism for the Migration of the Marginal Ice Zone," MIZEX Bull., VII, 54-64.

Chu, P.C., 1986c. "A Possible Air-Ice-Ocean Coupled Model for the Formation of Leads or Polynyas," MIZEX Bull., VII, 79-88.

Chu, P.C., 1986d. "A Seabreeze Mechanism in the Marginal Ice Zone," EOS, 67, 44, 1006.

Chu, P.C., 1987a. "Generation of Unstable Modes of the Iceward Attenuation Swell by Icebreeze," J. Phys. Oceanogr., 828-832.

Chu, P.C., 1987b. "An Instability Theory of Ice Air Interaction for the Formation of Ice-Edge Bands," J. Geophys. Res., 92, 6966-6970.

Chu, P.C., 1987c. "An Icebreeze Mechanism for an Ice Divergence/Convergence Criterion in the Marginal Ice Zone," J. Phys. Oceanogr., 17, 1627-1632.

Publications: (cont.)

Chu, P.C., 1987d. "An Air-Sea Feedback Mechanism for Quasi-Geostrophic Water Movement near a Fast Shelf-Ice Edge with a Small Curvature," Chinese J. Atmos. Sci., Allerton Press, New York, 11, 31-42.

Chu, P.C., 1987e. "A Seabreeze Mechanism for Ice Edge Upwelling," Chinese J. Atmos. Sci., Allerton Press, New York, forthcoming.

Chu, P.C., 1987f. "A Mesoscale Air-Ice-Ocean Feedback Mechanism for the Ice Drift in the Marginal Ice Zone," The 7th OMAE Preceedings (IV), 83-90.

Chu, P.C. and R.W. Garwood, Jr., 1987. "Comments on `A Coupled Dynamic-Thermodynamic Model of an Ice-Ocean System in the Marginal Ice Zone'," J. Geophys. Res., forthcoming.

Conference Presentations:

Chu, P.C., "An Icebreeze Mechanism in the Marginal Ice Zone," American Geophysical Union, San Franscisco. Dec. 8-12, 1986.

Chu, P.C., "An Air-Ice-Ocean Feedback Mechanism in the Marginal Ice Zone," The International Union of Geodesy and Geophysics (IUGG), Vancouver, Canada, August 9-22, 1987.

Title: The Equatorial Mixed Layer

Investigators: R.W. Garwood, Jr., Associate Professor of Oceanography and P. Chu, Adjunct Research Professor of Oceanography

Sponsor: National Science Foundation

Objective: Find a new feedback mechanism between the clouds and the oceanic mixed layer. Clouds reduce the solar radiation at the ocean surface by scattering and absorption, which cools the ocean surface layer by increasing mixed layer entrainment. The cooling of the ocean mixed layer lowers the evaporation rate, which will diminish the clouds. This is a negative feedback mechanism. On the other hand, precipitation dilutes the surface salinity, stabilizing the upper ocean and reducing mixed layer deepening. The reduction in the mixed layer depth will increase the sea surface temperature by concentrating the net radiation plus heat fluxes downward across the sea surface into a thinner layer. The increase of sea surface temperature augments the surface evaporation, which in turn produces more clouds. This is a positive feedback mechanism.

Publications: Chu, P.C., R.W. Garwood, Jr., and P. Muller, "Two Component Thermodynamic Air-Sea Interaction," Under preparation for J. Phys. Oceanogr.

Chu, P.C., R.W. Garwood, Jr., and R.L. Haney, Effects of Entrainment on Air-Sea Interaction in the Equatorial Region," Under preparation for J. Phys. Oceanogr.

Chu, P.C., "An Instability of Air-Sea Interaction for Coastal Upwelling," Adv. Atmos. Sci., Springer-Verlag, New York, forthcoming.

Conference Presentation: Chu, P.C., and R.W. Garwood, "Thermodynamic Feedback between Summer Monsoon and Ocean Temperature and Salinity," International Union of Geodesy and Geophysics, Vancouver, Canada, August 9-22, 1987.

Title: Studies of the Oceanic Planetary Boundary Layer

Investigator: R.W. Garwood, Jr., Associate Professor of Oceanography

Sponsor: Office of Naval Research

Objective: The long range scientific objective of this research has been to understand the role of the oceanic planetary boundary layer (OPBL) in the distribution of energy, momentum and mass in the upper ocean in response to atmospheric forcing.

Summary: Mathematical models for turbulent entrainment by the ocean surface mixed layer are being developed and verified by comparison of numerical simulations with oceanic observations for studies including: (i) the transient response of the OPBL to diurnal heating. (ii) the effect of planetary rotation on the turbulent kinetic energy budget, (iii) thermodynamic coupling between the OPBL and surface ice in the marginal ice zone, (iv) the role of the OPBL in the flux of nutrients and chemical tracers, (v) mixed layer effects on cross-frontal transport of heat and momentum, and (vi) forcing of the mixed layer by the ocean interior.

Publications:

Mettlach, T. R., R. L. Haney, R. W. Garwood, Jr. and S. Ghan, 1986: "The Response of the Upper Ocean to a Large Summertime Injection of Smoke in the Atmosphere," J. Geophys. Res., 92, 1967-1974.

Traganza, E. D., D. Redalje, and R. W. Garwood. Jr., 1987: "Chemical Flux and Upwelling Fronts in the California Coastal Zone," Continental Shelf Res., 7, 89-105.

Garwood, R. W., Jr., 1987: "Unsteady Shallowing Mixed Layer," Proceedings 'Aha Huliko'a, Hawaiian Winter Workshop, January 1987, Hawaii Institute of Geophysics Special Publication, P. Muller and D. Henderson. Eds., 119-129.

Garwood, R. W., Jr., P. C. Gallacher, and P. Muller, 1987: "Reply to Comments on 'Wind Direction and Equilibrium Mixed Layer Depth: General Theory'," J. Phys. Oceanogr., 16, 171-172.

Conference Presentations:

Gallacher, P. C. and R. W. Garwood, Jr., 1986: "Wind Direction and Mixed Layer Depth: Mid-Latitude Simulations," Trans. Am. Geophys. Union, 66, 1281. Ocean Sciences Meeting, January 1986, New Orleans.

McManus, J. J., R. W. Garwood, Jr., and C. R. Dunlap, 1986: "Coupled Mixed Layer-Acoustic Model," Trans. Am. Geophys. Union, 66, 1335. Invited paper at Ocean Sciences Meeting, January 1986, New Orleans.

Gallacher, P. C. and R. W. Garwood, Jr., 1987: "Simulation of the Turbulent Kinetic Energy Budget in the Ocean Planetary Boundary Layer," AGU Fall Annual Meeting, San Francisco. Trans. Am. Geophys. Union. 68. 1312.

Theses Directed:

Jacques M. Fourniol, "Coupled Acoustic and Ocean Thermodynamic Model," M.S. in Oceanography and M.S in Engineering Science, June 1987.

Galo H. Garzon, "Effects of Rainfall on the Seasonal Thermocline," M.S. in Meteorology and Oceanography, June 1987.

Patrick C. Gallacher, "Importance of Rotation Shear Stress For Entrainment in the Ocean Mixed Layer," Ph.D. in Physical Oceanography. June 1987.

Title:	Topographic Interaction ARI: Mixing and Nutrient Enhancement near an Isolated Seamount
Investigators:	R.W. Garwood, Jr., Associate Professor of Oceanography and P. Chu, Adjunct Research Professor of Oceanography
Sponsor:	Office of Naval Research
Objective:	Participate in all the planning meetings for this new ONR accelerated research initiative and understand the effect of topography on the semi-geostrophic flow.
Publication:	Bannon, P.R. and P.C. Chu, "Anelastic Semigeostrophic Flow over a Mountain Ridge," J. Atmos. Sci., forthcoming.

Title: The Tropical and Equatorial Mixed Layer

Investigators: R.W. Garwood, Jr., Associate Professor of Oceanography, P. Muller, University of Hawaii, P. Chu, Naval Postgraduate School

Sponsors: (1) National Science Foundation, 1987-present (2) NPS Foundation Research Foundation, 1985-1986 (3) NPS Postdoctoral Cost-Sharing Grant, 1987.1988

Objective: The objective of this project is to identify and describe mechanisms by which turbulent kinetic energy is produced, dissipated and redistributed in tropical and equatorial turbulent boundary layers and to establish the relative importance of surface forcing (air-sea interaction) and interior forcing (horizontal and vertical advection) in determining the state of the tropical mixed layer system.

Summary: The National Science Foundation presently is funding this project at the Naval Postgraduate School and at the University of Hawaii, in conjunction with the Tropical Ocean-Global Atmosphere (TOGA) International Research Program. At NPS, oceanic and atmospheric climatological data bases have been collected and used to test hypotheses concerning the tropical mixed layer response to the atmosphere and to investigate possible thermodynamic feedback processes between the ocean mixed layer and the marine atmospheric boundary layer and clouds. A postdoctoral position was created and nationally advertised. Out of twelve applicants three were interviewed, and the position was awarded to Dr. Pecheng Chu who joined the NPS Research Faculty in November 1986.

Publications:

Garwood, R. W., Jr., 1987: "Unsteady Shallowing Mixed Layer," Proceedings 'Aha Huliko'a, Hawaiian Winter Workshop, January 1987, Hawaii Institute of Geophysics Special Publication, P. Muller and D. Henderson, Eds., 119-129.

Chu, P. C., and R. W Garwood, Jr., 1988: "Comments on A Coupled Dynamic-Thermodynamic Model of an Ice-Ocean System in the Marginal Ice Zone," J. Geophys. Res., 93, forthcoming.

Muller, P. and R. W. Garwood, Jr., 1988: "Review of Mixed Layer Dynamics - Progress and New Directions," Oceanography Report of Trans. Am. Geophys. Union, 69, Forthcoming.

Publications: (cont.)

Kuo, H. L. and P. C. Chu, 1987: "A Theoretical Model for the Steady Walker-Hadley Circulation in Equatorial Pacific," Submitted to J. Atmos. Sci.

Conference Presentations:

Garwood, R. W., Jr. and P. C. Chu, 1987: "Thermodynamic Feedback between Summer Monsoon and Ocean Temperature and Salinity," XIX General Assembly of the IUGG, Vancouver, Canada, August 9-22, 1987, IUGG Abstracts, 1, 166.

Chu, P. C., 1986: "A Seabreeze Mechanism in the Marginal Ice Zone," American Geophysical Union Fall Annual Meeting, San Francisco.

Chu, P. C., 1987: "An Air-Ice-Ocean Feedback Mechanism in the Marginal Ice Zone," XIX General Assembly of the IUGG, Vancouver, Canada.

Title: Underwater Ambient Noise Measurements to Monitor Precipitation

Investigator: J.A. Nystuen, Assistant Professor of Oceanography

Sponsor: NPS Foundation Research Program

Objective: To develop a meaning of monitoring rainfall at sea through ambient sound measurements. No adequate technique exists at this time.

Summary: I wrote a report explaining the acoustics physics of a drop impact and why this produces a unique sound underwater which can be used to identify precipitation. I identified the role that the drop size distribution has in producing sound underwater and in particular, the dual sound producing mechanisms from large raindrops. Large drops produce bubbles, which also contribute to the sound field as they are created. I examined the influence of wind on small raindrops. I have also implemented a numerical code on the NPS computer with which I can make further investigations into the impact mechanism of sound generation and I started to set up a laboratory artificial rain tower to study raindrops in a controlled environment. I began an analysis of an ocean ambient sound data set to identify precipitation at sea.

Publications:

J. A. Nystuen and D. M. Farmer: "The Influence of Wind on the Underwater Sound Generated by Light Rain," J. of Acoust. of Am., 82, p. 270-274, 1987.

J. A. Nystuen and D. M. Farmer: "The Sound Generated by Precipitation Striking the Ocean Surface," in Proceedings of Workshop on Surface Mechanisms of Sound Generated in the Ocean, Reidel, to be published as a book.

J. A. Nystuen: "Development of Technique for Measuring Rainfall at Sea," Report submitted to Institute of Ocean Sciences, Sidney, B.C., 1987, 50 p.

Title: The Coastal Transition Zone Experiment (CTZ)

Investigators: S.R. Ramp, Assistant Professor of Oceanography, and P.F. Jessen, Oceanographer

Sponsor: NPS Foundation Research Program

Objective: The objective of this project (in conjunction with other investigators at Oregon State University) was to examine the seasonal variation and temporal evolution of cold filaments off the California coast and their underlying current structure.

Summary: A standard grid of hydrographic stations in the CTZ. spanning from Pt. Reyes to north of Cape Mendocino, and from the coast to 150 km offshore, was occupied during February, March, May and June 1987. The March cruise was executed by NPS aboard the POINT SUR, and the other cruises were executed by investigators from Oregon State University aboard the WECOMA. The currents and hydrographic structure were mapped using conductivity, temperature, and depth (CTD) instruments, Acoustic Doppler Current Profiler (ADCP), and underway temperature and salinity (thermosalinograph) instrumentation. The data has been processed and analysis for scientific content is underway. Some of the problems being addressed are the seasonal evolution of the alongshore upwelling jet and its relation to cold filament formation, the strength of the fronts and the maximum currents in the region.

Conference Presentation: Ramp, Steven R., "Results from the Coastal Transition Zone (CTZ) Pilot Study, 1987," Corvallis, Oregon, September 1987. This talk contained material from both of my sponsored research projects for FY87.

Title: JETZ (Jets and Eddies in the Transition Zone)

Investigators: S.R. Ramp, Assistant Professor of Oceanography and P.F. Jessen, Oceanographer

Sponsor: Office of Naval Research

Objective: The project objective is to improve our understanding of the formation, vertical structure, and dissipation of the cold filaments observed in the satellite AVHRR sea surface temperature imagery off the coast of California, and to assess their importance to the coastal mass, salt, heat. and nutrient budgets. This research is part of a continuing program.

Summary: A research cruise was executed from the R/V POINT SUR to the region off Point Arena to study the oceanographic conditions in a cold filament. Real-time satellite data was obtained on board ship to guide the sampling. The filament was mapped using conductivity, temperature, and depth (CTD) profiles, expendable bathythermographs (XBTs), continuous underway surface salinity and temperature monitoring systems, and an Acoustic Doppler Current Profiler (ADCP). Surface drifters were also deployed by cooperating investigators from other institutions (Scripps and Woods Hole Oceanographic Institutions). Three maps were made in the (X,Y,Z) plane. The cruise was a success and most of the data have been processed by computer and are now being analyzed for their scientific content.

Conference Presentation: Ramp, Steven R., "Results from the Coastal Transition Zone (CTZ), Pilot Study, 1987," Corvallis, Oregon, September 1987. This talk contained material from both of my sponsored research projects for FY87.

Theses Directed: Snow, R L., "An Analysis of Frontal Strength Near Cold Filaments Using Continuous Underway Temperature and Salinity Data," in progress.

Fasciano. W.C., "Application of Laboratory Models to the Dynamics of Current Meandering Off Cape Mendocino," in progress.

Title: Interannual Variability of Arctic Sea Ice and Ocean Circulation

Investigator: A.J. Semtner, Jr., Professor of Oceanography

Sponsor: NPS Foundation Research Program

Objective: The objectives of this project are (i) to prepare gridded datasets of 30 years of monthly atmospheric forcing and sea-ice response for use with a coupled ice-ocean-model; (ii) to carry out a 30-year integration with the coupled model; and (iii) to develop programs to analyze modeled interannual variations of sea ice and ocean circulation.

Summary: The proposed work involves three important activities: (i) preparation of a 30-year record of Walsh's monthly atmospheric forcing fields and monthly maps of sea-ice extent into the same gridded format as that of the coupled model; (ii) the execution of a 30-year integration starting from the previous model data obtained with the average seasonal cycle for the 30-year period; and (iii) the development of programs to analyze modeled interannual variability of sea-ice and ocean circulation. These activities will set the stage for further work on the verification of the model performance relative to the observed interannual variations, as well as the investigation of dynamical causes of such variations.

In all the above mentioned activities, strong collaborative support is expected from John Walsh, who will be occupying the Arctic Research Chair beginning 1 September 1986. Dr. Walsh is very interested in such a collaboration by virtue of his long-term interests in meteorological data for the Arctic and in numerical forecasting of sea-ice variability. He also feels that the lack of ocean currents and of ocean heat flux has been the primary cause for limited forecasting skill of ice-only prediction models. He will bring considerable knowledge of the Arctic dataset (which he has put together over a number of years), as well as expertise in the analysis and interpretation of results from the ice component of the coupled model, to the research field. This will allow the remainder of the problems related to the running of the coupled model and the interpretation of oceanic fields to his investigator.

Title: Interannual Variability of Arctic Sea Ice and Ocean Circulation

Investigator: A.J. Semtner, Jr., Professor of Oceanography

Sponsor: National Science Foundation, Office of Polar Programs

Objective: The objectives of this project are (i) to carry out two multidecadal integrations of a sea-ice model, the first with an active three-dimensional ocean model and the second with only the mean annual cycle of ocean circulation from the first run; (ii) the analyze the skill of each model for simulating the observed interannual variations of sea-ice extent; and (iii) to determine the physical mechanisms by which year-to-year ocean variability affects that of the sea ice.

Summary: The proposed research would investigate the interannual variability of Arctic sea ice and ocean circulation using the coupled numerical model of Semtner (1986). That model has already shown considerable skill in reproducing the annual cycle of ice extent when forced with Walsh's 30-year mean climatological forcing. The inclusion of oceanic effects remedied the pronounced tendency of previous ice-only simulations to overestimate the ice extent. The present research seeks to understand and to predict the operationally and climatically important variations in ice cover from year to year.

Two experiments are proposed to be run and analyzed. These will be carried out in collaboration with Dr. John Walsh (who is funded separately), and they will use his full 30 year record of forcing and response. The first experiment will use the ice-ocean model, whereas the second will use the ice model with the 3-year average ocean conditions of the first run. Both experiments will be analyzed, as in the previous work of Walsh et al. (1985), to determine their skill in reproducing interannual fluctuations of sea-ice extent. The importance of changes in ocean circulation will be determined by contrasting the two experiments and by examining the oceanic contribution to interannual fluctuations of ice transport through Fram Strait and of surface heat flux both under ice and in open water.

Summary: (cont.)

The proposed budget is relatively modest, since the principal investigator does his own programming and already has a PC workstation to facilitate most computing tasks. A modest computing request will be submitted to NCAR for support via the oceanographic community allocation on the Cray X-MP machine.

Title: Interannual Variability of the Tropical Pacific Ocean

Investigator: A.J. Semtner, Jr., Professor of Oceanography

Sponsor: National Science Foundation NSF Office of Climate Dynamics

Objective: The objectives of this project are (i) to carry out multiyear simulations of the tropical Pacific Ocean using a comprehensive numerical ocean model, with surface forcing data from an NCAR atmospheric general circulation model; (ii) to compare the results with the observed record of El Nino events; (iii) to analyze the physical causes of the interannual variability of the tropical Pacific, and (iv) to examine the sensitivity of the simulations to degradation of the surface forcing through time and/or space averaging.

Summary: It is proposed to model the interannual variability of the tropical Pacific Ocean, using a 15-year record of atmospheric forcing from a version of the NCAR Community Climate Model. That record has been complied by Dr. Robert Chervin (Chervin, 1986a); and it represents the modeled atmospheric response to Oort's (1983) sea surface temperature observed during the years 1958 through 1973, a period which contained three major El Nino events. The skill of the ocean model's hindcast will be assessed. To the extent that the ocean model reproduces extremes of sea surface temperature that were present in the original boundary forcing, the dynamical causes of these events will be determined, including the relative contributions of zonal advection, upwelling, and anomalous surface heating. Several integrations with different sampling of surface forcing fields will be carried out to determine the requirements for measurements of surface wind stress and surface heat flux to reproduce the main results with the highest quality of specified forcing. The results will pave the way for coupled GCM studies of interannual variability and quantitative assessments of the potential of long-range forecasting. It will also contribute to the design of observing systems for the tropical Pacific Ocean.

Summary: (cont.)

The ocean model consists of an updated version of Semtner's (1974) code of the numerical formulation of Bryan (1969), with improved vertical mixing as in Pacanowski and Philander (1981). Two new features are the use of a stretched meridional coordinate near the equator and optimization to exploit the multiple processors of a Cray X-MP computer. Horizontal grid spacings of one degree of longitude and one-half degree of latitude, as well as a stretched vertical grid of fourteen levels, allow adequate resolution of the phenomena of interest. Forcing fields from the coarser atmospheric model grid will be interpolated to the oceanic grid.

The proposed budget is relatively modest, since the principal investigator does most of his own programming and already has a PC workstation to facilitate most computing tasks. A computing request will be submitted to NCAR for support via the oceanographic community allocation on the Cray X-MP machine.

Title: Support for Commander, Naval Oceanography Command Chair in Oceanography

Investigator: A.J. Semtner, Jr., Professor of Oceanography

Sponsor: Commander, Naval Oceanography Command

Objective: In accordance with the Memorandum of Understanding signed 11 November 1985 by Commander, Naval Oceanography Command and by the Superintendent, Naval Postgraduate School, it is proposed to continue to support the Commander, Naval Oceanography Command Chair in Oceanography. Dr John L. Spiesberger, WHOI, will occupy the Chair for five months.

Summary: Dr. John L. Spiesberger, WHOI, will be in residence at NPS from 1 January through 31 May. He is a physical oceanographer working on ocean acoustic tomography in the Ocean Engineering Department at WHOI. Dr. Spiesberger will continue his research in acoustic tomography, with a strong concentration on his present project involving an acoustic source in Hawaii and receivers along the West Coast. We expect this will lead to some collaborative projects in acoustic tomography involving NPS students and faculty.

As the Chair occupants have delved more deeply into numerical ocean model development, it has become clear that, for efficiency and continuity, a dedicated, experienced M.S. level oceanographer/programmer is needed to support the efforts, including for interfacing tc the supercomputers at FNOC and NCAR. A major benefit accrued from having an oceanographer/programmer involved with the Chair is the development of a documented program library of ocean models for use by faculty and students, another is the acquisition of "corporate memory" to maintain and operate models. Thus, it is planned to support and oceanographer/programmer for three months on this project.

Since the occupancy of the Chair by Dr. Spiesberger is not for the entirety of the year, a number of shorter-term visits by specialists in various aspects of ocean prediction are planned. Several people who are members of the Working Group on Numerical Modelling for the World Ocean Circulation Experiment have already been contacted informally.

Title: A Numerical Study of Isolated Eddy Interaction with a Marginal Ice Zone

Investigator: D.C. Smith, IV, Assistant Professor of Oceanography

Sponsor: Office of Naval Research

Objective: To investigate the physical dynamics of ocean eddy interaction with a marginal ice zone.

Summary: An investigation of the effect of ocean mesoscale circulation on ice motion in a marginal ice zone was conducted. Results were obtained using a coupled two layer ocean-ice model forced by winds. The results indicated that certain ocean eddies can be destroyed rapidly by atmospheric forcing at the ice edge. The sensitivity of the results to different wind speeds and directions was investigated. The project is ongoing with future investigation of the effects of atmospheric forcing on ocean frontal zones.

Publication: Smith, D. V., IV, A. A. Bird and W. P. Budgell, 1987: "A Numerical Study of Isolated Eddy Interaction with a Marginal Ice Zone," Submitted to J. Geophys. Res.

Conference Presentation: Smith, D. C., IV, and A. A. Bird: "A Numerical Investigation of Isolated Eddy Interaction with a Marginal Ice Zone," presented at the fall meeting of American Geophysical Union.

Title: A Numerical Study of Isolated Eddy Interaction with an Unstable Jet

Investigator: D.C. Smith, IV, Assistant Professor of Oceanography

Sponsor: National Science Foundation

Objective: To investigate the dynamics of Gulf Stream ring interaction with the Gulf Stream

Summary: A study of eddy interaction with the Gulf Stream was conducted using a regional 2 layer ocean numerical model. The circumstances under which rings coalesce with the Gulf Stream were investigated by conducting numerous experiments with different initial conditions. The sensitivity of eddy coalescence with the Stream to various physical parameters such as eddy size and strength was determined. The research is ongoing with comparison being made to recently published results which suggest that eddies can induce meandering in oceanic jets and conversely that jets can induce a propagation tendency in eddies previously unreported.

Title: Density, Shear and Turbulence Measurements in the Upper Ocean

Investigators: T.P. Stanton, Adjunct Research Professor, of Oceanography, E.B. Thornton, Professor of Oceanography

Sponsor: ONR Oceanography

Objective: To participate in collaborative open ocean studies of mixing events associated with fine-scale current, shear and double diffusive processes. High resolution, non-invasive acoustic doppler current profilers are being developed to meet these objectives.

Summary: Studies of finescale shear and turbulent microstructure in the open ocean have continued with our participation in PATCHEX, and the development of two high resolution acoustic doppler current profiling systems. A twelve day space/time series of thermohaline structure, vertical current shear and temperature microstructure in the mixed layer and upper thermocline was measured as one component of the four ship PATCHEX program. The data processing was completed in February of this year, and an analysis of atmospheric forcing and horizontal structure of the measurement domain using objective analysis techniques has been the subject of a recently completed thesis. The role of diffusive processes and internal wave strain in enhancing diffusion rates at the base of the mixed layer is currently being analyzed using both doppler current profiler data and microconductivity data. The periodic spatial coverage of the 10 km square measurement domain obtained with our towyo profiling package will be used to estimate the extent of mixing features identified from intense microstructure measurements made by the other participants in PATCHEX.

During FY87 our transverse doppler profiler has been successfully deployed allowing upper ocean measurements of three component velocity profiles to be recorded over 10 cm - 20 m length scales. The unique transverse geometry and coherent doppler processing allow velocity fluctuations to be resolved down to turbulent scales. The system is being prepared for deployments in several ONR sponsored upper ocean turbulence programs including SAXON and CEAXEX, to study surface wave related mixing and sub-ice turbulent boundary layers.

Summary: (cont.)

A prototype 20 MHz coherent doppler velocimeter has been completed to determine its ability to measure oceanic turbulence down to dissipation scales (<1cm). Coherently sampled acoustic backscatter from a millimeter cube sample volume allows non-invasive velocity measurements to be made from a small, field-deployable package. A series of tank tests and field deployments are planned for FY88 in collaboration with turbulence groups at other institutions to compare the performance of the CDV with existing velocity microstructure measurement techniques.

Conference Presentations:

T. P. Stanton and L. Washburn: "Velocity Shear and Thermohaline Structure Through an Upwelling Filament," AGU Fall Meeting, San Francisco, CA. December 1986.

L. Washburn and T. P. Stanton: "Finestructure and Mixing Activity Through an Upwelling Filament," AGU Fall Meeting, San Francisco, CA, December 1986.

Itsweire, E. C., T. R. Osborn and T. P. Stanton: "Observations of Temperature and Salinity Ramps in the Seasonal Thermocline," 3rd Symposium of Density Stratified Flows, Caltech, February 1987.

T. P. Stanton: "High Resolution Acoustic Doppler Velocity Profile Measurements," IUGG/IAMAP, August 1987.

Theses Directed:

"Analysis of Water Column Stability Using Shipboard and Submarine Density and Shear Measurements," Edward G. Beale, Jr., Master of Science Meteorology and Oceanography, December 1986.

"An Analysis of Horizontal Temperature Gradients and Heat Content in the Mixed Layer and of the Surface Forcing During PATCHEX," John Murray, Master of Science in Meteorology and Oceanography, September 1987.

Title: Density, Shear and Turbulence Measurements in the Upper Ocean

Investigator(s): T.P. Stanton, Adjunct Research Professor of Oceanography and E.B. Thornton, Professor of Oceanography

Sponsor: ONR, Physical Oceanography

Objective: To continue analysis of MILDEX and DOLPHIN 84 data sets and develop techniques to make 1 m 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 the 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 Presentations:

T. P. Stanton and M. P. McCann, "Horizontal Variability in the Mixed Layer During MILDEX," AGU Fall Annual Meeting, San Francisco, Dec 9-13, 1985.

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-parallex at each point and selection 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). Two M.S. theses have been conducted under this research.

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.

E. B. Thornton, T. McGee, and D M Burych, "Predicting Erosion on the Recessive Monterey Bay Shoreline," Proc. of Sediments '87 Conference. ASCE, 1809-1824, 1987.

Title: Modeling of Wave Transformation in Monterey Bay

Investigators: E. B. Thornton, Professor of Oceanography and C.-S. Wu, Adjunct Research Professor of Oceanography

Sponsor: Department of Boating and Waterways, State of California

Objecrive: 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 of 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. One M.S. thesis was directed under this research.

Publications:

Wu, C.-S., and E. B. Thornton, "Wave Numbers, and Linear Progressive Waves," J. of Waterways, Port, Coastal and Ocean Engineering, vol. 112. no. 4, 536-540, July 1986.

Wu, C.-S., and E. B. Thornton, "A Discussion on "3-D Model of Shoreline Response to Structure," J. of Waterway, Port, Coastal and Ocean Engineering, vol. 112, no. 5. 1986, 543-546.

Wu, C. S., and E. B. Thornton, "Combined Refraction Diffraction of Waves Over Monterey Submarine Canyon," 20th International Conference on Coastal Engineering, Taiwan, Nov 1986.

Title: Nearshore Wave Processes

Investigator: 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 was 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, "Velocity Moments in the Nearshore," J. Waterways, 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, Plenum Publishing Corporation (forthcoming).

E. B. Thornton, and R. T. Guza, "Chapter 8: Wind Wave Transformation," Nearshore Sediment Transport Study Monogram, Plenum Publishing Corp. (forthcoming).

R T. Guza, and E. B. Thornton, "Chapter 9: Runup and Surf Beat," Nearshore Sediment Transport Study Monogram, Plenum Publishing Corp. (forthcoming).

Publications: (cont.)

E. B. Thornton, and R. T Guza, "Chapter 10: Nearshore Sediment Transoort Study Monogram. Plenum Publishing Corp. (forthcoming).

E. B. Thornton, and R. T. Guza, "Chapter 16: Models for Surf Zone Dynamics," Nearshore Sediment Transport Monogram, (forthcoming).

C.S. Wu., E. B. Thornton, R. T. Guza, "Nearshore Current Model Compared with Field Data," J. of Geophysical Research, 90, 4951-4958, 1985.

E. B. Thornton, and R. T. Guza. "Surf Zone Longshore Currents and Random Wave: Field Data and Models," J. of 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, 16, (11), 1165-1178, 1986.

D. E. Martens, and E. B Thornton, "Nearshore Zone Monitoring System," Proc. of Coastal Hydrodynamics Conf., ASCE, 579-588, 1987.

S. M. Abdelrahman, and E. B. Thornton, "Changes in the Short Wave Amplitude and Wavenumber Due to the Presence of Infragravity Waves," Proc. of Coastal Hydrodynamics Conf., ASCE, 458-478, 1987.

D. J. Whitford, and E. B. Thornton, "Measuring Wind and Wave Forcing of Longshore Currents During SUPERDUCK - A Preliminary Analysis," Proc. of Coastal Hydrodynamics Conf., ASCE. 589-602, 1987.

D. A. Huntley, R. T Guza, and E B. Thornton, "Evidence for Phase-Coupling Between Edge Wave Modes," (submitted to Journal of Physical Oceanography).

S. M. Abdelrahman and E. B. Thornton, "Longshore Current Induced by Oblique Incident Waves Riding on Infragravity Waves," (submitted to J. Geophysical Research).

Title: Offshore Historial Wave Climate

Investigator: E. B. 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 design 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.

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 sixteen permanent faculty and eight visiting and adjunct faculty, the Department hosts the work of the ONT Chaired Professor in Surface Ship Technology. This position was filled by E.L. Wilson from the University of California, Berkeley who was working on Efficient Finite Element Analysis Methods for Complex Ship Problems.

Research results are published in the student theses, project reports, and in papers which are published in 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, thermal stress analyses have been conducted for 2 dimensional models of some of the U.S. Navy's superheater header systems that have shown peculiar failures.

Professor Shin has been active in Underwater Shock and Vibration studies. Sponsored 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 aim in the formulation of mathematical models to predict the ultimate strength of submarine structures in resisting underwater shock. Additionally, sponsored 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 performance of viscoelastic waveguide energy absorbers.

DYNAMIC SYSTEMS AND CONTROL (DSC)

This area, new to the Mechanical Engineering Department, started with the hiring of Professor D.L. Smith three years ago and Professor L.W. Chang two years ago. During this reporting period (FY87) 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 sponsored 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 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.

During FY87, an interdisciplinary group was formed including the participation of the Electrical Engineering Department and Computer Science Department in addition to Professors Healey and Smith from the Mechanical Engineering Department. The group initiated a research program in the area of Navigation, Planning, Dynamics and Control for Autonomous Underwater Vehicles. The project is continuing.

HEAT TRANSFER FLUID MECHANICS AND HYDRODYNAMICS (HTFMH)

In this area, Professors Nunn and Kelleher have continued ongoing work sponsored by NWC at China Lake in the modelling of heat transfer and thermodynamics 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.

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 Nucleat 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. This work is continuing while Professor Marto is on sabattical leave in Europe.

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 System 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, 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 begun in FY 86 in the modelling of fluid/thermal phenomena following initiation of a fire was expanded. 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 work is continuing.

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.

Professor Joshi has initiated work in cooling of electronic components by liquid immersion techniques with Professor Kelleher. The work is sponsored by NWSC Crane, and is beginning to develop a research activity in fluid-thermal processes relating to the welding of new Navy HSLA steels.

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 sponsored by the Office of Naval Research and leads to the ability to inner 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 was the subject of a Ph.D. dissertation by COL 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 Professor McNelley and Perkins. Professor Challenger, also in this area returned from leave at ONR-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, who was 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, has been pursuing research in the Superplastic Forming of Aluminum Alloys. The work at the Naval Air Systems Command, 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. Professor Challenger has started a Welding Research

Laboratory and has been active in examining the microstructure of the weld and the heat affected zone in HSLA steels. The development of Welding Research at NPS is ongoing.

All U.S. Navy sponsored research was funded by the NPS Direct Research Fund.

Title: Constitutive Equation Development for HSLA-100 Steel

Investigator: K.D. Challenger, Associate Professor of Mechanical Engineering

Sponsor: David Taylor Naval Ship Research and Development Center/Office of Naval Research

Objective: This is a three year project and the NPS portion of the overall project is to develop a constitutive equation describing that stress is a function of strain, strain rate and temperature from ambient to -196°C. This equation will be used as one input to a finite element analysis of crack-tip behavior of HSLA steels in an attempt to model the ductile to brittle transition behavior of these alloys.

Summary: This was the first year of this project. As such a large fraction of the time was spent in building an experiment of facility capable of performing constant strain rate tests (from initial load through fracture) at cryogenic temperatures. The facilities were completed and critical testing performed at quasi-static strain rates (1X10 sec). A constitutive equation, originally developed by Voce, was modified and found to satisfactorily describe the quasi-static stress-strain relationship of this alloy. However, general questions arose on the strain hardening and fracture mechanisms for this alloy that will have to be addressed in the final two years.

Conference Presentation: K.D. Challenger, J.E. Hamilton and D. Bissot, "Constitutive Equation Development for HSLA-100 at Cryogenic Temperatures," for presentation and publication at the 8th Int'l Conference on the Strength of Metals and Alloys, Tampere, Finland, August 1988.

Thesis Directed: LT J.F. Hamilton, "The Effect of Temperature on the Tensile Properties of HSLA-100," MSME, June 1987.

Title: Low Temperature Solid-State Bonding

Investigator: K.D. Challenger, Associate Professor of Mechanical Engineering

Sponsor: NPS Foundation Research Program

Objective: The objective of this research is to determine the various mechanisms whereby strong metallurgical bonds can be produced between metals and non-metals at low temperatures (below the temperature where bulk diffusion will contribute to the bonding).

Summary: This was the first year for this project, thus considerable time was expended designing and building the bonding apparatus. The equipment uses a hydraulic ram to produce the required pressure for bonding and induction heater to control the temperature during bonding. Silver interlayers were used as bonding aids because silver oxide is unstable above 150°C and thus a sample coated with silver and heated to 150°C would result in oxide free surfaces for bonding. Cu/Ag/Cu bonds and Cu/Cu were produced and analyzed both for their mechanical strength and the chemical composition at the interface. Scanning electron microscopy using energy dispersive X-ray analysis and scanning Auger analysis was performed at the bond interface. Good bonds (strength in excess of 40,000 psi) were produced at temperatures of 200 and 250°C using in both Cu/Cu and Cu/Ag/Cu bonds. No interdiffusion across the bond interface was detected. Thus, the bonding must be due to electrostatic (electron transfer) and/or electrochemical attraction between the two surfaces bonded.

Thesis Directed: LT P.A. Muffler, "Development of Methods for Low Temperature Diffusion Bonding," MSME, Sept. 1987.

Title: Microdeformation of Metal-Matrix Composites

Investigator: K.D. Challenger, Associate Professor of Mechanical Engineering

Sponsor: Naval Weapons Support Center, Crane Draper Laboratories

Objective: The objective of this research is to determine the cause of the dimensional instability exhibited by many metal-matrix composites.

Summary: By analyzing the test specimens and test results produced by the Draper Laboratories over the past 5 years, we have shown that the dimensional instability of SiC reinforced Al-alloys results from two different sources: (1) dimensional changes due to metallurgical changes with time (phase changes) in the matrix alloy, and (2) microcreep due to residual stresses in the composite that were caused by the difference in the thermal expansion coefficients of the SiC particles the Al-alloy matrix.

Title: Physical Metallurgy of Welding High-Strength Steels

Investigator: K.D. Challenger, Associate Professor of Mechanical Engineering

Sponsor: David Taylor Naval Ship Research and Development Center

Objective: The long-range objective of this research project is to develop a fundamental understanding of the physical metallurgy of welding high-strength steels. This includes the effect of the welding process variables on the phase transformations that occur as a result of the weld thermal cycle and the effect of the resulting microstructures on the mechanical/fracture properties of the weldment.

Summary: The research during this year focused on the weldability of the new steel alloy under development by the Navy as a replacement for HY-100 namely HSLA-100. This alloy is precipitation hardened by epsilon copper particles during the heat treatment of the steel. The effects of the weld thermal cycle on this type of steel are not fully understood. HSLA-100 appears to have more resistance to hydrogen assisted cracking than HY-100 and because of this, the ultimate objective of the large development project concerning with this alloy is to produce a high-strength (100 ksi yield strength) steel that does not require preheating prior to welding.

During the past year the effect of cooling rate of the weld thermal cycle on the microstructure and mechanical properties of gas metal are welds in HSLA-100 was completed. Plate thickness, heat input and the initial temperature of the plates to be welded were varied in order to produce cooling rates (at 540 ^{o}C) which varied from 22 C/sec to 42 C/sec. The mechanical properties were determined by DTNSRDC and the microstructural characterization completed by NPS.

All welds met the required mechanical properties. One area of concern arose, however; a weldment system is designed such that the tensile strength of the base metal is less than that of the HAZ or weld metal. All composite tensile tests (tests across the weld including the HAZ and base-metal) failed in the weld metal except at the highest cooling rate. Thus, even though the weldments met the desired minimum strength and ductility, the filler metal used in these welds is weaker than the base metal and HAZ indicating that further development of an appropriate filler metal may be required.

Summary: (cont.)

The microstructures were carefully characterized using scanning and transmission electron microscopy (SEM and TEM) and standard optical metallography. All of the weld metal exhibited the desired acicular ferrite. The ferrite laths appeared to be nucleating from non-metallic inclusions during the decomposition of austenite. The HAZ microstructures were very interesting and we believe may explain why this steel has good hydrogen cracking resistance. The coarse grained HAZ is essentially 100% bainitic but most of the bainite laths are coated with retained austenite. This retained austenite should be thermally stable unlike that present in martenistic materials. Since the diffusion of hydrogen is quite slow in austenite or compared to ferrite, and since hydrogen assisted cracking occurs by a mechanism that involves the concentration of hydrogen in the triaxial stress field at the tip of a crack by diffusion, it seems feasible that the presence of the austenite coating on the bainite laths may prevent the diffusion of hydrogen and thus reduce the susceptibility to hydrogen assisted cracking (the greatest problem in welding high strength steels).

Future research will attempt to verify this conclusion.

Publication:

Deb, P., Challenger, K.D. and Therrien, A.E., "Structure-Property Correlation in SMA and GMA Weldments of HY-100 Steel," Met. Trans., 18A, 987-999, 1987.

Conference Presentation:

Challenger, K.D., "Welding the Cu-Precipitation Hardened HSLA Steels," presented at both the AWS Annual Conference, Chicago, March 1987 and the IIW Annual Congress, Sofia, Bulgaria, July 1987.

Theses Directed:

LT K.D. Mickelberry, "The Effect of Cooling Rate on the Weld Metal Microstructure of HSLA-100 Welds," MSME, Sept 1987.

LT G.P. Potkay, "Characterization of the Microstructure in the HAZ of HSLA-100," MSME, Sept., 1987.

Title: Dynamic Models and Motion Controls of High-Performance Industrial Robots

Investigator: L.W. 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 joint flexibility of the PUMA robot was quantified and built into a theoretical model. The flexibility of each joint has been experimentally identified and determined. With this quantifled joint flexibility, the model can be used to simulate the robot system. To verify the model, the simulation results will be compared with the experimental results and a dynamic measurement of the robot motion is being planned. In addition, a control design is being conducted for the experimental flexible arm on which a mathematical model was built and had been validated. The computer simulation of the control system is being performed and the experiment is being implemented.

Publications: Petroka, R.P. and Chang, L.W., "Experimental Validation of a Dynamic Model (Equivalent Rigid Link System) on a Single-Link Flexible Manipulator," submitted for publication in the ASME Journal of Dynamic Systems, Measurement and Control.

Chang, L.W. and Gannon, K.P., "A Dynamic Model on a Single-Link Flexible Manipulator," submitted for publication in the ASME Journal of Vibration, Acoustics, Stress, and Reliability in Design.

Chang, L.W., "A Nonlinear Control for Flexible Systems," in progress.

Chang, L.W., "Dynamics and Control of Mechanical Manipulators in Cartesian Coordinates," in progress.

Chang, L.W., "A Dynamic Model for Mechanical Manipulators with Flexible Joints," in progress.

Chang, L.W. and Park, K.S., "A Motion Control of a Single-Link Flexible Manipulator," in progress.

Conference Presentations:

Petroka, R.P. and Chang, L.W., "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.

Chang, L.W. and Gannon, K.P., "A Dynamic Model on a Single-Link Flexible Manipulator," ASME Vibration Conference, Boston, September 27-30, 1987.

Theses Directed:

Petroka, R.P., "Computer Simulation and Experimental Validation of a Dynamic Model (Equivalent Rigid Link System) on a Single-Link Flexible Manipulator," Master's Thesis, June 1986.

Warren, J.L., "Simulation and Control of the Unimate PUMA 560 Robotic Manipulator," Master's Thesis, June 1986.

Gannon, K.P., "Modeling and Experimental Validation of a Single-Link Flexible Manipulator," Master's Thesis, Dec 1986.

Gonyier, D.K., "Experimental Studies of Joint Flexibility for the PUMA 560 Robot," Master's Thesis, March 1987.

Park, K.S., "Control System Simulation for a Single-Link Flexible Arm," Master's Thesis, Sept. 1987.

Title: Transient Buoyancy Induced and Mixed Convection Flows

Investigator: Y. Joshi, Assistant Professor of Mechanical Engineering

Sponsor: NPS Foundation Research Program

Objective: The major objective of this program is to obtain a fundamental understanding of buoyancy induced and mixed convection transient and steady flows. Specific applications of these processes to current problems in technology are also to be examined. This effort is a continuation of a program started during FY86.

Summary: Naturalconvection liquid cooling of discrete, protruding heat sources was chosen as the first configuration to be studied. A detailed experimental program was started during FY87. The faculty is now ready. It will allow computer aided data acquisition of thermocouples along with flow visualization. An instrumented vertical channel with a number of discrete heat sources is currently under study. These experiments are being carried out in water. The geometry closely approximates direct immersion cooling of circult board arrays. The measurements of temperature and flow visualizations will be helpful in modelling such flows computationally.

Publications:

Y. Joshi, "Leading Edge Effect in Transient Vertical Natural Convection Flow," International Journal of Heat and Mass Transfer, forthcoming.

Y. Joshi, "Wall Plume at Extreme Prandtl Numbers," International Journal of Heat and Mass Transfer, forthcoming.

Y. Joshi, "Transient Natural Convection Flows," Encyclopedia of Fluid Mechanics, Vol. 8 , edited by N.P. Cheremisinoff, forthcoming.

Title: Development of Subminiature Multi-Sensor Hot-Wire Probes for Improved Turbulence Measurements

Investigator: P.M. Ligrani, Associate Professor 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 tested. Typical lengths are 100×10^{-6}m and a 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 structures will also be investigated to give a complete understanding of highly anisotropic, highly sheared, and inhomogeneous turbulent flow fields.

Publications:

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 NPS69-84-010, November 1984.

P.M. Ligrani and P. Bradshaw, "Subminiature Hot-Wire Sensors: Development and Use," Journal of Physics E-Scientific Instruments, Vol. 20, No. 3, pp. 323-332, March 1987.

Publications: (cont.)

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, Vol. 5, No. 6, pp. 407-417, August 1987.

P.M. Ligrani, R.V. Westphal and F.R. Lemos, "Development of Subminiature Multi-Sensor Hot-Wire Probes - Part 1 Horizontal-Wire and Crossed-Wire Results," NASA Technical Memorandum, NASA-Ames Research Center, November 1987.

P.M. Ligrani and R.V. Westphal, "Subminiature Cross-Hot Wire Probes: Development and Use," Journal of Physics E - Scientific Instruments, 1987.

R.V. Westphal, A. Nakayama and P.M. Ligrani, "Spatial Resolution Effects in Turbulent Boundary Layers from Subminiature Cross-Hot Wire Probes," Experiments in Fluids, 1987.

Conference Presentation:

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

Investigator: P.M. Ligrani, Associate Professor of Mechanical Engineering

Sponsor: Wright Aeronautical Laboratories, Wright Patterson Air Force Base

Objective: To study the effects of intense secondary flows, expecially 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.

Publications: Ligrani P.M., Ortiz A., Joseph J.L., and Evans D.L., "Effects of Embedded Vortices on Film-Cooled Turbulent Boundary Layers," submitted to ASME Transactions - Journal of Turbomachinery, 1987.

Ligrani, P.M., Joseph S.L., and Ortiz A., "The Thermal Behavior of Film-Cooled Turbulent Boundary Layers as Affected by Longitudinal Vortices: Effects of Blowing Ratio," in preparation for International Journal of Heat and Fluid Flow, 1987.

Conference Presentation: Ligrani P.M., Ortiz A., Joseph S.L., and Evans D.L., "Effects of Embedded Vortices on Film-Cooled Turbulent Boundary Layers," ASME 33rd International Gas Turbine and Aeroengine Conference and Exposition, Amsterdam, June 1988.

Theses Directed: S.L. Joseph, "Effects of an Embedded Vortex on Heat Transfer in Film Cooled Turbulent Boundary Layers," December 1986.

D.L. Evans, "Study of Embedded Vortex with Film Cooling Cross Flow," March 1987.

A. Ortiz, "The Thermal Behavior of Film-Cooled Turbulent Boundary Layers as Affected by Longitudinal Vortices," September 1987.

Title:	Effects of Embedded Vortices on a Single Film Cooling Jet in a Turbulent Boundary Layer
Investigator:	P.M. Ligrani, Associate Professor of Mechanical Engineering
Sponsor:	Wright Aeronautical Laboratories, Wright Patterson Air Force Base
Objective:	To obtain fundamental fluid mechanics information on the interaction between an embedded vortex and a single film cooling jet within a turbulent boundary layer.
Summary:	The interaction of film-cooling jets with embedded vortices is important to the thermal design of turbine blades and turbine end-walls. The interaction of one jet and a longitudinal vortex will be studied using measurements of surface heat transfer, mean temperature, and mean velocities.

Title: Effects of Unsteadiness on Laminar-Turbulent Transition in Straight Channel Flow

Investigators: P.M. Ligrani, Associate Professor of Mechanical Engineering, and B. A. Singer, Adjunct Research Professor of Mechanical Engineering

Sponsor: Office of Naval Research

Objective: To investigate the effects of unsteadiness on transition in straight channel flow.

Summmary: Results from this study will elucidate fundamental mechanisms operative in the laminar-turbulent transition process as it is affected by mean flow unsteadiness. Information will be obtained on: (1) parameters governing the unsteady flow, (2) events occuring during the onset and development of transition, (3) the interaction between organized induced unsteadiness and transition, and (4) how heat transfer in transitioning channel flow is affected by unsteadiness. Straight channel flow is employed to provide a well defined test case for complex transitioning flows.

Title: Laminar/Turbulent Transition in a Curved Channel

Investigator: P.M. Ligrani, Associate Professor of Mechanical Engineering, B.A. Singer, Adjunct Research Professor of Mechanical Engineering, and M.D. Kelleher, Professor of Mechanical Engineering

Sponsor: AVSCOM, U.S. Army Aviation Research and Technology Activity via the 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 flow such as dean vortices 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 flow visualization techniques. Later, hot-wires will be used to probe the flow, and wall heat transfer measurements will be made. Mean velocity measurements will be made using a specially designed five-hole pressure probe.

Theses Directed: M. Siedband, "Flow in a Curved Channel Undergoing Laminar/Turbulent Transition," March 1987.

R.D. Niver, "Structural Characteristics of Dean Vortices in a Curved Channel," June 1987.

L. Baun, "A Study of Laminar/Turbulent Transition in a Curved Channel," September 1988.

Title: Investigation of the Influence of Porosity on the Behavior of M-50 Bearing Steel

Investigator: T.R. McNelley, Professor of Materials Engineering, Department of Mechanical Engineering

Sponsor: Air Force Wright Aeronautical Laboratories

Objective: To determine the effect of microporosity on the rolling contact fatigue resistance of M-50 bearing steel and to determine the effectiveness of hot isostatic pressing (HIP) in closing the mircoporosity.

Summary: Microporosity, originally reported by this investigator, has been confirmed by other laboratories to exist in many heats of M-50 steel. Closure of it may be accomplished by HIP. The HIP temperature must be below the usual anstenitzing temperature; this is because the steel must be given its usual final hardening treatment to remove grain boundary carbides formed as a result of slow cooling after completion of HIP. Comparison of the behavior of M-50 steel. HIP'ed to close microporosity, will be made to material, from a heat known to contain microporosity, given only its normal hardening treatment.

Publication: A. Garg, T.R. McNelley and J.L. Perry, "Analysis of Microporosity Associated with Insoluble Carbides in VIM-VAR AISI M-50 Steel," Metallography, Vol. 20, 1987, pp. 89-98.

Title: Ultra-Fine Grained Superplastic Aluminum-Magnesium Alloys: Thermomechanical Processing and Microstructure

Investigator: T.R. McNelley, Professor of Materials Engineering, Department of Mechanical Engineering

Sponsor: Naval Air Systems Command

Objective: To develop refined microstructures of 1.0-5.0 m grain size in wrought Aluminum - based alloys, including Al-Mg, Al-Mg-Li and Al-Li materials, to facilitate warm temperature, cavitation-free superplasticity.

Summary: An intensive examination of thermomechanical processing and the influence of processing variables has been done to determine the extent of microstructural refinement attainable in wrought Aluminum alloys. Grain size as small as 1.0 m has been attained by warm rolling treatments wherein the rolling is done at a temperature below the solvus for the strengthening alloy addition. The grain refinement occurs by a mechanism of continuous recrystallization during processing. This is a recovery process involving dislocation rearrangements during the intervals between rolling passes and during heating and the initial stages of subsequent superplastic deformation. It has been found that factors that facilitate recovery such as increased reheating time or increased rolling temperature (within the temperature range of continuous recrystallization) or alloy modification enhance the extent of continuous recrystallization and the resultant superplastic ductility. It has been found, for instance, that an Al-8Mg-1.0 Li alloy may exhibit ductility 1000% at 300°C and strain rate of 10 S.

Publications: E.-W. Lee and T.R. McNelley, "Microstructure Evolution During Processing and Superplastic Flow in a High-Mg, Al-Mg Alloy," Journal of Materials Science and Engineering, Vol. 93, 1987, pp. 45-55.

T.R. McNelley and S.J. Hales, "Materials Research at NPS: Superplastic Aluminum Alloys," Naval Research Reviews, NPS Issue, Vol. 39. No. 1, 1987, pp. 51-57.

Publications: (cont.)

S.J. Hales, S.B. Oster, B.W. Sanchez and T.R. McNelley, "Grain Refinement and Superplasticity in an Li-Containing Al-Mg Alloy by Thermomechanical Processing," in Proceedings of the Fourth International Conference on Al-Li Alloys: Al-Li IV, E.A. Starke and B. Baudelet, eds., CNRS, Paris, forthcoming, Fall, 1987.

E.-W. Lee and T.R. McNelley. "Application of a Thermomechanical Process for Grain Refinement to 7475 Aluminum," Journal of Materials Science and Engineering, Vol. 96, 1987, pp. 253-258.

E.-W. Lee and T.R. McNelley, "Superplastic Aluminum-Magnesium Alloys," Journal of Metals (Materials Forum), Vol. 39, No. 12 (forthcoming), 1987.

S.J. Hales and T.R. McNelley, "Microstructure Evolution by Continuous Recrystallization in Thermomechanically Processed Al-Mg Alloys," Acta Metallurgica, forthcoming.

Conference Presentations:

E.-W. Lee, S.J. Hales and T.R. McNelley, "Control of Microstructure and Mechanical Properties in Al-Mg-Li-Zr Alloys by Thermomechanical Processing," Annual Fall Meeting of TMS-AIME and ASM, Orlando, Florida, October, 1986.

S.J. Hales and T.R. McNelley, "Microstructure Evolution by Continuous Recrystallization in Thermomechanically Processed Al-Mg Alloys," 116th Annual Meeting of TMS-AIME Denver, Colorado, February, 1987.

A.A. Salama, T.R. McNelley and S.J. Hales, "Models for Superplastic Deformation of Thermomechanically Processed Al-Mg Alloys," 116th Annual Meeting of TMS-AIME, Denver, Colorado, February, 1987.

T.R. McNelley, S.J. Hales and A.A. Salama, "Superplastic Response by Continuous Recrystallization in High-Mg, Al-Mg, Alloys," WESTEC - 87, Los Angeles, Ca., March, 1987.

S.J. Hales, S.B. Oster, B.W. Sanchez and T.R. McNelley, "Thermomechanical Processing and Superplasticity in Al-Mg-Li-Zr Alloys," Fourth Int'l Conference on Aluminum - Lithium Alloys: Al-Li IV, Paris, June, 1987.

Theses Directed:

J.E. Wise, "The Influence of Total Strain, Rate and Reheating Time During Warm Rolling on the Superplastic Ductility of an Al-Mg-Zr Alloy," MSME, March, 1987.

B.W. Sanchez, "Processing and Superplasticity in Lithium - Containing Al-Mg Alloys," MSME, March, 1987.

D.K. Solomis, "The Effect of Processing and Superplastic Deformation on Ambient Ductility of Al-10Mg-0.1Zr," MSME, March 1987.

D.L. Stewart, "Investigation by Differential Scanning Calorimetry of Microstructure in a Superplastic Al-Mg-Zr Alloy," MSME and Mechanical Engineer, June, 1987.

A.A. Salama, PhD expected. December, 1987.

Patent Application:

T.R. McNelley, E.-W. Lee and S.J. Hales "Method of Achieving Fine-Grained Superplasticity in Aluminum Alloys of High Magnesium Co."

Title: Jet Vane Heat Transfer Modeling

Investigators: R. H. Nunn, Professor of Mechanical Engineering and M. D. Kelleher, Professor of Mechanical Engineering

Sponsor: Naval Weapons Center, China Lake

Objective: Development of analytical/empirical models to predict the heat transfer characteristics of airfoils immersed in a rocket engine exhaust nozzle.

Summary: Installation of PHOENICS code for heat transfer computational fluid dynamics. Initial predictive calculations for two-dimensional steady turbulent compressible flows with shocks. Development of IR thermography methods for measurement of heat transfer rates in complex geometries. Development of simulation code using lumped-parameter modeling methods to predict vane spacial and temporal thermal response.

Publications: Nunn, R. H., and Kelleher, M. D., "Jet Vane Heat Transfer Modeling," NPS69-86-010, Oct. 1986.

Leitner, A., "Thrust Vector Control Heat Transfer Modeling," NPS69-86-005, Sep. 1986.

Conference Presentations: Nunn, R. H. "Jet Vane Heat Transfer Modeling," presented to KTA-9 meeting, NPS, July, 1986.

Nunn, R. H. "Modeling of Jet Vane Heat-Transfer and Simulation of Thermal Response," presented to KTA-9 meeting, NWC, Sep., 1987

Theses Directed: Spence, T.M., "Applications of IR Thermography in Convective Heat Transfer," MSME, March 1985.

Yukselen, A., "Heat Transfer Modeling of Thrust Vector Control Systems," MSME, Mar. 1985.

Title: Damping Properties and Applications of Quiet Metal Alloys

Investigator: Jeff Perkins, Professor of Materials Science, Department of Mechanical Engineering

Sponsor: David W. Taylor Naval Ship 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, Fe-Cr, Ti-Ni and others. 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 in order to delineate damping mechanisms and factors which influence them in these alloys.

Publications:

Kenji Adachi, Jeff Perkins and C.M. Wayman, "The Crystallography and Boundary Structure of Inter-Plate-Group Combinations of 18R Martensite Variants in Cu-Zn-Al Shape Memory Alloys," Acta Metallurgica (In press, 1987).

John Reskushich and Jeff Perkins, "Damping Behavior of INCRAMUTE: Strain Dependence and Heat Treatment Effects," Naval Postgraduate School Technical Report No. NPS 69-87-001, Monterey, California, September 1986.

John F. O'Toole and Jeff Perkins, "Damping Behavior of an Fe-Cr-Mo Alloy: Strain Dependence and Heat Treatment Effects," Naval Postgraduate School Technical Report No. NPS 69-87-002, Monterey, California, December 1986.

L.W. Leary and Jeff Perkins, "Damping Behavior of SONOSTON and INCRAMUTE: Degradation Effects Near Room Temperature," Naval Postgraduate School Technical Report No. NPS 69-87-003, Monterey, California, December 1986.

Kenji Adachi, Jeff Perkins and C.M. Wayman, "The Crystallography and Boundary Structure of Inter-Plate-Group Combinations of 18R Martensite Variants in Cu-Zn-Al Shape Memory Alloys," Acta Metallurgica (forthcoming, 1987).

Publications: (cont.)

Jeff Perkins, "Tweed Microstructures and the Evolution of High Damping in Cu-Mn-Based Alloys," to be published in Proceedings of Phase Transformations '87 The Institute of Metals, London, 1987.

J.T. Cronauer and Jeff Perkins, "Damping Behavior of a Ti-Ni Shape Memory Alloy: Comparison with Cu-Mn-Based and Fe-Cr-Based High Damping Alloys," Naval Postgraduate School Technical Report No. NPS 69-87-006, Monterey, California, June 1987.

W.D. Escue, T.F. Kellogg and Jeff Perkins, "Corrosion Behavior of High Damping Alloys in Seawater," Naval Postgraduate School Technical Report No. NPS 69-87-007, Monterey, California, June 1987.

G.R. Patch and Jeff Perkins, "Development of a Data Acquisition and Analysis System for High Damping Alloy Evaluation," Naval Postgraduate School Technical Report No. NPS 69-87-008. Monterey, California, September 1987.

Saleem Akhtar, T.F. Kellogg and Jeff Perkins, "Corrosion Behavior of High Damping Alloys in 3.5% NaCl Solution," Naval Postgraduate School Technical Report No. 69-87-009, Monterey, California, September 1987.

Conference Presentation:

Jeff Perkins, "Tweed Microstructures and the Evolution of High Damping in Cu-Mn-Based Alloys," to be published in Proceedings of Phase Transformations '87, The Institute of Metals, London, 1987.

Theses Directed:

John F. O'Toole, LT, USN, MSME, "Heat Treatment Effects on High Damping in VACROSIL-010, an Fe-Cr-Based Alloy."

L.W. Leary, LT, USN, MSES, "Damping Degredation in INCRAMUTE and SONOSTON Due to Low Temperature Storage."

David B. Ferguson, LCDR, USN, MSME, "Characterization of Damping Properties in Two Fe-Cr-Based Alloys."

Joseph T. Cronauer, LT, USN, MSME, "A Comparison of High Dampling Shape Memory Alloys with Cu-Mn-Based and Fe-Cr-Based Alloys."

William D. Escue, LT, USN, MSME, "Characterization of the Corrosion Behavior of Various High Damping Alloys."

Theses Directed: (cont.)

Gregory R. Patch, CDR, USN, MSME, "Computerization of Data Acquisition, Data Analysis and Data Correlation for High Damping Alloys."

Saleem Akhtar, LCDR, Pakistan, MSME. "Corrosion Performance of Selected High Damping Alloys in Marine Environments."

Title:	Analytic Model of Gas Turbine Installations
Investigator:	P.F. Pucci, Professor of Mechanical Engineering
Sponsor:	Naval Sea Systems Command
Objective:	Continue development of an analytical model and computer program for the design of an inlet air and exhaust gas system for a gas turbine engine installed in naval ships.
Summary:	In FY87, the previous work was extended and modified. The program was used to determine the performance of an existing ship's gas turbine engine installation.
Thesis Directed:	G.B. Todd, LCDR, USN, "Gas Turbine Propulsion Engine Performance Prediction," Master's Thesis, September, 1987.

Title:	Engine Design Review
Investigator:	P.F. Pucci, Professor of Mechanical Engineering
Sponsor:	Naval Sea Systems Command
Objective:	An Advisory Group, appointed by the Naval Sea Systems Command, was tasked to perform an independent review of two separate design proposals for an intercooled and regenerated gas turbine propulsion engine. These designs were in response to NAVSEA's request for such a proposal (RFP).
Summary:	The Advisory Group, chaired by the PI, was composed of the PI and three additional members from prestigious universities each representing an expertise in a portion of the total engine design. Each member wrote a separate review which was collated by the chairman.
Publication:	Forthcoming report to NAVSEA.

Title: Mixing Tube Design

Investigator: P.F. Pucci, Professor of Mechanical Engineering

Sponsor: Naval Sea Systems Command

Objective: Assist the Naval Sea Systems Command in the evaluation of the DDG-51 Class mixing tube design.

Summary: The principal investigator has had a research program in the design and testing of exhaust gas eductors and in the design of air inlet and exhaust gas systems for gas turbine engines installed on naval ships. At the request of NAVSEA, the PI assisted them in the evaluation of the DDG-51 Class gas turbine engine exhaust eductor design and in the planning of one-fifth scale model tests of the air inlet and exhaust gas systems for the DDG-51, by attending design reviews in Washington, DC and at the ship designer offices in New York, consulting with NAVSEA personnel in Washington,DC and DTNSRDC personnel in Carderock and Annapolis, MD, visiting test engineers at GE Cincinnati and at the Ohio State University.

Title: Jet Vane Thrust Vector Control System Heat Transfer Modeling

Investigators: D. Salinas, Associate Professor of Mechanical Engineering, M.D. Kelleher, Professor of Mechanical Engineering, and R.H. Nunn, Professor of Mechanical Engineering

Objective: Analytical and empirical models will be developed to predict the heat transfer characteristics of jet vanes and jet tabs immersed in a supersonic flow.

Summary: During the past year the effort to model the heat transfer characteristics of jet vanes used in thrust vector control systems has continued. This effort has focused on using the PHOENICS-84 computer code to model the flow field in the supersonic flow over a jet vane. The PHOENICS-84 code replaced the PHOENICS-81 code that was utilized in the AY86 effort. The new 84 code was to provide much needed graphics output which was not operational with the older 81 code. Unfortunately, the graphics capability of the 84 code never became operational as well. This problem is presently being addressed and its resolution is expected in FY88.

The AY87 effort sought to confirm the analytical results obtained in the AY86 effort which used the PHOENICS-81 code. A major part of this effort was undertaken by Lt. M. Dulke for his Master's degree research activity. The effort produced results for two geometries of wedges; the sharp leading edge model, and the blunt leading edge model. The results for both of these models under subsonic flow conditions were in reasonable agreement with the AY86 results. Difficulties for supersonic flow conditions were encountered and meaningful results were not obtained. The present AY88 effort is devoted to resolving the difficulties encountered in AY87 effort.

Publication: M. Dulke, "Heat Transfer Modeling of Jet Vane Thrust Vector Control (TVC) Systems," a Master's Thesis for satisfaction of a Master's Degree in Mechanical Engineering at the Naval Postgraduate School. Degree granted in December, 1987.

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, California

Summary: NAVAIR has initiated a program for the modernization of existing test cell facilities and the design and construction of new test cell facilities. The overall cost of the project has been given a gross estimate of $700 million. An estimate of $22 million for RDT&E has been given. One part of the research effort is to obtain some understanding of the flow field within a test cell facility. This investigator, under the sponsorship of NCEL, has undertaken the task of obtaining a numerical similation of a test cell facility. The PHOENICS-84 code has been utilized for this work. A thorough three-dimensional analysis of the test cell facility at Cubi Point in the Phillipine Islands has been completed. The results of the analysis will be presented in a NPS technical report presently in preparation. In addition, analyses of two other test cell facilities, one at Lemoore Naval Station and another at Denmark, were undertaken by U.S. Naval officers as Master's thesis projects at NPS. These analyses are only partially completed. Follow on work will complete these analyses during AY88.

Publications: D. Salinas and C. Kodres, "Modeling the Aerothermal Characteristics of Jet Engine Test Cells," published in the Proceedings of 2nd International PHOENICS User Conference, 1987.

D. Salinas, "An Analysis of the Cubi Jet Engine Test Cell Facility," an NPS technical report presently in preparation.

K.D. Smith, "Analysis of the Coanda/Refraction Noise Suppression System at Lemoore Naval Air Station," A Master's Thesis for satisfaction of a Master's Degree in Mechanical Engineering at the Naval Postgraduate School. The degree was granted in December, 1987.

Title: Decelerating Flow About a Cambered Plate and Wake-Induced Parachute Collapse

Investigator: T. Sarpkaya, Distinguished Professor of Mechanical Engineering

Sponsor: Sandia National Laboratories

Objective: To develop theoretical and experimental methods to explain the reasons leading to the collapse of large parachutes and to devise methods to prevent it.

Summary: Large parachutes, delivered by low flying, high-speed aircraft, collapse shortly after the onset of deceleration. A fundamental theoretical investigation was undertaken through the use of the discrete vortex model. Extensive computer studies have shown that the cause of the collapse is the development of large vortices and their backward motion during the rapid deceleration of the parachute. In addition, extensive tests were carried out in a vertical water tunnel. The measured forces and the flow kinematics agreed surprisingly well with those predicted numerically. The investigation is continuing to determine the effect of porosity on the behavior of the parachute.

Publications: T. Sarpkaya, "An Experimental Investigation of Decelerating Flow about Two-Dimensional Cambered Plates." Internal Report to Sandia National Lab., published by the sponsor as: SAND87-7159, September 1987.

T. Sarpkaya, "Discrete Vortex Analysis of Unsteady Flow About Two-Dimensional Cambered Plates," Internal Report to Sandia National Lab., published by the sponsor as: SAND87-7160, September 1987.

Theses Directed: P. D. Munz, "Unsteady Flow About Cambered Plates," Master's and Engineer Degree Thesis, June 1987.

S. M. Mostafa, "Numerical Simulation of Unsteady Separated Flows," Ph.D. Thesis. June 1987.

Title: Internal Waves in Stratified Fluids

Investigator: T. Sarpkaya, Distinguished Professor of Mechanical Engineering

Sponsor: DARPA (Defense Advanced Research Projects Agency)

Objective: The non-acoustic detection of submerged bodies, operating in a stratified ocean environment, through the identification of the internal waves generated by the bodies.

Summary: Experiments were carried out in a large towing tank in homogeneous and density stratified water with various types of submerged bodies. The characteristics of the resulting internal waves were evaluated. In addition, the intensity and the scale of turbulence generated by various grids have been measured in order to assess the effect of the background turbulence on the motion of trailing vortices and on the internal waves.

Publications:

T. Sarpkaya and J. J. Daly, "Effect of Ambient Turbulence on Trailing Vortices," Journal of Aircraft, Vol. 24, No. 6, June 1987, pp. 399-404.

T. Sarpkaya and J. J. Daly, "Effects of Ambient Turbulence and Stratification on the Demise of Trailing Vortices," Naval Postgraduate School Technical Report NPS69-86-003, 1986 (173p).

T. Sarpkaya, S. K. Johnson, W. E. Gray, and J. J. Daly, "Vortex Motion in Homogeneous and Stratified Media," Naval Research Reviews, Vol. 39, 1987, pp. 3-8.

Thesis Directed: B. S. Miller, "Vortex Motion in Stratified Medium," Master's Thesis Dec. 1986.

Title: Separation Points on Cylinders in Oscillating Flow

Investigator: T. Sarpkaya, Distinguished Professor of Mechanical Engineering

Sponsor: National Science Foundation

Objective: The theoretical and experimental determination of the motion of separation points on various types of bluff bodies immersed in a time-dependent flow.

Summary: Experiments are being carried out in a large U-shaped water tunnel (the largest in the world) through the use of five different techniques such as the differential pressure probe, surface film probe, and flow visualization. The instantaneous positions of the separation points on the body are recorded relative to the wave cycle for various Keulegan-Carpenter numbers and Reynolds numbers. In addition, an extensive numerical analysis has been carried out through the use of the discrete vortex model. The experimental data will be compared with those already obtained numerically. The understanding of the motion of separation points in time dependent flow will shed considerable light on this very complex phenomenon. It should be noted that this investigation has been initiated only a few months ago (August 1987) and will continue for a period of about two and a half years.

Publications: T. Sarpkaya, "Oscillating Flow over Bluff Bodies in a U-shaped Water Tunnel," Proceedings of the AGARD Symposium on Aerodynamic and Related Hydrodynamic Studies Using Water Facilities, AGARD-CPP- 413, October 1986, pp. 6.1-6.15.

T. Sarpkaya, "Oscillating Flow About Cylinders: Experiments and Analysis," Forum on Unsteady Flow Separation ASME-FED, Vol. 52, 1987, pp. 139-146.

Thesis Directed: S. M. Mostafa, "Numerical Simulation of Unsteady Separated Flows," Ph. D. Thesis, June 1987.

Title: Vortex-Induced Disturbances on Fluid Interfaces

Investigator: T. Sarpkaya, Distinguished Professor of Mechanical Engineering

Sponsor: Chief of Naval Research

Objective: To relate the free-surface scars and striations generated by the motion of surface ships and submerged bodies to the motion and characteristics of the generating bodies for the purpose of SAR tracking and non-acoustic detection of target vehicles.

Summary: Numerous experiments have been carried out in a large towing tank with various lifting surfaces and submerged bodies in a homogeneous and a density-stratified medium. The characteristics of the resulting surface scars and striations have been evaluated in terms of the governing parameters. In addition, an extensive numerical analysis has been performed and a computer code has been developed to predict the characteristics of the surface disturbances. Experiments and analysis are continuing towards the evaluation of the characteristics of the scars in terms of the prevailing Froude numbers and towards the determination of the fluid velocities and vortex strengths.

Publications:

T. Sarpkaya, "Trailing Vortices in Homogeneous and Density-Stratified Media," Journal of Fluid Mechanics, Vol. 136, 1983, pp. 85-109.

T. Sarpkaya, "Trailing Vortex Wakes on the Free Surface," Proceedings of the 16th Symposium on Naval Hydrodynamics, July 1986, pp. 1-12.

Theses Directed:

W. D. Noble, "Characteristics of Vortices in Stratified Media," Master's Thesis, 1986.

B. S. Miller. "Vortex Motion in Stratified Medium," Master's Thesis, December 1986.

J. Elnitsky, II., "Interaction of a Vortex Pair with a Free Surface," Master's and Engineer's Degree Thesis, September 1987.

Title:	Firefighter Robot Prototype Development
Investigator:	D.L. Smith, Associate Professor of Mechanical Engineering
Sponsor:	Naval Surface Weapons Center/White Oak
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.
Publication:	Smith, D.L., Harris, J. and Lawrence, D., "Preliminary Studies for a Drilling Robot Firefighter," Naval Postgraduate School Progress Report NPS69-87-005TR, Sept. 1987.
Theses Directed:	K. Mohammed, LT, USN, "Non-Singular Modeling of Rigid Manipulators," Master's Thesis, Dec 1986.
	J.P. Harris, LT, USN, "Investigation and Development of a Micro-Computer Based Robotic Controller," Mechanical Engineer's Thesis, June 1987.
	D.A. Lawrence, LT, USN, "Robot Firefighter Drilling Loads," Master's Thesis, June 1987.
	C. Fancher, LT, USN, "Parameter Sensitivity in an Optimal Controller," in progress.
	S. Altinok, LT, Turkish Army, "Non-Singular Modeling of a Three Dimensional Rigid Manipulator," in progress.

INVESTIGATOR INDEX

DISTRIBUTION LIST

Defense Technical Information Center Cameron Station Alexandria, VA 22304-6145	2
Library of Congress, Unit X Documents Expediting Project Exchange and Gift Division Washington, DC 20540	1
Office of the Under Secretary of Defense for Research and Engineering The Pentagon Room 3E1006 Washington, DC 20301	1
Office of the Director Net Assessment The Pentagon Room 3A930 Washington, DC 20301	1
Director, Policy Research ISP/Research Pnt Room 1E439 Office of the Secretary of Defense Washington, DC 20301	1
Chief, Strategic Planning Directorate (Program Integration) OUSD/A Pnt Room 3E1065 Office of the Secretary of Defense Washington, DC 20301	1
Secretary of Defense The Pentagon Washington, DC 20301	1
Deputy Under Secretary of Defense (Research and Advanced Technology) The Pentagon - Room 4D745 Washington, DC 20350	1
Directorate for Budget and Finance The Pentagon Washington, DC 20301	1
Defense Logistics Agency Administrative Support Center Cameron Station Alexandria, VA 22304-6145	1
Department of Defense Manpower Data Center Monterey, CA 93940	1
Central Intelligence Agency OIR/LDSD/DB/Standard Dist. GE47 HQ Washington, DC 20505	1

Defense Advanced Research Projects Agency 1
Arlington, VA 22209

Defense Nuclear Agency 1
Assistant Director for Nuclear Assessments
and Applications
Washington, DC 20305

Defense Communications Agency 1
Code H340N
Washington, DC 20305-2000

Defense Mapping Agency 1
Washington, DC 20305

Library and Information Directorate 1
National Defense University
Ft. Lesley J. McNair
Washington, DC 20319-6000

National Aeronautics and Space 1
Administration
Washington, DC 20546

National Aeronautics and Space 1
Administration
Cleveland, OH 44135

Library 202-3 1
NASA/Ames Research Center
Moffett Field, CA 94035

Department of Military Strategy 1
National War College (NWMS)
Ft. Lesley J. McNair
Washington, DC 20319-6000

Commandant 1
Defense Intelligence College
ATTN: DIC-1A
Washington, DC 20340-5485

Library 1
Armed Forces Staff College
Norfolk, VA 23511-6097

Director Strategic Plans and Policy 1
J-5 Pnt Room 2E996
The Joint Staff
Washington, DC 20301

Scientific and Technical Advisor 1
J-8 Pnt Room 1E965
The Joint Staff
Washington, DC 20301

Scientific and Technical Advisor 1
STA-Box Route
USCINCPAC Staff
Camp H.M. Smith, Hawaii 96861

Bureau of Intelligence and Research 1
Office of External Research
U.S. Department of State
Washington, DC 20520

National Security Agency 1
ATTN: R641
Fort Meade, MD 20755

Joint Cruise Missiles Project 1
JCM-211
Washington, DC 20360

Joint Data Systems Support Center 1
ATTN: Technical Resource Center/C121P
The Pentagon, Rm. BF681B
Washington, DC 20301-7010

Secretary of the Navy 1
The Pentagon - Room 4E686
Washington, DC 20350

Assistant Secretary of the Navy 1
(Manpower & Reserve Affairs)
The Pentagon - Room 4E788
Washington, DC 20350

Assistant Secretary of the Navy 1
(Research Engineering and Systems)
The Pentagon - Room 4E736
Washington, DC 20350

Office of the Secretary of Defense/FM&P/ 1
DASD (MM&PP)/ED
Room 3B930, The Pentagon
Washington, DC 20301

Deputy Assistant Secretary of the Navy 1
(Manpower Installations & Logistics)
The Pentagon
Room 3C963
Washington, DC 20301

Deputy Assistant Secretary of the Navy 1
(Force Management and Personnel)
The Pentagon - Room 4E789
Washington, DC 20350

Deputy Under Secretary of the Navy (Policy) 1
DUSN(P) Pnt Room 4E725
Washington, DC 20350

Deputy Under Secretary of the Navy 1
(Special Research and Analysis)
DUSN (SR&A) Pnt Room 4E780
Washington, DC 20350

National Oceanic Atmospheric 1
Administration
Rockville, MD 28852

Executive Director 1
CNO Executive Panel Staff (OP-00K)
4401 Ford Ave.
Alexandria, VA 22302-0268

Chief of Naval Operations
Washington, DC 20350-2000

Code OP-06	1
Code OP-11	1
Code OP-15	1
Code OP-61	1
Code OP-91	1
Code OP-006	1
Code OP-009P	1
Code OP-009W	1
Code OP-092B	1
Code OP-094	1
Code OP-095	1
Code OP-602	1
Code OP-941	1
Code OP-942	1
Code OP-943	1
Code OP-944	1
Code OP-951	1
Code OP-953D	1

Chief of Naval Operations
Code OP-01
B2-E1
Washington, DC 20350-2000 — 1

Chief of Naval Operations
Code OP-009R, The Pentagon
Washington, DC 20350-5000 — 1

Naval Air Engineering Center
Lakehurst, NJ 08733 — 1

Naval Air Systems Command
Air 54113B
Jefferson Plaza
Washington, DC 20361 — 1

Naval Air Systems Command
APC205-0
Washington, DC 20361-1205 — 1

Naval Air Systems Command
Technical Director
Research and Technology (AIR-03A)
Washington, DC 20361 — 1

Commanding Officer
Naval Intelligence Support Center
(DS-31)
4301 Suitland Road
Washington, DC 20390-5140 — 1

Commander (NISC-DE00)
Naval Intelligence Support Center
4301 Suitland Road
Washington, DC 20390 — 1

Naval Oceanography Command
NSTL, MS 39529-5000 — 1

Naval Oceanographic Research Development Activity
NSTL Station
Bay St. Louis, MS 39529 — 1

Commander (NOIC)
Naval Operational Intelligence Center
4301 Suitland Road
Washington, DC 20390 — 1

Space and Naval Warfare Systems Command
Code PMW-162
Washington, DC 20363-5000 — 1

Naval Sea Systems Command
Washington, DC 20362-5101

- Code 05 — 1
- Code 003 — 1

Naval Supply Systems Command
Washington, DC 20376 — 1

Chief of Naval Research
800 North Quincy St.
Arlington, VA 22217-5000

- Code 11 — 1
- Code 100 — 1
- Code 102 — 1
- Code 102B — 1
- Code 111 — 1
- Code 114 — 1
- Code 112 — 1
- Code 1114 — 1

Office of Naval Research
Western Regional Office
1030 East Green St.
Pasadena, CA 91106 — 1

Library - Bldg 420
Navy/Marine Corps Intelligence Center (NMITC)
Dam Neck, VA 23461-5605 — 1

Librarian
Office of Naval Research, London
Box 39
FPO New York 09510-0700 — 1

Commander
Naval Air Development Center
Code 8131
Warminster, PA 18974-5000 — 1

Commander
Naval Air Development Center
Code 01B - Carol Van Wyk
Warminster, PA 18974-5000 — 1

Naval Air Propulsion Test Center
Trenton, NJ 08628 — 1

EWC Price 1
FLTDECGRUPAC
Bldg. 603
Naval Amphibious Base
Coronado, CA 92155-5006

Naval Coastal Systems Center 1
Panama City, FL 32407

Naval Environmental Prediction Research 1
Facility
ATTN: Library
Monterey, CA 93943

Naval Personnel Research and 1
Development Center
San Diego, CA 92152

Naval Ocean Systems Center 1
ATTN: Technical Library
Code 9642B
San Diego, CA 92152-5000

NAVSEASYSCMD 1
CEL-TD
Washington, DC 20362

Intelligence Officer (17) 1
Naval Ocean Systems Center
San Diego, CA 92152-5000

David W. Taylor Naval Ship Research 1
& Development Center
Technical Information Center
Code 5222
Annapolis, MD 21402-5067

David W. Taylor Naval Ship Research 1
& Development Center
Code 012-3
ATTN: Dr. D.D. Moran, Research Coordinator
Bethesda, MD 20084

Officer-in-Charge 1
White Oak Laboratory
Naval Surface Warfare Center
10901 New Hampshire Ave.
Silver Spring, MD 20903-5000

Commander 1
Naval Surface Warfare Center
Dahlgren, VA 22448-5020

Naval Underwater Systems Center 1
ATTN: Technical Library, 02152
Newport, RI 02841-5047

Chairman, Strategy Department 1
Naval War College
Newport, RI 02840

Chairman, Campaign and Strategy Department 1
Naval War College
Newport, RI 02840

Strategic Studies Group (SSG) 1
Naval War College
Newport, RI 02841-5010

Navy Tactical Support Activity 1
Bldg. 200G
Washington Navy Yard
Washington, DC 20374

Navy Campus Office 1
Code 011 Room 1053
Naval Military Personnel Command
Washington, DC 20370-5001

Director U.S. & International Studies 1
U.S. Naval Academy
Annapolis, MD 21402

Naval Weapons Center 1
Code 01
China Lake, CA 93555-6001

Naval Weapons Center 1
ATTN: Technical Library
Code 3431
China Lake, CA 93555-6001

Naval Weapons Center 1
Code 3205
China Lake, CA 93555-6001

Naval Research Laboratory 1
Washington, DC 20375

Naval Civil Engineering Lab 1
ATTN: Library - Code L08A
Port Hueneme, CA 93043-5003

Naval Training Systems Center 1
Code 7A
Orlando, FL 32813-7100

Documents Library 1
New London Lab
Naval Underwater Systems Center
New London, CT 06320

Naval Surface Weapons Center 1
P20
White Oak
Silver Spring, MD 20903-5090

Naval Undersea Warfare Engineering 1
Station (Code 80)
Keyport, WA 98345-0580

Naval Air Rework Facility 1
Naval Air Station, North Island
San Diego, CA 92135

Naval Safety Center 1
Naval Air Station
Norfolk, VA 23511

Naval Air Test Center Patuxent River, MD 20670	1
Naval Amphibious Group Eastern Pacific Naval Station Box 201 San Diego, CA 92136	1
Center for Naval Analyses ATTN: Acquisitions Unit Documentation 4401 Ford Ave. Alexandria, VA 22302-0268	1
Naval Center for Cost Analysis ATTN: Dr. Daniel Nussbaum NCA-1 Room 4A538, The Pentagon Washington, DC 20350-1100	1
Naval Data Automation Command ATTN: Executive Assistant Department of the Navy Washington, DC 20374	1
Naval Data Automation Command ATTN: Administrative Officer Department of the Navy Washington, DC 20374	1
Navy Department Library Building 44 Washington Navy Yard Washington, DC 20374-0571	1
Chief of Naval Education and Training Code N-02 Naval Air Station Pensacola, FL 32508	1
Naval Facilities Engineering Command Technical Library, Code 09M124 200 Stovall St. Alexandria, VA 22332-2300	1
Naval Facilities Engineering Command Western Division P.O. Box 727 San Bruno, CA 94066	1
Fleet Combat Direction Systems Support Activity San Diego, CA 92147	1
Navy Fleet Material Support Office Mechanicsburg, PA 17055	1
Naval Intelligence Support 4301 Suitland Road Washington, DC 20390	1
Department of the Navy Navy Military Personnel Command ATTN: LCDR, Glenn, NMPC-16431 Washington, DC 20370-5164	1

Oceanographer of the Navy
CNO (OP-006)
Naval Observatory
34 East Massachusetts Ave. NW
Washington, DC 20390-1800 — 1

Maury Oceanographic Library
Naval Oceanographic Office
Bay St. Louis
NSTL, MS 39522-5001 — 1

Technical Library
Code 3910
Naval Ordnance Test Station
ATTN: Washington/Hungerford
Indian Head, MD 20640-5000 — 2

Naval Ocean R&D Activity
ATTN: Code 125L/Library
NSTL, MS 39529-5004 — 1

Naval Ship Systems Engineering Station
ATTN: Code 005 - Dr. Ulozas
Philadelphia, PA 19112 — 1

Naval Underwater Systems Center
San Diego, CA 92132 — 1

Naval Weapons Station
Seal Beach, CA 90740 — 1

Naval Telecommunications Command
4401 Massachusetts Ave.
Code N12
Washington, DC 20390 — 1

Commander
Oceanographic Systems Pacific
ATTN: CAPT Alan R. More
Box 1390
Pearl Harbor, HI 96860 — 1

Strategic Systems Program Office
ATTN: Library
Washington, DC 20376 — 1

Commandant of the Marine Corps
(HQSP-2)
Washington, DC 20380 — 1

U.S. Marine Corps Development and
Education Command
Quantico, VA 22134 — 1

Director Plans Division
HQ USMC Code PL
Arlington Annex Room 2020
Washington, DC 20380 — 1

Deputy Director for Intelligence
HQ USMC Code INT
Arlington Annex Room 3233
Washington, DC 20380 — 1

Advanced Amphibious Study Group 1
P.O. Box 247
Quantico, VA 22134-0247

Pentagon Library 1
JDHQ-PL-R Pnt Room 1A518
Washington, DC 20310

Academics Officer 1
Staff NCO Academy
MCDEC
Quantico, VA 22134-5050

Long Range Planning Division 1
DAMO-SSL Pnt Room 3B521
Office of the Army Chief of Staff
Washington, DC 20310

Foreign Area Officer Proponent Team 1
DAMO-SSF Pnt Room 3D561
Office of the Army Chief of Staff
Washington, DC 20310

Commander 1
U.S. Army Joint Support Activity
P.O. Box 11343
Washington, DC 20008-0543

U.S. Army Air Defense School 1
ATTN: ATSA-CDT-S
Fort Bliss, TX 79916-7050

U.S. Army Information Systems Engineering 1
Integration Center
Fort Huachuca, AZ 85613-7300

U.S. Army Defense Ammunition Center 1
& School Evaluation Division
ATTN: SARAC-DEV, McIntosh
Savanna, IL 61074

CDR USAEPG 1
ATTN: STEEP-MO
Fort Huachuca, AZ 85613-7110

U.S. Army Foreign Sciences Technology 1
Center
220 7th Street N.E.
Charlottesville, VA 22901

Director 1
USA Materiel Analysis Activity
ATTN: AMXSY-GC (Mr. Rich Mezan)
Aberdeen Proving Ground, MD 21005-5066

HQ U.S. Army Military Entrance 1
Processing Command
2500 Green Bay Rd.
ATTN: MEPCPAT-AR
North Chicago, IL 60064-3094

U.S. Army Missile Command 1
Redstone Scientific Information Center
ATTN: AMSMI-RD-CS-R/Documents
Redstone Arsenal, AL 35898-5241

U.S. Army Research Office 1
ATTN: Technical Library
P.O. Box 12211
Research Triangle Park, NC 27709-2211

U.S. Army Space Program Office 1
ATTN: John Kimmel
2810 Old Lee Highway
Fairfax, VA 22031-4304

U.S. Army Training & Doctrine Command 1
Fort Monroe, VA 23651

U.S. Army War College 1
ATTN: Library
Carlisle Barracks, PA 17013-5050

U.S. Military Academy 1
West Point, NY 10996

Director 1
USA Materiel Analysis Activity
ATTN: AMXSY-GC (Mr. Rich Nezan)
Aberdeen Proving Ground, MD 21005-5071

Librarian 1
ATTN: Marina Griner
Post Library
Bldg. 31
Fort Benjamin Harrison, IN 46216-5100

US Army Aviation Systems Command 1
ATTN: AMSAV-DACL
4300 Goodfellow Blvd.
St. Louis, MO 63120-1798

SA-ALC/MMEDO 1
ATTN: Diana Zepeda
Specifications/Standardization Library
Kelly Air Force Base, TX 78241-5280

Commandant 1
Air Force Institute of Technology
(AFIT-CIP-DPMPC)
Wright-Patterson AFB, OH 45433-6583

AFHRL/LRS TDC 1
ATTN: Susan Stiller
Wright-Patterson AFB, OH 45433

AFWAL Technical Library 1
AFWAL/GLISL
Wright-Patterson AFB, OH 45433

2750 Air Base Wing/DPE 1
Wright-Patterson AFB 45433

Air Force Astronautics Laboratory 1
Technical Library
Edwards AFB, CA 93523-5000

AUL/LSE 1
87198
ATTN: Dorothy Calhoun
Maxwell AFB, AL 36112-5564

Air Force Office of Scientific Research Bolling Air Force Base Washington, DC 20362	1
C3CM Joint Test Force Kirkland AFB Albuquerque, NM 87117	1
HQ USAF/IN Washington, DC 20330-5110	1
Deputy Director for Planning Integration AF/XOXI Pnt Room 4D1083 Washington, DC 20330	1
Library Air War College Maxwell AFB, AL 36112	1
Headquarters Space Division, PR-MIPR Control P.O. Box 92960 Worldway Postal Center Los Angeles, CA 90009	1
U.S. Coast Guard Academy New London, CT 06320	1
National Oceanic and Atmospheric Administration/NESDIS E/RA Room 601 - WWB Washington, DC 20233	1
National Science Foundation Washington, DC 20550	1
Officer-in-Charge Dept. of Naval Science California Maritime Academy P.O. Box 1392 Vallejo, CA 94590	1
Officer-in-Charge Dept. of Naval Science Massachusetts Maritime Academy State Pier Buzzards Bay, MA 02532	1
Officer-in-Charge Personnel Support Activity Detachment Bremerton, WA 98314-5305	1
Pacific Missile Test Center Point Mugu, CA 93042	1
CDR Ronald Paul Bence Naval Sea Systems Command (Sea 06WP4) Washington, DC 20362-5101	1
Dr. R.N. McDonough Applied Physics Laboratory Johns Hopkins University Laurel, MD 20707	1

HLIB-K-8103 SERIALS
University of Houston
ATTN: Serials Department
Houston, TX 77004 — 1

Mitre Corporation, Mail Stop D460
ATTN: Library Center
Burlington Rd.
Bedford, MA 01730 — 1

PRC Systems Services Company
1500 Planning Research Dr.
McLean, VA 22102 — 1

University of Texas at Austin
Applied Research Laboratories
ATTN: Librarian
P.O. Box 8029
Austin, TX 78713-8029 — 1

Dr. Robert M. Williams
Naval Air Development Center
Code 505A
Warminster, PA 18974-5000 — 1

CDR Ted Hayes
CNWS
Naval War College
Newport, RI 02841 — 1

Dr. Hal Palmer
MRJ Inc.
10455 White Granite Dr.
Oakton, VA 22142 — 1

CAPT Joe Papay
1135E Bobo Ave.
Yuma, AZ 85364 — 1

Mr. Edwin Jones
BDM
2600 Garden Rd.
North Bldg.
Monterey, CA 93940 — 1

Dr. Lynn E. Wolaver
Air Force Institute of Technology
AFIT/NR
Wright-Patterson AFB, OH 45433 — 1

Dr. Carl Schneider
Director of Research
United States Naval Academy
Annapolis, MD 21402 — 1

LCDR Michael J. Quinn
USS BLUE RIDGE (LCC-19)
FPO San Francsico, CA 96628-3300 — 1

Robert E. Edelson
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Dr.
Mail Stop 30:445
Pasadena, CA 91109 — 1

Commanding Officer
Naval Ship Weapons Systems
Engineering Station
Data Information Branch
Code 5125
Port Hueneme, CA 93043 — 1

Commanding Officer
Naval Weapons Station
Command Library
Code 012L
Seal Beach, CA 90740-5000 — 1

Mare Island Naval Shipyard
Technical Library
Code 202.13 - Stop T-4/483
Vallejo, CA 94590-5100 — 1

Naval Electronics Systems
Engineering Center, San Diego
ATTN: Library - Code AL
P.O. Box 80337
San Diego, CA 92138 — 1

Naval School
Civil Engineer Corps Officers
Moreell Library, Code C-35
Port Hueneme, CA 93043-5002 — 1

Officer in Charge
NWSSB, Corona Site
Technical Library
Corona, CA 91720-5000 — 1

Navy Personnel Research and Development
Center
ATTN: Library
Code 23
San Diego, CA 92152-6800 — 1

Supervisor of Shipbuilding, Conversion,
and Repair, USN
ATTN: Library - Code 245
San Francisco, CA 94135 — 1

Naval Supply Center
Technical Division Library
Bldg. 311-2, Code 103L
Oakland, CA 94625 — 1

Technical Library
Naval Underwater Systems Center
New London CT 06320 — 1

Naval Underwater Systems Center
Technical Library
Bldg. 80, Room 2065
New London, CT 06320-5594 — 1

Marine Corps Historical Center
Bldg. 58
Washington Navy Yard
ATTN: Library - Code HDS-4
Washington, DC 20374-0580 — 1

Naval Electronic Systems Security Engineering
Technical Library, 110L
Naval Security Station
3801 Nebraska Ave., N.W.
Washington, DC 20393-5270 — 1

Navy Regional Data Automation Center
Technical Library - Code 2052
Bldg. 143
Washington Navy Yard
Washington, DC 20374 — 1

Naval Sea Systems Command
SEA 09B317 Technical Library
Department of the Navy
Washington, DC 20362-5101 — 1

Naval Observatory Library
34th & Massachusetts Ave., N.W.
Washington, DC 20390-5100 — 1

Navy Department Library
Bldg. 44
Washington Navy Yard
Washington, DC 20374-0571 — 1

Naval Aerospace Medical Institute
Code 03L, Bldg. 1953
Pensacola, FL 32508-5600 — 1

Naval Coastal Systems Center
Technical Information Center
Code 06112
Panama City, FL 32407-5000 — 1

Commanding Officer
Naval Education and Training Program Management Support Activity
Code 042
Pensacola, FL 32509-5100 — 1

Navy Supply Corps School
ATTN: Library
Athens, GA 30606 — 1

Consolidated Navy Electronic Warfare School
ATTN: Tactical Pub. Library
Bldg. 516 - Code 330L
Corry Station
Pensacola, FL 32511 — 1

Naval Facilities Engineering Command
Pacific Division
ATTN: Library
Pearl Harbor, HI 96860-7300 — 1

Naval Avionics Center
ATTN: Library
6000 East 21st St.
Indianapolis, IN 46218-2189 — 1

Fleet Intelligence Center Pacific
ATTN: Library
Box 500
Pearl Harbor, HI 96860-7450 — 1

Commander
Pearl Harbor Naval Shipyard
ATTN: Library (Code 244.5)
Box 400
Pearl Harbor, HI 96860 — 1

Commanding Officer
Naval Weapons Support Center
Code 016 - Aaron Pettiford
Crane, IN 47522-5001 — 1

Naval Ordnance Station
Code 50D - Technical Library
Louisville, KY 40214 — 1

Supervisor of Shipbuilding, Conversion and Repair, USN
ATTN: Library - Code 240.C
New Orleans, LA 70142-5700 — 1

Naval Aviation Depot Operations Center
Naval Air Station
ATTN: Code 5322, Technical Library
Patuxent River, MD 20670-5449 — 1

Naval Research Laboratory
Code 2620, Library
Washington, DC 20375 — 1

Naval Intelligence Support Center
Code 63
4301 Suitland Road
Washington, DC 20390 — 1

Naval Test Pilot School
Library
Naval Air Test Center
Patuxent River, MD 20670 — 1

United States Naval Academy
Nimitz Library
Annapolis, MD 21402 — 1

Naval Ordnance Station
ATTN: Technical Library
Indian Head, MD 20640 — 1

Navy Tactical Support Activity
Bldg. 200G
Washington Navy Yard
Washington, DC 20374 — 1

Supervisor of Shipbuilding, Conversion and Repair
ATTN: Technical Library
495 Summer St.
Boston, MA 02210 — 1

Portsmouth Naval Shipyard 1
Code 863
ATTN: Library
Portsmouth, NH 03804-5000

Supervisor of Shipbuilding, Conversion 1
and Repair, USN
Flushing & Washington
Brooklyn, NY 11251-9000

Naval Facilities Engineering Command 1
Philadelphia Naval Base
Bldg. 77-L, Code 04A5-L
Philadelphia, PA 19112

Naval Development Center 1
Technical Information Center
Code 8131
Warminster, PA 18974

Commander 1
Philadelphia Naval Shipyard
Hull, Machinery, Electrical
Ordnance, and Electronics Technical
Manual Repository
ATTN: Code 2500
Philadelphia, PA 19112-5087

Naval Academy Preparatory 1
School (NAPS)
Naval Education and Training Center
Newport, RI 02840

Naval War College 1
ATTN: Library - SAN 321-4370
Newport, RI 02841-5010

Charleston Navy Shipyard 1
Technical Library
Code 202.3
Bldg. 234, Rm 204
Charleston, SC 29408

Commanding Officer 1
Naval Electronic Systems Engineering
Center, Charleston
4600 Marriott Dr.
North Charleston, SC 29418-6504

Fleet and Mine Warfare Training 1
Center
Naval Base
Charleston, SC 29408

Men-Riv Library 1
Bldg. 732
Naval Weapons Station
Charleston, SC 29408-7000

Commanding Officer 1
Submarine Training Facility
Naval Base
Charleston, SC 29408-5300

Navy Fleet Ballistic Missile Submarine Training Center
ATTN: Library
Charleston, SC 29408 — 1

Department of the Navy
Office of the General Counsel
Law Library, Rm 450
Crystal Plaza, Bldg. 5
Washington, DC 20360 — 1

Commanding Officer
Fleet Combat Training Center
Atlantic
Dam Neck
ATTN: Code 213
Virginia Beach, VA 23461 — 1

James Carson Breckridge Library
Education Center
MCDEC (Code E038)
Quantico, VA 22134-5050 — 1

Marine Corps Technical Library
LMA-1 CWB, Rm 311
Headquarters Marine Corps
Washington, DC 20380 — 1

Doctrine Center Library
Code C0914
MCDEC
Quantico, VA 22134-5001 — 1

McCain Library
Naval Amphibious School
Naval Amphibious Base
Little Creek
Norfolk, VA 23521 — 1

Naval Air Systems Command
Air 5004
ATTN: Library
Department of the Navy
Washington, DC 20361 — 1

Naval Audit Service
ATTN: Library
P.O. Box 1206
Falls Church, VA 22041 — 1

Space and Naval Warfare Systems Command
Technical Library
Code 18-53
Washington, DC 20363-5100 — 1

Naval Electronic Systems Engineering Center
ATTN: Library, Bldg. 74
P.O. Box 55
Portsmouth, VA 23705 — 1

Commanding Officer 1
Naval Sea Support Center
Atlantic
St. Juliens Creek Annex
ATTN: Library
Portsmouth, VA 23702

Naval Military Personnel Command 1
Technical Library
NMPC-NO13DD
Arlington, Annex
Washington, DC 20370

Naval Safety Center 1
Naval Air Station
ATTN: Library
Code 053
Norfolk, VA 23511

Naval Sea Systems Command 1
Library Documentation Branch
SEA 09B31
Department of the Navy
Washington, DC 20362

Naval Surface Warfare Center 1
Technical Library, Code E23
Dahlgren, VA 22448

Navy Environmental Health Center 1
Naval Station, Bldg. X-353
ATTN: Library, Code 44
Norfolk, VA 23511-6695

Navy Regional Data Automation Center 1
Code 20
Norfolk, VA 23511-6497

Office of the Judge Advocate General 1
Library - Code 64.3
Department of the Navy
200 Stovall St.
Alexandria, VA 22332-2400

Operational Test and Evaluation Force 1
ATTN: Library
Norfolk, VA 23511-6388

Office of Naval Research 1
Library, Code 01232L
Ballston Tower I
800 North Quincy St.
Arlington, VA 22217-5000

Norfolk Naval Shipyard 1
Library - Code 202.3
Bldg. 29
Portsmouth, VA 23709

Officer in Charge 1
Naval Mine Warfare
Engineering Activity
Library - Code 322
Yorktown, VA 23691

Supervisor of Shipbuilding, Conversion and Repair, USN
P.O. Box 215
Code 202.1
Portsmouth, VA 23705 — 1

Puget Sound Naval Shipyard
Engineering Library
Code 202.5
Bremerton, WA 98314 — 1

Doctrine Center Library
Code C0914
MCDEC
Quantico, VA 22134 — 1

Naval Undersea Warfare Engineering Station
ATTN: WQEC Library
Code 3011
Keyport WA, 98345 — 1

Supervisor of Shipbuilding, Conversion and Repair, USN
Technical Library C/243L
Seattle, WA 98115-5003 — 1

Commanding Officer
Atlantic Fleet Weapons Training Facility
FPO Miami 34051-9000 — 1

PWC Technical Library
USN Public Works Center
Code 400T
FPO San Francisco, CA 96630-2937 — 1

Base Library
Box 470
US NAS Sigonella
FPO New York 09523 — 1

Office of Naval Research
Branch Office, London
ATTN: Library
P.O. Box 39
FPO New York 09510 — 1

LCDR S.S. Aly
Naval Military Personnel Command
(NMPC-164)
Washington, DC — 1

Director
USACSW
ATTN: AMSEL-SW-PE-RD (J. Mulligan)
Vint Hill Farms Station
Warrenton, VA 22186 — 1

Library
The Rand Corporation
1700 Main St.
P.O. Box 2138
Sant Monica, CA 90406-2138 — 1

LT Cynthia Wilberg 1
1401 S. Edgewood St.
Arlington, VA 22204

Mary Schaefer 1
TASC
1700 N. Moore St.
Suite 1220
Arlington, VA 22209

Naval Postgraduate School Monterey, CA 93943	No. of Copies
Superintendent	1
Provost	1
Director of Programs, Code 03	1
Director Mil. Ops., Code 04	1
Dean of Information & Policy Sciences, Code 05	1
Dean of Science and Engineering, Code 06	1
Dean of Educational Development, Code 011	1
Director, Research Administration, Code 012	25
Director of Academic Planning, Code 013	1
Dean of Academic Administration, Code 014	1
Library, Code 0142	6
Legal Office, Code 006	1
Department of:	
Chair, Com. Sci, Code 52	1
Chair, Math, Code 53	1
Chair, Admin. Sci, Code 54	1
Chair, Ops. Res, Code 55	1
Chair, NSA, Code 56	1
Chair, Physics, Code 61	1
Chair, Elec. and Comp. Eng, Code 62	1
Chair, Meteor, Code 63	1
Executive Director, Defense Resources Management Education Center, Code 64	1
Chair, Aeron, Code 67	1
Chair, Ocean, Code 68	1
Chair, Mech Eng, Code 69	1
ASW Academic Group, Code 71	1
Space Systems Academic Group, Code 72	1
EW Academic Group, Code 73	1
Command, Control & Communications Group, Code 74	1
Curricular Officer of:	
Operations Research/Systems Analysis, Code 30	1
Aeronautical Engineering, Code 31	1
Electronics & Communications, Code 32	1
Weapons Engineering & Antisub Warfare, Code 33	1
Naval Engineering, Code 34	1
Air-Ocean Sciences, Code 35	1
Administrative Sciences Programs, Code 36	1
National Security & Intelligence Programs, Code 38	1
Command, Control & Communications, Code 39	1
Director of Aviation Safety, Code 034	1

GPO 588-536/99226