03 860

1.0
1.1
1.25   1.4   1.6

4.5
5.0
5.6

2.8   2.5
3.2   2.2
3.6
4.0   2.0

1.8

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
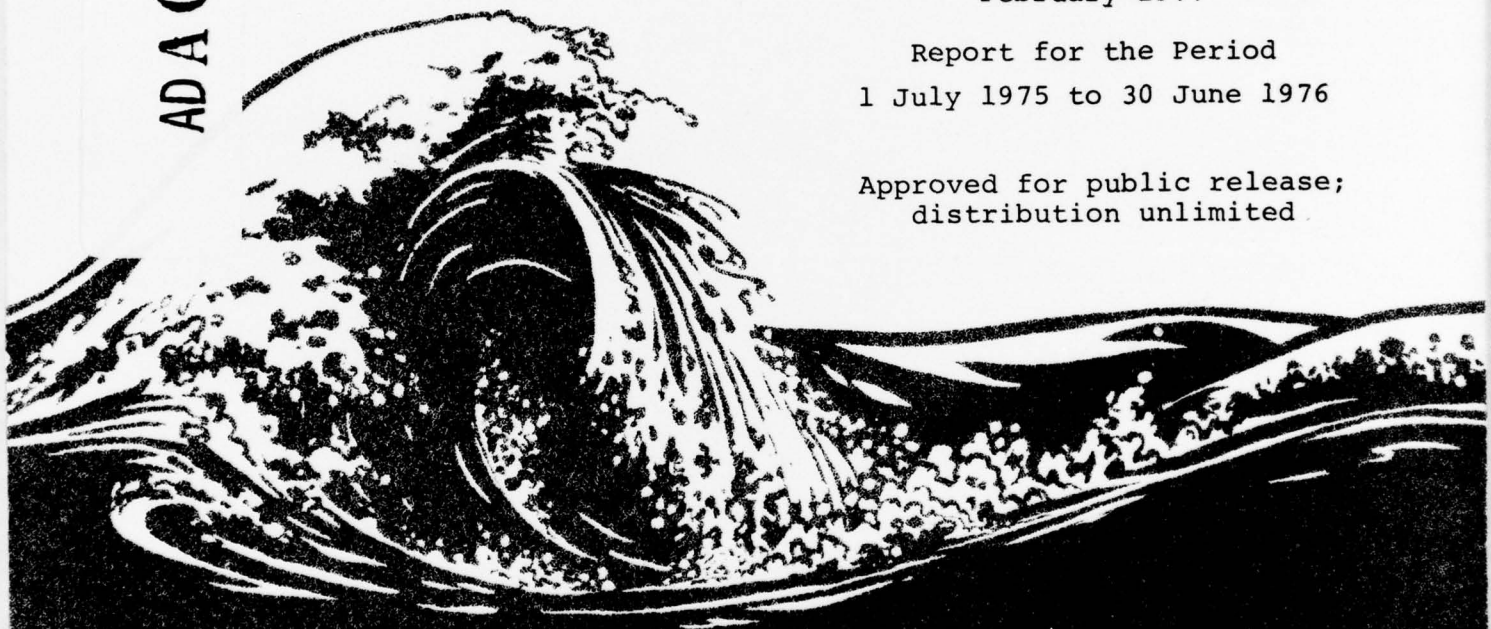
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ADA038603

A SUMMARY OF THE
NAVAL POSTGRADUATE SCHOOL
RESEARCH PROGRAM

February 1977

Report for the Period
1 July 1975 to 30 June 1976

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NAVAL POSTGRADUATE SCHOOL

EXCELLENCE THROUGH EDUCATION

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CALIFORNIA

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral I. W. Linder, USN   Jack R. Borsting
Superintendent   Provost

        The work reported herein was supported by the various
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two hundred and twenty-six summaries of research work were carried out under funding to the Naval Postgraduate School Research Program. This research was carried out in the areas of Meteorology, Electrical Engineering, Mathematics, Operations Research, Aeronautics, Oceanography, Mechanical Engineering, and Physics. A tabulation in the index identifies the area of research and the principal investigator.

TABLE OF CONTENTS

I

IV

XI

A SUMMARY OF RESEARCH ACTIVITIES

1. INTRODUCTION AND BACKGROUND

The principal thrust of research at the Naval Postgraduate School (NPS) stems from its mission:

> To conduct and direct advanced education of
> commissioned officers, and to provide such
> other technical and professional instruction
> as may be prescribed to meet the needs of the
> naval service; and in support of the foregoing
> to encourage a program of research in order to
> sustain academic excellence.

The basic mission statement relates the research program to academic excellence. The graduate educational process necessarily involves teaching of principles which come from the frontiers of technical and professional knowledge. The research program provides the means for faculty scholarly activities at or near these frontiers and permits officer students, in the limited time available for their advanced education, to complete a meaningful thesis project. Almost all NPS students are required to submit an acceptable thesis as part of their educational program. Most of these theses are directly related to the research project of the faculty advisor. Also, as in most higher educational institutions, the research program is the activity by which the institution carries out its traditional function of generation of new knowledge. At NPS this function contributes to the Navy's RDT&E knowledge and technology base.

In summary, the three objectives of the School's research program are:

> To obtain new and valuable knowledge that con-
> tributes to the solution of Navy problems; to
> vitalize classroom instruction and student thesis
> work through continued relevance to changing Navy
> problems; and to maintain the professional com-
> petence of the faculty through personal involvement
> at the dynamic horizon of their field.

Historically, research has been important to NPS since its founding. The Navy Department General Order 21 of 9 June 1909 which directed the establishment of the School of Marine Engineering (the original NPS) also directed that the facilities of the newly established U. S. Navy Engineering Experiment Station at Annapolis be made available for research activities. With the move of NPS from Annapolis to Monterey,

the research program was first called out for separate funding.
An initial grant from the Chief of Naval Research for instru-
mentation and equipment was obtained in 1954. This grant was
continued at the same modest level through 1958. The next
year it was increased to allow employment of research tech-
nicians to improve efficiency. In addition, the first research
quarters were alloted to select faculty members. (During a
research quarter, the faculty member has no teaching schedule
and is assigned only research duties.)

As the concentration of Navy graduate education in the
School increased, interest in research as an essential element
in quality developed. Consequently, the Office of Naval Research
(ONR) support was soon supplemented by research projects from
other government laboratories, activities, and agencies. This
sponsored research program, begun only modestly in 1959, has
grown to be the major part of the NPS research program. Since
1965, it has consistently been larger than the ONR program.

The following sections briefly describe the program and
summarize the areas of interest and competence of the academic
departments and review the research output for the academic
year 1975-76 (FY 76):

2. PROGRAM DESCRIPTION

    a. Research in support of the Navy's RDT&E objectives:

        In fulfillment of the research program objectives, NPS:

            Initiates and conducts scientific and applied
            research (6.1) of a long-range nature in areas
            of special interest to the Navy.

            Conducts exploratory development (6.2) deriving
            from scientific program areas or in other areas
            specifically requested by the Navy.

            Performs scientific research and exploratory
            development where uniquely qualified, for
            other agencies of the Department of Defense and
            in areas related to defense for other Federal
            Government agencies.

            Furnishes consulting services for the Navy and,
            where specially qualified, for other agencies
            of the Department of Defense and, in defense-
            related efforts, for other Government agencies.

To carry out the program effectively, within the educational
framework, certain guidelines exist to govern acceptable projects.

First, and of primary importance, the project must have high technical merit and be consistent with quality graduate professional education.

Second, the project must be consistent with faculty competence and capabilities. In order for a particular academic department to have a significant research competence, the faculty concentrates its research efforts over a limited number of academic sub-fields and disciplines. Projects outside these areas are not usually accepted.

Third, adequate research facilities must be available. While NPS research facilities are generally excellent and up-to-date, they will not support "big science" (i.e., programs requiring facilities involving large capital investment).

Fourth, all projects must be related to areas of interest in national defense. There is no question that the emphasis in research at NPS is in military-related areas. This restriction is due less to statutory limitations (Military Procurement Authorization Act for FY 1970, Section 203, the so-called "Mansfield Amendment") than to student and faculty interests which are naturally in military-related areas.

Fifth, the time available by faculty and students to achieve useful research results is constrained by the educational program. Projects which have near-term deadlines are difficult to accomplish because of teaching and class schedule requirements.

Finally, the last guideline relates to the usefulness of the research output in the student's future. Since the student is seldom in a position upon graduation significantly to influence larger systems or management problems, thesis research should be in areas which may become useful later in his career. Consequently, knowledge or technology base problems which influence future technical or management systems are natural.

b. Research in support of the Navy's Graduate Education Program.

The student comes to the Naval Postgraduate School as a professional naval officer. The objective of the educational process at NPS is to help the student become a professional person in his chosen technical and/or management area. These areas are represented by the various curricula. The fundamental characteristics, therefore, of the education process are basically those of a professional graduate school. This means the educational process has a problem-solving orientation.

The first dimension of the process familiarizes the student with the basic problem-solving structure or morphology which

underlies professional practice. This may be summarized as
follows: In dealing with a technical or management problem,
the professional person must study the situation carefully in
order to define the problem; he must decide how to simplify it
so he can discover and apply the correct governing principles;
he must then devise a plan using these skills and principles to
reach a decision; finally, having reached a decision, he must
check his work thoroughly and attempt generalizations. The
second dimension involves learning the necessary skills and
principles in each step of the problem-solving structure. These
basic principles are imparted mainly through sub-professional
exercise designed to demonstrate their use. These exercises
result in mastery of theory, understanding of the methods of
application, and knowledge of practical standards and procedures.
In the final dimension, which is research oriented, the student
must solve or significantly contribute to the solution of a
professional problem in his chosen curriculum, that is, he must
apply the structure, skills, and principles in an acceptable
thesis.

The educational process outlined above is designed to
graduate an officer who has an immediate competence to practice
his chosen technical or management profession as well as the
naval profession in general. In addition, he should have a
zest for further study and learning. Finally, he should have
the capability to interpret correctly and meaningfully research
results in his technical or management profession.

The research program contributes to the emphasis and focus
of the educational process. As mentioned above, problem-
solving tends to be uniform across the professions, the specific
problems vary widely. The research program provides numerous
examples of the unique militarily related technical and manage-
ment situations that the officer will encounter in his future
career. The principles and skills as they are taught are closely
related to military problems, which in turn are derived mostly
from a broad research program. Further, the actual thesis work
is usually part of the overall research program. Thus, the
program provides a distinct and unique focus to the educational
process. In addition, because of the classroom and laboratory
emphasis on Navy problems, the total environment of the educa-
tional process at NPS is well matched to the student officer.

The research program contributes to the excellence of the
educational process. The quality of the process is heavily
dependent upon the superiority of the faculty. As mentioned
before, a major objective of the research program at NPS is the
maintenance of the professional competence of the faculty in
their professional field.

As a graduate quality institution, NPS maintains close
contact not only with the Navy community, but also with the

academic community. The research program is a primary means for maintaining this contact and interaction. The result of such interaction is a continuing interest by faculty members in other academic institutions in the Naval Postgraduate School. Specifically, a number of faculty members from other institutions have served as visiting faculty or as Postdoctoral Fellows.

    c.   Program Management

The research program may be conveniently devided into two parts: the Foundation Research Program and the Sponsored Research Program. The Foundation Research Program is funded by grants from the Chief of Naval Research (for 6.1) and the Director of Navy Laboratories (for 6.2). It is administered internally by a faculty Research Council which receives proposals, allocates funds, and evaluates results of prior projects. The Dean of Research is Chairman of the Research Council.

The Sponsored Research Program is administered on a reimbursable basis. Proposals are submitted to the individual government sponsors who fund or do not fund the projects according to their requirements and the technical merit of the proposed project.

DEPARTMENT OF COMPUTER SCIENCE

The research program of the Computer Science Department supports and is supported by both the Naval Postgraduate School's Computer Facility and the department's own extensive laboratories. A rapidly expanding research effort includes work in: hardware and software performance measurement methods and applications; business applications and management techniques; compiler and operating system design, implementation and optimization; microcomputer structures, software, and systems design; signal processing; computer graphics; microprogramming, multiprocessing and emulation; computer systems architecture; and software engineering.

The research program has permitted the development of a number of functional laboratories which support further research as well as instruction. These include a microelectronics laboratory where microprocessors and single board computers are interfaced with a variety of equipment to become imbedded computers; a microcomputer laboratory which includes a number of microcomputer development systems as well as a multi-user development system; a multiprocessor emulation facility consisting of a microprogrammable multi-interpreter system, for the emulation of various computer systems; and, the Naval Postgraduate School Computer Laboratory, which supports work in software engineering. The laboratory boasts both a multiprocessor system with an array processor and analog front end, to support signal processing and pattern recognition, and also a graphics capability which includes each of the principal types of graphics terminals.

MICROCOMPUTERS

The work of G. A. Kildall, U. R. Kodres, and V. M. Powers has made this department a recognized center of expertise which has contributed to Navy-wide efforts to formulate standards for microcomputers. V. M. Powers has conducted evaluations of the application of microcomputers to the Autodin communications system and to surface radar tracking. U. R. Kodres continues to explore the application of the interconnected networks of microcomputers. A multi-terminal microcomputer development system has been acquired to provide continuing support for G. A. Kildall's work in microcomputer languages and operating systems.

PERFORMANCE MEASUREMENT AND SOFTWARE RELIABILITY

N. Schneidewind has conducted extensive work in the development and application of performance measurement techniques including the analysis of multiprogrammed computer performance; the relationship between program structure and error detection; and the development of stochastic models for software error prediction.

SIGNAL PROCESSING

The research area of G. A. Rahe continues to be concerned with anti-submarine warfare and identification of nuclear explosions; however, faculty interest in image processing is developing rapidly.

ADMINISTRATIVE AND BUSINESS APPLICATIONS

C. P. Gibfried participated in a survey of management information systems employed in Naval Aviation maintenance, which produced a new standard of performance measurement. Other activities of C. P. Gibfried include an analysis of an automated system for the centralized assignment of Naval Enlisted Personnel.

COMPILER DESIGN AND IMPLEMENTATION

A significant portion of the research of L. Rich has been devoted to the development and implementation of an extended BASIC compiler on the IBM-360/67 and the PDP 11-45/UNIX systems. However, design and testing of retrieval systems is another of L. Rich's current research programs.

INTERACTIVE GRAPHICS

The principal effort in the Graphics area has been the design and implementation of software interfaces and language extension for the support of interactive graphics by G. M. Raetz. This work provided the necessary foundation for the mechanization of certain anti-submarine warfare programs on a storage tube display by G. M. Raetz and G. A. Rahe. V. M. Powers had led a faculty task group concerned with the development of new computer capabilities for three dimensional tracking and with the application of color raster-scan displays.

SOFTWARE ENGINEERING

G. L. Barksdale, Jr. continues to work in the area of operating system design and implementation. However, a current special interest area is text and graphics processing-techniques where he has already developed and installed libraries on several systems. An initial major software engineering effort resulted in a compatible and portable set of program development, maintenance, and documentation tools.

Title: Large Scale Network Optimization

Investigator: Gerald Brown, Associate Professor, Computer
                  Science and Operations Research

Sponsor: Foundation Research Program (6.2)

Objective: To study mathematical methods leading to
                  efficient optimization of large scale pure
                  network cost minimization models.

Summary: An evaluation was made of many methods for
                  pure network optimization with the view
                  of producing extremely fast computer routines
                  and a robust mathematical treatment of the
                  class of problems. Several computer packages
                  were developed for the capacitated transshipment
                  problem and the transportation problem.
                  Test problems as large as 20,000 equations
                  and 50,000 variables have been solved to
                  date with computational times and costs
                  far less than any known competing implementation.
                  Additional routines have been developed
                  for network problems with nonlinear costs,
                  transportation and transshipment problems
                  with relatively few sources and a large
                  number of destinations, and single commodity
                  distribution problems imbedded in large
                  multicommodity models. The improvements
                  in network solution times have been exploited
                  by larger optimization systems using pure
                  network subproblems. The network package
                  GNET has been distributed to many universities
                  and to several federal and Department of
                  Defense agencies. In addition, several
                  hundred information requests have been received
                  for various aspects of the results. Continuing
                  research focuses on still larger problems,
                  with a working goal of 1,000,000 variable
                  models.

Publications: G. Bradley, G. Brown and G. Graves, "GNET,
                  A Primal Network Computer System for Solution
                  of Capacitated Network Flow Problems," copyright
                  1975.

4

Conference
Presentations: G. Bradley, G. Brown and G. Graves, "Tailoring
Primal Network Codes to Classes of Problems
with Common Structure," presented at the
Joint National Meeting of ORSA/TIMS, Las
Vegas, November 1975.

G. Bradley, G. Brown and G. Graves, "Surrogate
Programming Approach to Solution of Large
Scale Network Problems," presented at the
Joint National Meeting of ORSA/TIMS, Philadelphia, PA,
March 1976.

Title: Analysis of Binary Trees Arising from Applications in Sorting and Information Retrieval

Investigators: Gerald Brown, Associate Professor, Computer Science and Operations Research, and Bruno Shubert, Associate Professor, Operations Research

Sponsor: Foundation Research Program (6.1)

Objective: This study examines combinatorially the binary trees which arise in many computer science applications involving sorting, information retrieval and other fundamental techniques. The analysis is intended to provide information necessary to analyze algorithms based on manipulation of binary trees, thus providing a method to estimate work factors, memory region, and other characterizations of expense and efficiency of computer programs.

Summary: A closed form counting formula for the number of binary trees with n nodes and height k was developed and restated as a recursion more useful computationally. A generating function for the number of nodes given height was developed and used to find the asymptotic distribution of binary trees. An asymptotic probability distribution for height given the number of nodes was derived for equally likely binary trees. Random binary trees (resulting from insertion sorting a random string of key symbols) were counted in terms of the mapping of permutations of n symbols to binary trees of height k. An explicit formula for this number was given with an equivalent recursive definition for computational use. A generating function was derived for the number of symbols given height. Lower and upper bounds on random binary tree height were developed and shown to approach one another asymptotically as a function of n, providing a limiting expression for the expected height. The random binary trees were examined further to provide expressions for the expectations of the number of vacancies

at each level, the distribution of vacancies
over all levels, the comparisons required
for insertion of a new random symbol, the
fraction of nodes occupied at a particular
level, the number of leaves, the number of
single vacancies at each level, and the number
of twin vacancies at each level. A random
process was defined for the number of symbols
required to grow a tree exceeding any given
height. Tabulations and figures were prepared
for all new results.

Publications: G. G. Brown and B. O. Shubert, "On Random
Binary Trees," Technical Report, NPS55Bw76061,
June 1976.

Title: Aviation Maintenance Performance Measurement Systems

Investigator: CDR C. P. Gibfried, USN, Assistant Professor of
                   Computer Science

Sponsor: Naval Air Integrated Logistics Support Center

Objective: To study and evaluate organizational and inter-
                   mediate level aviation maintenance activities in
                   order to determine the critical measures of effec-
                   tiveness (are the "right" functions being performed?)
                   and measures of efficiency (are functions being
                   performed done well?).

Summary: Intermediate maintenance organizations at the Naval
                   Air Stations at Pensacola, Cecil Field, Moffett
                   Field, and Whidbey Island were visited and their
                   "state of the art" intermediate aviation maintenance
                   management information systems were studied and
                   compared. Organizational maintenance activities
                   at the Naval Air Station at Whidbey Island and
                   Miramar were similarly analyzed and compared. A
                   student thesis on intermediate maintenance infor-
                   mation systems was presented to the project sponsor
                   NAILSC; a second report concerning organizational
                   maintenance is currently being prepared.

Thesis   I. L. Olden, "A Performance Measurement System for
Directed: the Aircraft Intermediate Maintenance Department
                   Officer," Master's Thesis, June 1976.

Title: Micro Navigation Computer

Investigator: V. Michael Powers, Assistant Professor, Computer
                 Science

Sponsor: Naval Electronic System Command

Objective: To provide laboratory facilities appropriate for
                 evaluating trial configurations and programs, and
                 to evaluate possibilities in the development of
                 definitions of functions and uses of microcomputers
                 for shipboard navigation calculations.

Summary: The support helped to provide laboratory equipment
                 used in the theses listed below. Algorithms were
                 programmed, in the language BASIC, which do not
                 require the operator to enter data from tables
                 while performing celestial fix calculations. The
                 experience gained during this effort also contri-
                 buted to the formulation of a position paper on
                 Navy-wide standardization for microcomputers.

Publications: V. M. Powers, "A Navigational Microcomputer and
                 Shipboard Information Distribution," Technical
                 Report NPS-72PW76011, 7 January 1976.

Theses   J. P. Moore, D. B. Rainsberger, "The Design of a
Directed: Celestial Navigation Microcomputer with Thoughts
                 on an Integrated Information Distribution System,"
                 Master's Thesis, June 1975.

                 L. R. B. Pedroso, "ML80=a Structured Machine-
                 oriented Microcomputer Programming Language,"
                 Master's Thesis, December 1975.

                 R. D. Blocksom, Jr., "Experimentation and Design
                 for a Computer Fiber Optic Data Line," Master's
                 Thesis, December 1975.

Title:	Aspects of Microcomputer Standards
Investigator:	V. Michael Powers, Assistant Professor, Computer Science
Sponsor:	Naval Electronic System Command
Objective:	To contribute some NPS experience with micro-computer standardization issues to a broad-based technical statement which would be useful in formulating a policy with regard to a standard for microcomputers in the Navy.
Summary:	Inputs in the form of opinions and recommendations have been provided to the sponsor. Some of these inputs have affected the structure and content of the NELC document –

> "Position paper on microprocessor/micro-computer standardization," Code 4300, NELC, December 17, 1975 –

and some have not.

Conference Presentation:	V. M. Powers, "High Level Languages," a presentation made to the Navy Microprocessor Technology Task working session, 25 September 1975, Naval Electronics Laboratory Center, San Diego.
Publications:	V. M. Powers, "Aspects of Microcomputer Standards," Technical Report, NPS-52Pw76101, 28 October 1976.

Title: Range Studies Program: Information Trans-
                    mission, Processing and Display Group

Investigator: V. Michael Powers, Assistant Professor, Computer
                    Science

Sponsor: Naval Torpedo Station

Objective: To advise and assist NTS in long-range efforts
                    to plan and implement improvements in the
                    transmission, processing and display of informa-
                    tion in their underwater three-dimensional
                    tracking ranges in support of programs concerned
                    with MK 46 and MK 48 torpedoes, MK 27 and MK 30
                    targets, and operational weapon system tests.

Summary: During FY 76 we have continued to aid the com-
                    puter and display system enhancement effort.
                    Consideration has begun of the impact on computer
                    resources of the use of advanced track-smoothing
                    techniques. In-situ sensors were the object of
                    a brief study. Principles of design, and methods
                    of implementation, of color coding the range
                    display on color, raster-scan graphics equipment
                    have been investigated.

Publications: V. Michael Powers, Section 7 of "Range Study
                    Program," O. B. Wilson, NPS-71W176081, August
                    1976.

Theses   M. E. Bisgrove, "On the Use of Color in Raster-
Directed: Scan Graphics," Master's Thesis, June 1976.

                    D. M. Craig, "Solid-State Digital In-Situ
                    Acoustic Data Acquisition," Master's Thesis,
                    December 1975.

                    C. H. Wilson, "Surface Search Radar Tracking by
                    a Microcomputer Kalman Filter," Master's Thesis,
                    June 1976.

                    R. L. Nesslage, "The Design of a User Interfaced
                    for a Color, Raster-Scan Graphics Device,"
                    Master's Thesis, June 1976.

Title: Microcomputer Laboratory

Investigator: V. Michael Powers, Assistant Professor, Computer
                    Science

Sponsor: Naval Electronic Systems Command

Summary: Equipment from various sources has been assembled
                    into a laboratory for hands-on development work
                    in microcomputer systems and applications. Uses
                    include instructional laboratories and faculty
                    and student research. The principle hardware
                    includes two Intellec 8 Mod 80 each with dual
                    floppy disks and CRT terminals, a Microkit with
                    cassette tape and TV terminal, and a Sycor 440
                    with five terminals and a fixed disk. Communication
                    lines to the PDP-11/50 Unix system and the duplex
                    360/67 system are available for interchange and
                    cross-development. Locally developed software
                    includes a new BASIC compiler, PDP-11 communica-
                    tions modules and resident software maintenance
                    tools.

Publications: V. M. Powers, "A Navigation Microcomputer and Ship-
                    board Information Distribution," Technical Report
                    NPS-72Pw76011, 7 January 1976.

Theses   R. D. Blocksom, Jr., "Experimentation and Design
Directed: for a Computer Fiber Optic Data Link," Master's
                    Thesis, December 1975.

                    L. R. B. Pedroso, "ML80: A Structured Machine-
                    Oriented Microcomputer Programming Language,"
                    Master's Thesis, December 1975.

                    J. P. Moore, D. B. Rainsberger, "The Design of
                    a Celestial Navigation Microcomputer," Master's
                    Thesis, June 1975.

Title: Spotlight AN/UYK-20 Display Controller

Investigators: G. A. Rahe, Professor of Computer Science
G. M. Raetz, Instructor of Computer Science

Sponsor: Naval Electronics Systems Command

Objective: Develop and evaluate a AN/UYK-20 display controller to mechanize the NPS SPOTLIGHT acoustic signal processor on a Tektronix 4014 terminal.

Summary: SPOTLIGHT is an integrated signal processing and display system developed at the Naval Postgraduate School designed to improve target identification in passive acoustics. The system is presently being introduced into SOSUS. A display mechanization on the relativity inexpensive Tektronix 4014 storage tube and controlled by the Navy's standard minicomputer the AN/UYK-20 would allow more wide spread use of SPOTLIGHT. Lack of availability of a AN/UYK-20 dictated that the proposed development be conducted on the Naval Postgraduate School Computer Laboratory PDP 11 system.

A successful mechanization of SPOTLIGHT on Tektronix 4014 was produced in C language under the UNIX operating system. Complete documentation including hardware descriptions, listings of the programs and a User's Manual are available in the Naval Postgraduate School Computer Laboratory report. A demonstration of the system was provided to the sponsor and to the contractor designated to implement the system.

Thesis Directed: W. A. Fuson, "Evaluation of the Direct View Storage Display for Signal Analysis," _Master's Thesis_, 1976

Title: Carrier Aircraft Management Distributed
                    Information System

Investigators: G. A. Rahe, Professor of Computer Science
                    G. M. Raetz, Instructor of Computer Science
                    D. E. Harrison, Professor of Physics and
                    Chemistry

Sponsor: Naval Air Systems Command

Objective: To define the parameters of a distributed
                    computer-aided command and control system
                    which will support flight and maintenance
                    operations of the Air Group of an Aircraft
                    carrier. A specific objective is to demonstrate
                    the feasibility of an interactive graphics approach
                    to aid in information exchange and display.

Summary: A display device proposed as on with the
                    capabilities to implement the graphics require-
                    ments for the information management system was
                    procured. The installation, interfacing, and
                    initial checkout were completed. The software
                    interface requirements to make the device opera-
                    tional in the environment of the UNIX timesharing
                    system on the PDP 11/50 computer system were
                    established. A computer graphics software inter-
                    face has been designed, implemented, and is
                    operational. The completion of the display device
                    within the constraints of the proposed distributed
                    information system can continue.

                    The basic system design concept of the distributed
                    information system for control stations in the Air
                    Group has been accepted by the sponsor. A pre-
                    sentation of the system was made to personnel from
                    Naval Weapons Center at China Lake, which has been
                    designated to mechanize the system.

Conference   Raetz, G. M., "A Distributed Information System
Presentation: for Air Operations," technical paper presented at
                    American Society of Naval Engineers' Conference,
                    October 7-8, 1976.

Thesis   S. L. Nelson, "Graphics Subsystem for a Terminal
Directed: with Conic Section Capabilities," Master's Thesis,
                    1976.

Title: Seismic Signal Characterizations Using Graphics
                  Techniques

Investigators: G. A. Rahe, Professor of Computer Science
                  C. E. Irvine, Research Associate, Computer Science

Sponsor: U. S. Arms Control and Disarmament Agency

Objective: To support the use of techniques developed by the
                  NPS for acoustic signal processing to detect and
                  identify seismic signals of low yield underground
                  nuclear explosions.

Summary: Signal processing and graphical techniques developed
                  in this program based on previous work on acoustic
                  signals processing at the Naval Postgraduate School
                  has been applied to a large body of seismic data.
                  The result of this was the discovery of apparent
                  positive differences in signal characteristics of
                  the P codas of earthquakes and explosions.

                  In previous research on detection of seismic signals
                  from small events, discrimination of explosions
                  from earthquakes has been uncertain and based on
                  exclusion.

                  A numerical discriminant has been developed by
                  Dr. J. Evernden, the ACDA consultant on this pro-
                  ject, which appears to be effective to the threshold
                  of the network detectors. It is strongly recom-
                  mended that ACDA consider a follow up study to
                  substantiate Dr. Evernden's results.

                  A secondary but invaluable output of this project
                  has been the compilation of a large quantity of
                  seismic data into a format which will allow other
                  research pursuits in a scholarly manner.

Publications: C. Irvine and G. Rahe, "Seismic Signal Characteri-
                  zation," Technical Report NPS 52Ra 76081, August 1976.

DEPARTMENT OF MATHEMATICS

The major areas of research in the Department of Mathematics
are: (1) Numerical analysis, (2) Optimization, (3) Applied
statistics, (4) Analysis, (5) Personalized System of Instruction
(PSI). The individual investigations under each of these are
described briefly below.

NUMERICAL ANALYSIS

Most of the work in numerical analysis was directed toward
efficient computation, particularly of problems encountered in
meteorology and related fields and coordinated with the Depart-
ment of Meteorology, NEPRF, and FNWC. C. Comstock, with a
student, has applied finite elements to obtain better modeling
of certain atmospheric waves; R. R. Fossum, C. Comstock and
F. D. Faulkner are analyzing the Fourier coefficients arising
in meteorology as a time series to improve prediction; R. Franke
has produced an efficient code for solving stiff ordinary
differential equations arising in finite-element methods in
partial differential equations; Franke is developing basic
functions for optimal approximation in two variables that are
better suited to computation; F. D. Faulkner has developed an
iterative method for the solution of the Helmholtz equation in
a sphere, for the FNWC global model; A. L. Schoenstadt is
analyzing the numerical effects of discretization of the primi-
tive equation by use of Fourier transforms.

OPTIMIZATION

I. B. Russak has continued work in optimal control, deriving
necessary conditions with constraints of the form $F(t,x) \leq 0$
and second-order differential equations; Russak is examining
potential performance limits of envisioned air to air missiles;
Faulkner and W. E. Bleick are analyzing the FNWC optimum ship
routing program; H. Marks is modeling a total planning cycle
for war based on the notion of ordering of war results.

APPLIED STATISTICS

P. C. C. Wang is developing a methodology for forecasting
the technological threat from the Soviet and other navies for
NISC; Wang and R. H. S. Stolfi are carrying out an analysis of
the associated weapon system acquisition process for the most
recent weapon of a given category; Wang, with several students,
is modeling stochastically the sound speed fluctuation due to
the existence of bubbles in the upper ocean for ONR; Wang is
developing a methodology utilizing an intra-organizational
structure to coordinate modernization, including the acquisition

of facilities involving high technology, and in applying this
to improve modernization of certain departments at NEWSES.
T. Jayachandran and Schoenstadt are developing simulation models
to compare efficiency and accuracy of the Lieberman-Ross and
Mann-Grubbs methods for computing relability of bounds for
series-exponential system.

ANALYSIS

E. J. Stewart is investigating the algebraic and numerical
properties of a method of evaluating matrix exponentials arising
in the solution of differential equations; Schoenstadt has
analyzed various problems in self-sustained oscillations in
nonlinear systems, and the stability of solutions; D. L. Davis
has developed various necessary and/or sufficient conditions
for the stability of causal, recursive, "all-pole," multi-
dimensional filters.

PSI

M. D. Weir has computed an evaluation of the relative
effectiveness of PSI in teaching linear algebra at the NPS,
a paper is forthcoming in the PROCEEDINGS of the Rocky Mountain
Consortium Symposium on Innovative Teaching in University level
mathematics.

Title: On the Stability of Multidimensional Digital
                    Filters

Investigator: Daniel L. Davis, Associate Professor of
                    Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: To obtain necessary and/or sufficient conditions
                    for the stability of causal, recursive,
                    "all-pole" multidimensional digital filters
                    in terms of geometric inequalities between
                    the coefficients of the transfer function
                    which describes the filter.

Summary: Present methods for determining the stability
                    of a filter are iterative and consequently
                    it is difficult to determine the "cause"
                    of filter instability in terms of the transfer
                    function coefficients. In the present
                    research, a new approach to the problem
                    of filter stability has been developed
                    by means of which it is possible to determine
                    the precise inequalities which must hold
                    between coefficients in order to guarantee
                    stability. Such criteria are known for
                    one dimensional filters and are practically
                    essential in filter design. Although the
                    method of this research is not yet fully
                    developed, stability criteria for relatively
                    complicated multidimensional filters can
                    be derived as a result of its application.
                    Moreover, the approach is completely general,
                    irrespective of the order or dimension.

Publications: Daniel Davis and L. Souchon, "Stability
                    Conditions for N-Dimensional Digital Filters,"
                    IEEE Asilomar Conference, Nov. 1975.

Title: Numerical Solution of Helmholtz's Equation

Investigator: F. D. Faulkner, Professor of Mathematics

Sponsor: Office of Naval Research, Naval Environmental
                  Research Facility, Fleet Numerical Weather
                  Central

Objective: Faster and/or more accurate programs for
                  solving the Helmholtz equation.

Summary: This is part of a continuing investigation
                  for more effective methods in solving elliptic
                  partial differential equations. An iterative
                  method was made up and programmed to effect
                  the numerical solution of the Helmholtz
                  equation in the surface of a sphere, the
                  earth. An iteration is in two steps. First,
                  the non-polar values are updated while the
                  polar values are held fixed. Then the polar
                  values are updated; this generates a second-
                  ary correction for all other terms. The
                  problem is in use in the FNWC global model
                  program, to solve for the surface pressure.

Publications: F. Faulkner, "The Numerical Solution of the
                  Helmholtz Equation in a Sphere", Technical
                  Report, NPS53Fa76025, February 1976.

Title: An Analysis of the Minimum Time Ship Routing
                    Program

Investigators: F. D. Faulkner and W. E. Bleick, Professors
                    of Mathematics

Sponsor: Fleet Numerical Weather Central

Objective: To analyze the minimum time ship routing program
                    for effectiveness and improvement.

Summary: FNWC performs a ship routing service (Optimum
                    Track Ship Routing, OTSR) for defense-related
                    shipping. This routing is done principally
                    by a group, called routers, who make use of the
                    weather maps, their knowledge of climatology,
                    and various data about the ship to chart a course.
                    The objective is to effect the passage in
                    minimum time with no damage.

                    FNWC has had for some time also a program, GMTR,
                    that was made up to effect the same service
                    fully automatically. The input data includes
                    ship performance curves, tolerable wave heights,
                    departure time and place, and destination.
                    Available in the FNWC data bank are anticipated
                    seas for the duration; these start with a
                    three-day forecast and are blended into clima-
                    tology over the last part of a long route. This
                    program generates a minimum-time route, subject
                    to the wave constraints.

                    All routes are updated, if it is judged worth-
                    while, every twelve hours. When the journey is
                    over, the GMTR program generates a route which is
                    based on the analyzed sea data, that is, on the
                    recorded best-estimate of the seas. It also
                    compares the route actually followed with the
                    GMTR route and post-voyage route.

                    The first objective of the study is to determine
                    the effectiveness of and compare the various
                    procedures, to see where improvement might be
                    effected and how much is feasible. A second
                    objective was to examine various data critically
                    to see if the problem was modeled correctly.

                    The analysis has been seriously delayed by many
                    unsuspected errors in the program VERIFY which
                    generates the required data. We have just
                    received (December 1976) the last of the data for
                    1975. The initial analysis of these routes
                    indicate that the routing service is effective

and the human routers may do a trifle better
than the version of GMTR existing prior to
15 December 1976; there is not a clearcut
difference.

A modification has been made to GMTR so
that it can operate with a five-day forecast,
rather than the present three-day. This has
been checked out and appears ready to use
operationally.

Publications: None

Title: The Use of Time Series in Improving Meterological Forecasting

Investigators: R. R. Fossum, Dean of Research, C. Comstock and F. D. Faulkner, Professors of Mathematics

Sponsor: Foundation Research Program (6.2)

Objective: To improve meteorological forecasting by the use of time series. Let us consider a typical meteorological variable such as the 500 mb height over the surface of the earth. It can be represented as finite Fourier series

$$\sum_{1}^{N} a_i\, Y_i(\phi,\theta)$$

in which ϕ is latitude, θ is longitude, and Y_i is a composite of Legendre functions in $\cos \phi$ and trigonometric functions of θ. The coefficients a at a time t define a time series $A_n = (a_{in})$. At each time t_n, new values are generated by integrating to get predictions

$$\hat{A}_{n,1},\ \hat{A}_{n,2},\ldots \hat{A}_{n,10},$$

say, for a 5-day forecast. In the interval t , t observations are made. The predicted values, the observations, and usually, an equation such as the balance equation, are combined to yield filtered or analyzed values $\hat{A}_{n+1}$. In this way a set of corrections to predicted values is generated.

    It is the purpose of this study to analyze the set of corrections

$$Z_n = \hat{A}_n - \hat{A}_{n-1,1}$$

as a time series to see if it shows trends that can be predicted to improve the forecasts. Initial work was done by Jones (1964). Since that time new techniques for integrating and for generating the Fourier series have been developed.

Preliminary programs have been generated
and it appears that the numerical programs
are almost ready. Jones suggested a stationary
(time invariant) time series. Initial analysis
of simulated data indicates that it is inadequate.
A program for a series of the ARIMA type,
(Auto Regressive Integrated Moving Average)
has been made up.

The principal problem envisioned is
to sort out the terms in Z_n that are significant,
to estimate those with a series of proper
low degree, and to adjust the various parameters
so as to effect a suitable compromise between
improvement and computational complexity.

Publications: None

Title: Numerical Solution of Very Large Sparse
Systems of Stiff Ordinary Differential Equations

Investigator: R. Franke, Associate Professor, Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: The objective was to generate a computer
code which could solve the very large, sparse,
stiff, and implicit ordinary differential
equations arising when the finite element
method is used to discretize the space domain
of time dependent partial differential equations.
Sparse storage techniques for the matrices
and an iterative linear equation solver
were to be used to make efficient use of
storage.

Summary: An existing program, DFASUB, due to Brown
and Gear (R. L. Brown and C. W. Gear, "Documentation
for DFASUB - ...," Report No. UIUCDCS-R-
73-575, University of Illinois at Urbana-
Champaign, Urbana, Illinois, July 1973)
was selected as being an appropriate starting
point. DFASUB was modified to incorporate
the objective ideas and to be more user
oriented. Investigation of the linear system
of equations for the quasi-Newton iterates
in Gear's method revealed that iterative
techniques should be very efficient for
their solution. This was subsequently verified
when test problems executed several times
faster, using less storage, than programs
previously used for this type of problem.
The versatility of the program allows the
user to easily incorporate standard elimination
techniques for solution of linear systems
when necessary. The program is available
and being used for production computer runs.

Publications: Richard Franke, "A Program for the Numerical
Solution of Large Sparse Systems of Algebraic
and Implicitly Defined Stiff Differential
Equations," Technical Report #NPS53Fe76051,
May 1976.

Title: Analysis and Evaluation of Procedures for Computing Lower Bounds for System Reliability

Investigators: T. Jayachandran, Associate Professor of Mathematics, and A. L. Schoenstadt, Assistant Professor of Mathematics

Sponsor: Foundation Research Program (6.2)

Objective: Analyze competing procedures available for computing lower bounds on system reliability from individual component failure data. More specifically, for two of the most commonly cited, the statistically exact Lieberman-Ross (L-R) Method and the approximately optimal method of Mann and Grubbs (M-G), (a) Determine the effect in the L-R bound of a priori ordering the component failure data, (b) Determine a measure of the amount of data unused in calculating the bound, (c) Evaluate the accuracy of the M-G procedure, (d) Study the robustness of the L-R and M-G procedures when the exponential assumption is violated, i.e., for example when the failure times have Weibull distributions instead of exponential, and (e) Determine the accuracy of M-G bounds for parallel systems and other coherent systems with different types of data such as time to failure data or success-failure data.

Summary: The statistically exact L-R method suffers from two major drawbacks. First, the computed bounds can be altered by a permutation in the order in which the components failed, even though the absolute failure times are unchanged. Second, the procedure does not utilize all the component failure data which is available, i.e., some data is "lost." Both aspects of this method were investigated in some detail. Using analytic techniques, expressions were derived for the mean and variance of the L-R bounds as a function of sample size, thus yielding insights into the effect of data order permutation. Expressions were also derived for the expected

amount of "lost" data. Then, simulation
techniques were used to investigate the
effect of lost data, by simulating subsystem
failures, then a priori ordering the resulting
failures to make maximum use of the available
data. It was determined that this a priori
ordering did not improve the estimating
procedure.

Investigations into objectives (c) through
(e) is ongoing.

Publication: A. L. Schoenstadt, "The Influence of Data
Order on the Lierberman-Ross Method," NPS
Technical Report #NPS53Zh76047, April 1976.

Title: Minimum Storage Solution of Capacitated
                    Rooted Trees

Investigator: H. B. Marks, Associate Professor of
                    Mathematics

Sponsor: Naval Postgraduate School

Objective: To study wiring networks for large controller
                    actuated traffic signal systems.

Summary: Wiring networks for large controller actuated
                    traffic signal systems were modeled by rooted
                    trees. Minimum allowable wire size was sought.
                    Using definitions of "network complexity"
                    based on "maximal binary subtree" and "admissible
                    solution process," it proved that there is a
                    junction processing sequence for a complexity
                    n network using $n + 1$ computer storage units,
                    but not less. A junction sequencing algorithm
                    was given to produce a sequence of the type
                    guaranteed by the existence theorem. In this
                    paper, interest was in the sequencing process;
                    the wiring problem was exemplary. The algorithm
                    was related to, but distinct from, that of
                    Nakata and Redziejowski. This program was
                    utilized by the Texas Highway Department and
                    the Bureau of Public Roads. The theory was
                    presented at a Navy Combinatorics Conference.

Publications: None

Title: Effects of Certain Configuration Parameters
                on a Particular Air to Air Interceptor Missile
                with Optimal Guidance

Investigator: I. B. Russak, Associate Professor of
                Mathematics

Sponsor: Pacific Missile Test Center

Objective: To examine the potential performance limits
                of advanced conceptual air to air interceptor
                missiles for the Navy. This is one part of
                a continuing effort concerning this topic
                (see annual research summary report for FY 75)
                and deals with the effects of configuration
                parameters (such as, engine size, the inclu-
                sion of aerodynamic surfaces, etc.) on per-
                formance.

Summary: The effort (begun by the investigator during
                FY 73) to determine performance limits of
                certain air to air missiles was continued.
                The resulting optimally guided vehicles of
                earlier work (see annual research report for
                FY 75) were investigated to determine sensi-
                tivity of perfornamce to configuration para-
                meters. The results (such as, the fact that
                aerodynamic surfaces do not significantly
                improve performance) give guidelines for
                optimal missile configurations

Publications: I. B. Russak, "Effects of Certain Configur-
                ation Parameters on a Particular Air to Air
                Interceptor Missile with Optimal Guidance,"
                Technical Report NPS53Ru75103, October 1975.

Title: Necessary Conditions for General Problems Involving Higher Derivative Bounded State Variables

Investigator: I. B. Russak, Associate Professor of Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: To obtain necessary conditions for solution of a complex problem in optimal control involving constraints of the form $\psi(t,x) = 0$ in which the control effects the state x through a set of second order differential equations.

Summary: By using the techniques of the calculus of variations, a set of first order necessary conditions is obtained for the above problem. The distinctions are made clear between these results and those obtained for problems in which the control effects the state x through differential equations of order not higher than one. The problem considered includes many direct applications to current naval projects, such as, optimal guidance of missiles.

Publications: None

Title:	Investigation of Geostrophic Adjustment
Investigator:	A. L. Schoenstadt, Assistant Professor of Mathematics
Sponsor:	Fleet Numerical Weather Central and Naval Environmental Prediction Research Facility
Objective:	To investigate the effect of various numerical computation schemes on the process of geostrophic adjustment.

Summary: Geostrophic adjustment is the process by which an atmosphere modeled by the meteorological primitive equations tends toward geostrophic balance. Winninghoff (1968) investigated some of the numerical consequences of discretizing (e.g. spatially centered second order finite differences) the primitive equations. This investigation extended his work. The one-dimensional dispersive wave equation was investigated using Fourier transform techniques. It was showed that discretization tended to spread the effect of local imbalances more than the differential case, and that the transient behavior in the discretized case was somewhat different than in the differential case. Further extensions are planned.

Publications: A. L. Schoenstadt, "The Effect of Spatial Discretization on the Steady State and Transient Solutions of a Dispersive Wave Equation," to appear in Journal of Computational Physics.

Title: Analysis of Reliability Estimating Methods

Investigator: A. L. Schoenstadt, Assistant Professor of Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: Analyze certain properties of the Lieberman-Ross procedure for computing system reliability bounds from subsystem (component) failure data.

Summary: The Lieberman-Ross (LR) method is a statistically exact procedure for determining lower bounds on system reliability from subsystem (component) failure data. The procedure suffers, however, from two major drawbacks. First, the computed bounds can be altered by a permutation in the order in which the components failed, even though the absolute failure times are unchanged. Second, the procedure does not utilize all the component failure data which is available, i.e., some data is "lost." Both aspects of this method were investigated in some detail. Using analytic techniques, expressions were derived for the mean and variance of the LR bounds as a function of sample size, thus yielding insights into the effect of data order permutation. Then, simulation techniques were used to investigate the effect of lost data, by simulating subsystem failures, then a priori ordering the resulting failures to make maximum use of the available data. It was determined that this a priori ordering did not improve the estimating procedure.

Publication: A. L. Schoenstadt, "The Influence of Data Order on the Lieberman-Ross Method," NPS Technical Report NPS53Zh76047, April 1976.

Title: A General Methodology for Forecasting the
Technological Threat from the Soviet Navy

Investigator: Peter C. C. Wang, Associate Professor of
Mathematics and National Security Affairs, and
Associate Professor R. H. Stolfi, National
Security Affairs

Sponsor: Navy Intelligence Support Center

Objective: To develop a general methodology for fore-
casting the technological threat from the
Soviet and similarly organized navies of the
Eurasian Communist Countries.

Summary: The methodology is based on a dynamic general
structural model of the process of defense
material acquisition in the Soviet Union. The
outputs of the process of defense material
acquisition are weapons and weapons platforms
which are to the most substantial part of the
technological threat. The methodology concen-
trates on *Weapons performance characteristics*
(WPC) and changes in the WPCs, to define the
relevant acquisition cycles and indicate the
directions of future improvement.

Publications: None

Title: Stochastic Bubble Model on Sound Propagation

Investigator: Peter C. C. Wang, Associate Professor of
                     Mathematics

Sponsor: Office of Naval Research

Objective: To model stochastically sound speed fluctua-
                     tion due to the existence of bubles in the
                     upper ocean. A specific objective is to
                     model how low frequency sound speed fluctua-
                     tion is influenced by existence of bubbles
                     in the upper ocean. This is a continuing
                     project with Office of Naval Research (ONR)
                     under contract NR-042-286 on Stochastic
                     models.

Summary: Preliminary models were developed earlier,
                     and experimental verification of these models
                     shows that successful predictions of maximum
                     fluctuation of low frequency sound occurs
                     at the resonance frequency of the bubbles.
                     This preliminary model has been expanded in
                     several more realistic ways. i.e., (1) Wilson's
                     propagation formula is no longer restricted
                     to a linear form, and (2) bubble populations
                     are treated as random variables rather than
                     mean values.

Publications: P. C. Wang, "Stochastic Models of the Scat-
                     tering of Sound by Bubbles in the Upper Ocean,"
                     Quarterly of Applied Mathematics, January
                     (1975)

                     P. C. Wang, "Asymptotics of Stirling Numbers
                     of the 2nd Kind," Proceedings of the American
                     Mathematical Society, (1975)

Title: Modernization Plan for the Technical Data
                Department of the Naval Ships Weapon Systems
                Engineering Station

Investigator: Peter C. Wang, Associate Professor of
                Mathematics

Sponsor: Naval Ship Weapons Systems Engineering
                Station

Objectives: To develop a methodology which utilizes an
                intra-organizational structure to coordinate
                a modernization that requires the acquisition
                of facilities involving high technology, and
                to propose a modernization plan based on
                mothodology developed in the above objective
                for the Technical Data Department of Naval
                Ship Weapons Systems Engineering Station to
                reduce technical and organizational risks.

Summary: A technical report is under preparation and
                it should be completed and ready for distri-
                bution sometime early in April 1977.

                As a by-product of this ongoing Naval Post-
                graduate School study on the 1980 requirements
                for equipment and technology for Naval Ship
                Weapons Systems Engineering Station, a joint
                symposium by Naval Postgraduate School and
                Naval Ship Weapons Systems Engineering Station
                on Automated Production of Engineering Data
                and Display of Digitized Engineering Data was
                held on January 13-14, 1977.

Publications: None

Title: Continuation on a General Methodology for
                    Forecasting the Technological Threat from
                    the Soviet Navy

Investigators: Peter C. C. Wang, Associate Professor of
                    Mathematics, Russel H. S. Stolfi, Associate
                    Professor of National Security Affairs

Sponsor: Naval Intelligence Support Center

Objective: Statistical techniques to represent multi-
                    variate data will be studied. New techniques
                    will be developed and implemented in order
                    to handle intelligence analysis, and; to
                    extend the general methodology developed to
                    cover weapon platforms.

Summary: The general methodology for forecasting the
                    technological threat from red navies system-
                    atically reconstructs the Weapon system acqui-
                    sition process for the most recent weapon in
                    a particular category. On the basis of the
                    reconstruction of the recent past, the method-
                    ology moves forward to construct the acqui-
                    sition process for the future version of the
                    selected category of weapon.

Publications: None

Title: Discrete Transforms and Convolutions

Investigator: Carroll O. Wilde, Professor of Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: Study the problem of finding the convolution
operation that is appropriate for a given
discrete transform, and the reverse problem
of finding a transform for a given convolution.

Summary: Image science includes the total scenario
of starting with a given object, forming
an image of the object, transmitting the
image from one location to another, detecting
the transmitted image, processing the detected
image, and displaying the processed image.
Of primary concern for computer application
is the case where the image is digitized,
so that it can be represented as a discrete
function over a set of lattice points, and
discrete transforms and convolutions play
a vital role in digital image science.

The overall objective has been approached
by concentrating on one of the specific
one-dimensional problems involved. Given
a finite group $G = \{g_1, \ldots, g_n\}$, with
g_1 the identity, we relabel the elements
as $\{1, \ldots, n\}$. If x, y are n-dimensional
column vectors, we define the convolution
of x and y to be the vector $x * y$ whose
i^{th} component is

$$(x*y)_i = \sum_{j=1}^{n} x_{ij^{-1}} \, y_j \; .$$

The problem is to find a discrete transform,
which is represented by a unitary matrix
M whose columns form a representation of
the original group, such that $M(x*y) = MxMy$.
(The justaposition on the right denotes
the linear product:

$$MxMy = \sum_{i,j} x_i y_i \, (\alpha_i \alpha_j),$$

where $\alpha, \ldots, \alpha_n$ are the columns of M.)
If we define the incidence matrices
$\Lambda_1, \ldots, \Lambda_n$ by

$$\Lambda_k = (\lambda_{ij}^k)_{n \times n}, \text{ where } \lambda_{ij}^k = \begin{cases} 1 & \text{if } i = kj \\ 0 & \text{if } i \neq kj \end{cases},$$

then convolution can be represented by

$$(x * y) = x^T \Lambda_i y .$$

With this notation, the above problem can
be reduced to that of solving a matrix equation
of the form

$$\sum_{i=1}^{n} t_i \Lambda_i = \begin{pmatrix} t_1^2 & t_1 t_2 & \cdots & t_1 t_n \\ t_2 t_1 & t_2^2 & \cdots & t_2 t_n \\ t_n t_1 & t_n t_2 & \cdots & t_n^2 \end{pmatrix}$$

By equating columns, we can replace this
matrix equation by n eigenvalue problems
$A_i t = \lambda t$, where $t = (t_1, \ldots, t_n)^t$. Successful
solution of the n simultaneous eigenvalue
problems under the constraints noted above
would then yield the desired matrix M.

In addition to the above delineation
of the problem, results to date have included
solution of the problem for almost all groups
through order eight. Continuation of the
study is centering on efforts to find algorithms
so that the process can be extended to more
complicated groups.

In conjunction with the above efforts,
a continuing image science seminar has been
conducted through the research period.
The seminar has featured speakers from NPS,
Stanford University, Stanford Research Institute
and ESL, Inc., and NUC. Several colloquium
lectures were given during the 1976 fall quarter
at NPS, and a symposium was also held at NPS
during the same quarter. Longer range goals

include formation of a dedicated image science
research laboratory at NPS, and possibly
development of a new curricular program if
a need can be identified.

Publications: None

DEPARTMENT OF ADMINISTRATIVE SCIENCES

The Administrative Sciences Department is a newly created organizational unit responsible for academic programs designed to educate officers and DOD civilians in a variety of functional management specialties. As such, it is a large, multidisciplinary department with diverse research projects oriented to support the management tasks within the Navy and the Deparment of Defense. For ease of exposition, the program is classified into the following six areas of concentration: Systems Acquisition Management Research, Manpower/Personnel Management Research, Health Care Delivery Management Research, Technology Transfer Management Research, Management Science Research, and Resource Allocation/ Financial Management Research. The present focus of the research in these areas is summarized in the following paragraphs.

SYSTEMS ACQUISITION MANAGEMENT RESEARCH

Research in this area is wide-ranging. R. R. Judson is studying policies for the use of reliability improvement warranties. C. R. Jones' area of interest is the behavior of defense contractors, particularly in a high inflation environment. He works with M. G. Sovereign on this, who also studies the Navy budgeting process for escalation. C. K. Eoyang is developing a taxonomy of management approach to systems acquisition that will serve as one basis for improving the acquisition management system. M. B. Kline, W. C. Giauque and J. P. Hynes studied the relationship of threat and system performance requirements via decision analytic techniques for the advanced naval gun system. M. B. Kline and five systems acquisition management students performed a systems engineering management analysis of the Standard Missile Program. W. J. Haga evaluated the utilization of naval RDT&E manpower through the use of organizational structure variables. S. M. Dean is conducting an extensive study of the Navy industry shipbuilding process.

MANPOWER/PERSONNEL MANAGEMENT RESEARCH

This area encompasses not only the traditional areas of manpower and personnel management but also education and training issues, and human resources management as well as human factors research. J. K. Arima is developing an objective measure of Navy recruiter effectiveness. This is a follow-on effort to his completed study, "A Systems Analysis of Navy Recruiting." W. J. Haga investigated the relationship between various naval combat unit sizes and HRM command climate scores. W. C. Giauque identified areas in the naval education and training system where formal decision analytic methods could improve decision making. J. D. Senger studied the relationship of age and race-related attitudes

toward supervisory and peer leadership in the Navy. J. K. Arima
continued his studies of the effective utilization of small arms
via a series of limited purpose, live-fire field experiments.
R. A. Weitzman estimated the retention probabilities for naval
officers classified according to both commission source and first
and second billet assignments. C. B. Derr began the development
of a theoretical framework and methodology for analyzing stages
in a naval officer's career. C. K. Eoyang, in conjunction with
the Naval Personnel Research and Development Center, supported
the development of a long-range plan for naval research in human
resources management.

HEALTH CARE DELIVERY MANAGEMENT RESEARCH

W. C. Giauque, C. K. Eoyang, C. B. Derr and R. T. Harris
(at MIT) examined the integration of new medical practitioner
roles into the armed forces medical care delivery system. This
work provides the basis for more extensive work on methods of
overcoming organizational and behavioral obstacles to efficient
utilization, to work on the measurement and control of quality
of care and to examination of the economics of using paramedical
personnel. D. R. Whipple, in association with C. K. Eoyang,
C. B. Derr, K. L. Terasawa, W. M. Raike and T. A. Wyatt, provided
support to BUMED and, in particular, the newly instituted Planning,
Programming and Analysis Directorate in the areas of management
analysis and basic research. The management analysis included
analytical support for the PPBS system, team building and conflict
management workshops, a management information system conceptual
design, and suggested management and operational structure changes
to the health care delivery system. Basic research activities
included studies on the comparative costing of military vs
civilian models of health care delivery by D. R. Whipple and
K. L. Terasawa. These same investigators also analyzed aspects
of a multiregional health care voucher system.

TECHNOLOGY TRANSFER MANAGEMENT RESEARCH

J. W. Creighton and J. A. Jolly, in association with
officer and civilian thesis students, have been studying the nature
of the technology transfer process. In conjunction with the Naval
Facilities Engineering Command, three major activities were under-
taken. First, a survey of industrial research and development
budgeting effort was completed to provide a comparative baseline.
Second, an analysis of the perceived reward to a receiver of
technology transfer and its impact on the current predictive model
of technology transfer was made. And, third, a computer-based,

management information system was developed and tested for expenditure and benefits of field innovation. In addition, for NAVMAT, several activities were undertaken with the objective of providing an information base to accelerate the implementation of output from Navy research and development laboratories and centers. Symposia were given and studied as a means of transferring technology from generator to user. A study was made of the technical transfer functions of chief project engineers. Also, a study was made of the feasibility of national/regional technology transfer R&D centers. In addition, the identification of linder agents for the introduction of safety, anti-pollution and production devices was made.

MANAGEMENT SCIENCE RESEARCH

Work in this area, while frequently done in an applied context, is more basic and transferable to a variety of applications. W. C. Giauque explored the potential use of multi-attribute utility analysis in quality determination. This technique permits a quantitative measure of quality to be developed. This exploration was part of the health care research to determine medical standards in the presence of uncertainty and of multiple, often conflicting, outcome criteria. R. A. Weitzman continued the development of predictive techniques useful in manpower/personnel research. He developed a method for testing the relative accuracy of different numerical predictions, as well as a method which estimates pattern scores. The estimation procedure was compared with a method which calculates pattern scores directly but expensively. Finally, he compared methods of selecting item sets that maximize predictive validity. The data for this research is the biographical and test data obtained from Navy enlisted men. A. W. McMasters investigated the determination of maximal flows in nonplanar networks by using dual graphs. This work has application in communications and logistics. N. F. Schneidewind continued his analysis of software with the objective of refining his techniques for determining software reliability.

RESOURCE ALLOCATION/FINANCIAL MANAGEMENT RESEARCH

The work by M. G. Sovereign summarized under Systems Acquistion Management Research and D. R. Whipple, et al., summarized under Health Care Delivery Management Research are also integral to this area of research as well. In addition, C. R. Jones and several thesis students developed a method for estimating life cycle costs for high technology systems that have never before been produced or operated. D. C. Burns continued his work on an internal control simulation useful to both managers and auditors. P. J. Parker, current occupant of the Chief of Naval Operations (OP-96) Chair in Systems Analysis, continued his consultive research for the Chief of Naval Operations and the Secretary of the Navy.

Title: Measuring Recruiter Effectiveness

Investigator: J. K. Arima, Associate Professor of Administrative
                Sciences

Sponsor: Naval Personnel Research and Development Center

Objective: To develop an objective measure of Navy recruiter
                effectiveness that could be used as a criterion for
                validating recruiter selection procedures and for
                evaluating recruiter performance, training programs,
                work methods, operational procedures, and enlistment
                programs.

Summary: The study is a follow-on to the recently completed
                study, A System Analysis of Navy Recruiting. The
                basic premise of this research is that a measure
                or recruiter effectiveness must include a measure
                of what he actually produces and a measure of what
                he should have produced. The latter is assumed to
                be dependent on managerial policy that affects
                recruiter activity and on the inherent potential of
                a recruiter's territory for generating enlistments.
                The strategy of research has been to obtain several
                measures of recruiter productivity and, using step-
                wise multiple regression, to determine what charac-
                teristics of the recruiter's territory best predict
                production while controlling for managerial policy.
                The productivity of recruiters in California during
                the period June through October 1974 was selected
                for study because it was not quota bound. The
                sample consisted of 268 recruiters who had been on
                production duty at one station during the entire
                period. They represented 111 recruiting stations
                in the San Francisco, Los Angeles, and San Diego
                Navy Recruiting Districts. The territorial variables
                were entirely educational statistics and data which
                were current and could be directly mapped on re-
                cruiting station territory. They included enroll-
                ments in several categories, the minority proportion
                by several ethnic groups, achievement scores of 12th
                grade students, and a variety of financial data
                indicative of the characteristics of a community.
                The data from 399 school districts were mapped on
                the territory of the 111 recruiting stations. It
                was found that three different equations were re-
                quired to predict production in the three recruiting
                districts. Approximately one-third of the varia-
                bility in production among recruiters could be pre-
                dicted on the basis of the environmental variables.
                This is as much as one would hope to predict, since
                the remaining variance is accounted for by differ-
                ences among individual recruiters in motivation,
                ability, skills and experience; chance factors; and
                measurement error. Accordingly, it was shown what
                a recruiter could be expected to produce could be
                calculated for every station within a district.

Conference
Presentation: J. K. Arima, "Measuring Recruiter Effectiveness,"
                 a symposium presentation at the annual meeting of
                 the American Psychological Association, Washington,
                 D. C., September 1976.

Publications: Arima, J. K. "A Systems Analysis of Navy Recruiting,"
                 Special Report 76-3, Navy Personnel Research and
                 Development Center, April 1976.

Thesis   R. J. Sullivan, "Developing a Measure of Marine
Directed: Corps Recruiting Effectiveness," Master's Thesis,
                 June 1976.

Title:	Small Arms Field Experimentation Program
Investigator:	J. K. Arima, Associate Professor of Administrative Science
Sponsor:	U.S. Army Combat Developments Experimentation Command
Objective:	By a series of limited-purpose, live-fire field experiments, to develop knowledge regarding factors that affect the effective utilization of small arms.

Summary:

The fifth in this series of experiments was conducted to determine whether an information measure could be used to quantify the difficulty of a serial firing task involving one to several targets. The time to complete the firing task with a particular weapon could then be expressed as its information processing rate and, by inference, its handling characteristic. The theory was tested by livefire using a service .45 cal. automatic pistol and a .38 cal. revolver. Task sequences at four levels of difficulty were used, and each sequence was fired four times by eight officers familiar with the weapons. The average performance of each weapon for the three sequences requiring movement could be predicted with a multiple R of over .99, attesting to the appropriateness of the concept as a measure of handling quality.

A sixth experiment in the series was conducted on the instrumented BRAVO range at Ft. Hunter-Liggett, CA. The purpose of the experiment was to determine whether the small bracketing sight conceived by Arima and used in prior experiments would improve short range, quick fire of the M16A1 rifle under low light-level conditions (.25 foot candles). A squad of eight infantrymen individually fired at four, head-and-shoulder targets that appeared in a random order at 20 and 40 yd. with an up time of 2.5 sec. during which the first 1.5 sec. was accompanied by the simulated sound and flash of weapon firing. Analysis of the total of 320 shots showed that the weapon with the bracketing sight achieved an overall hit rate of 59.4 percent, while the hit rate of the unmodified rifle was 41.8 percent, resulting in a 42 percent better performance with the simple bracketing sight principle.

Conference Presentation:	J. K. Arima, "Measuring the Fit Between Person and Equipment," Paper presented at the annual meeting of the Western Psychological Association, Los Angeles, California, April 1976.

Theses Directed: C. L. Featherstone and R. J. Scaglione, "A
Feasibility Study for Determining a Small
Arms Measure of Effectiveness for Handling
Characteristics," <u>Master's Thesis</u>, September
1975.

H. L. Honbarrier, "A Field Experiment to Determine
the Effectiveness of a Circular Bracketing Sight,
at Low-Light Levels for the M16A1 Service Rifle,"
<u>Master's Thesis,</u> June 1976.

Title: Naval Material Command Technology Transfer

Investigators: J. W. Creighton, Professor of Administrative
                    Science

Sponsor: Naval Material Command

Objective: To accelerate the implementation of output
                    from the Navy Research and Development
                    Laboratories and Centers.

Summary: The scope of this project has included almost
                    any type of activity which would inhance the
                    effectiveness of the Navy's R&D investments.
                    The specific direction of the project has
                    been toward accelerating the rate by which
                    the output from the Navy Laboratories gets
                    into use.

                    The project has been directed by Professors
                    Creighton and Jolly and has been carried on
                    with the assistance of some of the students
                    in the NAVAIR Executive Management Program.
                    The following are the specific subject areas
                    treated under the project in FY 1976:

                        1.   The publication of the proceedings of
                    the June 1975 NAVMAT Technology Transfer
                    Methodology Meeting.   The work has been edited.
                    A preliminary report has been circulated to
                    key individuals.   The final proceedings have
                    been proof-read and should be mailed to ap-
                    proximately 5,000 recipients in September 1976.

                        2.   A study has been made of the technology
                    transfer functions of chief project engineers.
                    This study was made specifically to apply to a
                    test and evaluation center but the report is
                    directed toward the responsibilities of any
                    laboratory engineering manager to get research
                    results into use.   The work has been completed.
                    It will appear as the thesis of Mr. Jack Grubber
                    from the NAVAIR Test Center, Patuxent River,
                    Maryland.

                        3.   A feasibility study and operational plan
                    for national and regional technology transfer
                    R&D Centers.   The objective of this study is to
                    investigate the need for an implementation plan
                    for the establishment of centers to facilitate
                    the movement of technology between federal,
                    state, and local government agencies and the
                    private sector.   A report on this sub-project
                    will be completed in September 1976 and will
                    appear as the Thesis of Peter S. Hughes, Naval
                    Weapons Evaluation Facility, Kirtland Air Force

Base, Albuquerque, New Mexico, and
Milton H. Olson, Naval Weapons Center,
China Lake, California.

4. A study of symposia as a means
for transferring technology from generator
to user. This project will be complete
in September and will be reported in the
thesis of Mr. Donald Bennett from the
Pacific Missile Test Center, Point Mugu,
California, Kenneth Thornton, Pacific
Missile Test Center, Point Mugu, California,
and Mr. John Sweeney, Naval Air Station,
San Diego, California.

Publication: None

Title: Quantification of Technology Transfer and
                Utilization for the Naval Facilities
                Engineering Command

Investigator: J.W. Creighton, Professor of Administrative
                Science

Sponsor: Naval Facilities Engineering Command

Summary: The scope of this project was identified
                by letter 19 May 1976 from Commander, Naval
                Facilities Engineering Command to Superin-
                tendent, U.S. Naval Postgraduate School,
                Ref. 031B/JTR. The following summary
                addressed the work that has been done in
                response to the identified scope:

                1. A survey of Industrial Research and Development
                Budgeting Effort Selection, and Evaluation has been
                made. This will be reported as NPS Technical Report
                No. 54CF76092 of Mr. Howard C. Fish from the National
                Parachute Test Range, El Centro, California, and Mr.
                Joseph W. Wilson from the Pacific Missile Test Center,
                Point Mugu, California. This work was directed by
                Professors Creighton and Jolly.

                2. Research has continued in the area of R&D
                performance motivation in relation to the linker
                model. One aspect of this has been completed and
                has been reported.

                3. In an effort to develop a system for technology
                transfer utilization ratings for NAVFAC R&D work
                units,a study was undertaken to develop a system
                for automating the information system of a small
                service organization. This work was also directed
                by Professors Jolly and Creighton. The basic
                model was designed, then tried in the Field Engi-
                neering Support Office at the Civil Engineering
                Laboratory, Port Hueneme, with the aide of Mr.
                Gene Early to automate the system for keeping
                track of expenditures and cost benefits of field
                innovations. This work is to be reported on in
                September 1976(by Kenneth M. Suess, Naval Air
                Station, San Diego, California, and James F.
                Thaler, NAVAIR Propulsion Test Center, Trenton,
                New Jersey.) (Technical Report No. 54CF76091
                "Demonstration of the Feasibility of Automating
                the Information System of a Small Service Organ-
                ization Using a Generalized Computer Software
                Package." It is expected that this system can
                be adapted to rating work units at the Naval
                Facilities Engineering Command.

Publications: Keith E. Nuynhuis and James H. Welborn,
"Analysis of the Perceived Reward to the
Receiver and Its Impact on the Predictive Model
of Technology Transfer," Technical Report No.
55Jo76061, June 1976.

Title: Off-Shore Drilling

Investigator: J. W. Creighton, Professor of Administrative Science

Sponsor: Harry Diamond Laboratories and U. S. Geological Survey

Objective: To attain the implementation of safety, anti-pollution, and production devices on off-shore oil drilling rigs in the Gulf of Mexico.

Summary: This project was conducted by J. W. Creighton and James A. Jolly with the help of several students from the NAVAIR Executive Management Program. The Postgraduate School segment of the project for the implementation of safety devices has been completed although the Postgraduate School will probably be asked to cooperate in the future phases.

The Harry Diamond Laboratory has been working with the U. S. Geological Survey to develop devices for safety, anti-pollution, and increased production on the oil rigs but has had little success in getting the people on the rigs to use them. The specific mission of the Postgraduate School was to develop an implementation plan and suggest the organization required. Our report to the Harry Diamond Laboratory included the following:

1. Our study of the individuals and their linker characteristics indicated that six of the U. S. Geological Survey employees were skilled at doing implementation work, with two of these having a very high degree of capability.

2. A modification of the Harry Diamond Laboratory Survey Instrument was sent to the drilling crews so that members of the drilling crews who had desires for new things and new ideas could be identified.

3. A recommendation that the higher level linkers among the Geological Survey employees be charged with the implementation responsibility, and that this group should work with the high level information receivers among the oil drilling crews to work out an implementation plan.

4.   That the Geological Survey work more closely with the oil companies through the implementation organization to develop an atmosphere of acceptance, in place of the present atmosphere of resistance to the safety, and anti-pollution devices.

The Geological Survey had indicated to the Harry Diamond Laboratory that they would like to have future assistance from the Postgraduate School in the implementation of the project. It is anticipated that the earliest date this cooperation would be requested would be January 1977.

Publications: None

Title: Development of a Theoretical Framework and
a Methodology for Analyzing Stages in a Naval
Officer's Career

Investigator: C. B. Derr, Associate Professor, Administrative
Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To develop a theory and method for studying
officer career patterns

Summary: A thorough review of the existing research
on career patterns lead to several hypotheses
about career stages of naval officers. Further
discussions with Professors Dalton and Thompson
at Brigham Young University and Drs. Roberts
and Wilcox at NPRDC served to clarify initial
formulations. Finally, in this exploratory
research, two classes of MN 3105 were surveyed.
Tentative conclusions were reached as follows:
    1. Stage theory is relevant but not
telling
    2. Various communities espouse different
values and attract persons with corresponding
values (e.g., technical values for NAVAIR,
managerial values for Surface Warfare, security
values for CEC and Supply).
    3. It is presumed that at the early
period of one's career one is pre-selected
for higher rank by the quality of the billet
he occupies,
    4. Many officers are second-career oriented
    5. In-depth interviews are preferred
for collecting such sensitive information.
    A new research proposal entitled, "Naval
Officer Career and Quality of Life Study:
Implications for Retention and Work Productivity,"
builds on this exploratory research and has
been submitted to the Office of Naval Research
and approved.

Publications: None

Title: Development of a Methodology for Analyzing
                    Data Describing Officer Billets

Investigators: R. S. Elster, Associate Professor, Administrative
                    Sciences Department, and R. R. Read, Professor,
                    Operations Research Department

Sponsor: Foundation Research Program (6.1)

Objective: To develop and exercise methodologies useful
                    in comparing and contrasting naval officer
                    billets using data from job task inventories.
                    In the long run it is hoped the results will
                    facilitate the description of billets and
                    help to identify educational requirements.

Summary: A job task inventory questionnaire was prepared
                    by modifying (and abbreviating) earlier work.
                    It was administered to 96 Navy officers (mostly
                    students at NPS) and subjected to the techniques
                    of factor analysis, multidimensional scaling,
                    hierarchial clustering, and K-means cluster
                    analysis. The last of these techniques emerged
                    as the most useful in terms of the stated
                    objectives. It appears that a few billet
                    clusters (three in our data) are quite stable
                    in that they are sharply delineated from
                    the others and their content can be described
                    by a few task items. The clusters of the
                    remainder billets are not as clearly defined
                    but can be separated in useful ways.

                    The follow on step is to enhance the
                    questionnaire so that greater separation
                    power is available in certain areas, and
                    to apply it to a larger and more representative
                    sample. Cross validation techniques should
                    be included.

Publications: None

Theses Directed:

                    J. Lemke, Major (Fed. German Air Force),
                    "Methodologies of Officer Billet Classification,"
                    Master's Thesis, 1976.

Title: Long Range Planning on Naval Research in Human
                Resources Management

Investigator: C. K. Eoyang, Assistant Professor of Administrative
                Science

Sponsor: Navy Personnel Research and Development Center

Objective: To provide staff support and guidance to PERS-65
                in the formulation of a long range plan for
                research on the Navy's Human Resource Management
                Program.

Summary: Investigation of existing activities and functions re-
                lated to the Navy's HRM Program provided an infor-
                mation base from which were developed preliminary
                recommendations for a long range HRM research plan.
                Two draft documents were prepared for consideration
                by NPROC and PERS-65: A draft Operational Require-
                ment for HRM System Development, and a draft Navy
                Decision Coordinating Paper for HRM System Develop-
                ment.

Publications: None

Title: A Taxonomy of Systems Acquisition

Investigator: C. K. Eoyang, Assistant Professor, Administrative Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To identify basic characteristics of technical systems acquired by the military to understand the dynamics underlying the management of these systems.

Summary: The research in progress is scheduled to be completed by January 1977. To date, data for forty-eight weapon systems have been collected representing a variety of projects from the Army, Navy, and Air Force. They include aircraft, ships, missiles, and torpedoes. Statistical analyses are underway to determine the relative contribution of several variables to the total variance in cost, schedule, and performance. Preliminary results indicate that simplistic cause-effect relationships are not strongly supported by the data, although several findings suggest a few intrinsic system characteristics are significant.

Publications: None

Theses Directed:

LT D. D. Henry, "Performance Correlates of Weapon System Projects in the Military," Master's Thesis, December 1976.

Title: Decision-Making in the Naval Education and
                     Training System

Investigator: W. C. Giauque, Assistant Professor of Administra-
                     tive Sciences

Sponsor: Naval Training Equipment Center

Objective: To survey decision-making methods and organiza-
                     tion in the Naval Education and Training Command,
                     particularly at top management levels, and to
                     determine the potential role of and desirability
                     of formal approaches to selected top management
                     decision problems.

Summary: Traditionally top management decision-making
                     relies heavily on informal techniques--intuitive
                     judgments by experienced managers, traditions and
                     "rules of thumb" peculiar to each organization, or
                     informal consensus among a group of managers.
                     Currently there is increased interest in improving
                     the effectiveness of decision-making in the Naval
                     Education and Training Command not only because
                     of the unprecidented complexity of the task but
                     also because of the severe shortage of resources.
                     In this study, interviews were conducted with key
                     managers in the command staff, the support staff,
                     and at the largest operational command. A number
                     of areas were identified where more formal
                     approaches to decision-making should be used. A
                     summary of current decision-making techniques and
                     the potential role of improved techniques are
                     also included.

Publications: W. C. Giauque, "Decision Analysis and Its Applicator
                     to the Naval Education and Training Command,"
                     TAEG Report #27, July 1975.

                     W. C. Giauque, "Organizational Decision-Making,"
                     Technical Report NPS55Gi75081, August, 1975.

Title: Studies of the Effectiveness of Paramedical
Personnel Usage in Medical Care Delivery

Investigators: W. C. Giauque, Assistant Professor of Admini-
strative Sciences, Carson K. Eoyang, Assistant
Professor of Adminstrative Sciences, C. Brooklyn
Derr, Associate Professor of Administrative
Sciences, Reuben T. Harris, Assistant Professor,
Sloan School of Management, M. I. T.

Sponsor: Department of Defense, Manpower and Reserve
Affairs

Objectives: To examine the integration of new medical prac-
titioner roles into the armed forces medical
care delivery system, and identify major pro-
blem areas. This research is designed to lead
into more extensive work on methods of over-
coming organizational and behavioral obstacles
to efficient utilization, to work on the mea-
surement and control of quality of care, and
to examination of the economics of using para-
medical personnel.

Summary: We surveyed personnel in various roles in the
medical systems of each of the armed services,
including physicians, nurse pratitioners,
nursing supervisors, administrators, and corps-
men. Our major instrument consisted of over
4000 questionnaires, covering areas of job
definition, description of work setting, satis-
faction with various phases of work, attitudes
toward other medical roles, career plans, and
demographic data. We also conducted a series
of field interviews to supplement the question-
naire data. We found serious problems in the
administrative structure, particulary as re-
gards nurse pratitioners, a high degree of dis-
satisfaction among physician assistants regarding
many aspects of their work, particulary rank,
pay, status, and opporturnities for continuing
education, and a general lack of awareness among
new health practitioners. A de facto separation
of duties and patients among roles exists.
Significant differences in job structuring exits
among the services, indeed from place to place
within each service.

Conference
Presentations: William C. Giauque, C. Brooklyn Derr, Carson K.
Eoyang, and Reuben T. Harris, "Studies of the
effectiveness of Paramedical Personnel Usage
in Medical Care Delivery," Presented at the NATO
Conference in Systems Science in Health Care,
Paris, France, July 8, 1976.

Title: A Multiattribute Utility Approach to Measure Quality of Health Care

Investigator: W. C. Giauque, Assistant Professor, Administrative Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To demonstrate the power of a relatively new analytic technique, multiattribute utility analysis, in determining medical standards despite the presence of uncertainty and of multiple, often conflicting, outcome criteria.

Summary: Lacking objective standards of what "good" medical care is, the assessment of quality becomes a matter largely of judgment. Insofar as judgments and opinions differ, quality becomes impossible to measure. Even in cases where medical opinion subsequently agrees on proper procedures, a quantitative measure of quality still does not exist, making rational cost/benefit analysis more difficult. The factors which make quality standards difficult to define in medicine are (1) uncertainty is nearly always a major factor, both in the diagnosis of the patient's condition and in assessing the outcome of any procedure, and (2) it is usually necessary to simultaneously consider multiple, often conflicting outcome criteria. These are precisely the types of problems that multidimensional utility theory is designed to handle. In addition, this theory can also yield a quantitative measure of "goodness" for any particular course of action one cares to analyze. In this research the potential use of this technique in quality determination was explored and developed. Two particular medical problems: treatment of suspected streptococcal sore throat and treatment of hypertension, were investigated, and preliminary quality standards developed.

Publications: W. C. Giauque, "A Multiattribute Approach to Measure Quality of Health Care," Technical Report NPS55Gi76031, March 1976.

Thesis Directed:

R. E. Kapernick, "Medical Decision Analysis:
An Application in Hypertension," Master's
Thesis, March 1975.

Title: Organization Size and Command Climate of Navy
Ships

Investigator: William James Haga, Associate Professor of Adminis-
trative Science

Sponsor: Navy Personnel Research and Development Center

Objective: To examine structural antecedents of observed rela-
tionship of high scores on HRM Survey measures of
shipboard command climate to indices of crew
performance

Summary: A preliminary zero order correlation analysis found
no association between a ship's crew size and its
HRM command climate scores. The same lack of
association between these variables was also found
in air squadrons. However, a statistically signi-
ficant, but otherwise unremarkable, association
was found between the size of ships' departments
and the dapartments' HRM climate. This demonstrated
that a structural variable such as size only affects
crew attitudes at organization levels closer to the
individual. Further work has been suggested,
combining structural variables (mission, technology,
size, age of ship) into a partial and multiple
correlation analysis scheme with command climate as
the outcome criterion.

Publications: None

Thesis
Directed: L. O. Milam "The Human Resources Program and Ship-
board Habitability Considerations", Master's
Thesis, March 1976.

Title:　　　　Evaluation of RDT&E Manpower Utilization
　　　　　　　　Through Structural Variables:　Phase I

Investigator:　William J. Haga, Associate Professor, Adminis-
　　　　　　　　trative Sciences Department

Sponsor:　　　Foundation Research Program (6.2)

Objective:　　Explore the development of structural variables
　　　　　　　　as a surrogate, indirect, nonreactive indicator
　　　　　　　　of appropriate use of manpower in RDT&E,
　　　　　　　　using the Percentile Role Differentiation
　　　　　　　　Indicator (PRDI) as a theoretical template
　　　　　　　　for identifying deviations from an expected
　　　　　　　　degree of complexity for varying organization
　　　　　　　　sizes.

Summary:　　　Reductions of defense budgets in current
　　　　　　　　dollars by Congress, and in real dollars
　　　　　　　　by inflation, compel the Navy to reduce
　　　　　　　　military and civilian manpower.　RDT&E activi-
　　　　　　　　ties are attractive cut-back targets for
　　　　　　　　manpower specialists because of the impression
　　　　　　　　that they are an area of defense support
　　　　　　　　"tail" rather than combat "teeth."　An intuitive
　　　　　　　　approach to reducing RDT&E manpower would
　　　　　　　　be an across-the-board percentage cut.
　　　　　　　　Yet manpower specialists (DASD-M&RA and
　　　　　　　　Navy OP-121) know this approach involves
　　　　　　　　the unforeseen consequence of missing consider-
　　　　　　　　able "tail" while knocking out some "teeth."

　　　　　　　　　The original proposal was to explore
　　　　　　　　a way to give manpower specialists some
　　　　　　　　assistance in distinguishing "teeth" from
　　　　　　　　"tail" in terms of labeling RDT&E subunits.
　　　　　　　　Phase I involved six activities:

　　　　　　　　　1.　Reviews of prior DOD, GAO, OMB studies
　　　　　　　　of RDT&E effectiveness and recommendation.
　　　　　　　　This has been done.

　　　　　　　　　2.　Travel to BUPERS to explore the
　　　　　　　　quality and availability of structural data
　　　　　　　　from RDT&E units.　The Foundation grant
　　　　　　　　for Phase I did not include travel money.

　　　　　　　　　3.　Development of a structural data
　　　　　　　　report format and reporting procedures.
　　　　　　　　This has not been done.

　　　　　　　　　4.　Exploration of computer programs
　　　　　　　　for storing and processing a proposed structural

data base. This has not been done.

    5. Consideration of four basic structural variables to be analyzed through the PRDI. This has not been done.

    The Foundation Grant for Phase I was made in April 1975. At that time, I assumed that Louis Moore III would be employed as a consultant during the summer quarter of 1975 to complete (a) the programming of the PRDI for easy use through the input of formal organization structure data and (b) develop the PRDI algorithms under differing general assumptions about the character of organizations being analyzed. Moore was not engaged as a consultant because his contract was cancelled as a possible conflict of interest. Thusly, the PRDI was not consummated.

    Travel to BUPERS was unnecessary in large part because of the discovery of Navy manpower report documents available from central sources at Norfolk and San Diego. The manning documents on a handful of Navy RDT&E organizations were acquired for use in devising "teeth" and "tail" coding methods and in developing the format of a structural data report. No objective means of making the crucial "teeth" or "tail" distinctions could be found in the reported data. The only resort was to make arbitrary coding decisions which was the very kind of decision the study aimed to prevent. Even organizing the data for simple statistical descriptions proved forbidding because of the need for considerable coding and keypunching labor.

Publications: William J. Haga, "Probabilistic Base Generator for Role Differentiation in Formal Organizations," Journal of Mathematical Sociology, with Louis Moore III, in revision.

    William J. Haga, "Probabilistic Baseline Generator for Role Differentiation in Formal Organizations," Technical Report NPS53M176521, February 1975 (with Louis Moore III).

Theses Directed:

> LT Robert H. Spencer, USN, "Time Series Test of a Harmonic Series Model of Organization Differentiation," Master's Thesis, March 1975.
>
> LCDR Michael Tanner, USN, "Structural Evolution of a Procurement Command," Master's Thesis, March 1975.
>
> LT Steven R. Alexander, "Structural Evolution of Naval Air Squadrons," Master's Thesis, March 1975.

Title: Life Cycle Costing of an Emerging Technology

Investigators: Carl R. Jones, Associate Professor of Administrative
                  Science,   Ronald L. Johnson, Earle W. Knobloch,
                  John M. McGrath, & Kenneth R. Michna

Sponsor: Naval Electronics Laboratory Center

Objective: To develop a method for life cycle costing
                  applicable to an emerging technology such as fiber
                  optic data transmission methods.

Summary: For the proper guidance of R&D expenditures and
                  the inclusion of optical data transmission methods
                  in operational aircraft, it is necessary to develop
                  appropriate methods for estimating life cycle costs
                  for alternative coaxial/twisted pair wire and
                  optical fiber avionics. The cost performance
                  analysis began with an investigation of the alterna-
                  tive measures of effectiveness possible for various
                  coaxial/twisted pair and fiber optic systems. The
                  approach which structures the technological and
                  demand uncertainties of fiber optics is developed
                  through scenarios as a means of relating costs and
                  performance. It is suggested that Delphi and
                  experience curve techniques be used in conjunction
                  with ordered scenarios as a technological forecasting
                  technique for estimation of life cycle costs of
                  fiber optics. In addition, a review of the historical
                  and technological background of fiber optics and
                  their application to the Naval Electronics Laboratory
                  Center A-7 Airborne Light Optical Fiber Technology
                  (ALOFT) Program is included.

Publications: None

Title: Escalation Impact on DOD Budgeting and Contractor

Investigators: C. R. Jones, Associate Professor of Administrative
                  Sciences and M. G. Sovereign, Associate Professor
                  of Operations Research.

Sponsor: Office of Naval Research

Objective: To study the budgetary effects of escalation
                  provisions and the effect on defense contractor
                  conduct of various types of regulatory controls
                  imposed by procurement practices.

Summary: To meet this objective, two research activities
                  were undertaken. The first effort (described
                  below) involves the budgetary effect of escalation
                  including concepts for compensating for the uncer-
                  tainty introduced into budgeting by escalation.
                  The second effort (described below) involves those
                  aspects of escalation provision coverage which
                  directly affect (control) the contractor's de-
                  cision process as well as impact on DOD policy
                  on industry profits.

                  The measurement of inflation is central to ans-
                  wering the question of what is the level of real
                  resources the Navy receives. Price changes are
                  not the same for all commodities. There are three
                  major alternative levels at which the inflation
                  can be measured for budget purposes: economy-wide
                  (total Navy budget), industry-wide (appropriation
                  category) or individual firm (contract or project).
                  The measurement of inflation is quite sensitive
                  to the choice of measurement technique. For example,
                  although DOD methods show a decreasing real expendi-
                  ture trend for the Navy in recent years, if inflation
                  is measured by the Gross National Product Deflator
                  (GNPD), an increasing trend is seen. However,
                  examination of individual contracts shows that price
                  rises for some Navy expenditures have been consid-
                  erably above that of the GNPD. Approaches for
                  improved measurements at the various levels are
                  discussed.

                  Utilizing the refined model of a representative
                  defense contractor, the contractor response to in-
                  centive controls, ideological controls and coercive
                  controls was studied. Models were developed for
                  share-lines and weighted guideline factors (incen-
                  tive controls), rate of return policies (ideological
                  controls) and for government furnished items and
                  progress payments (coercive controls). Combining
                  these models with the representative defense con-
                  tractor model in a situation with escalation pro-

visions permitted the study of such controls on contractor conduct. Qualitative (direction of charge) results were not obtained, but a few of the algebraically complicated complete expressions were obtained.

Publications: C. R. Jones, et al., "Life Cycle Costing of an Emerging Technology: The Fiber Optics Case," Technical Report, NPS55Js76031, April 1976.

Theses
Directed: T. A. Ippel, "The Impact of Inflation on Profit as Determined by Contractual Provisions of Naval FPIF Shipbuilding Contracts," Master's Thesis, March 1976.

H. L. Leon, Jr., "The Ship Acquisition Process: An Interorganization Perspective," Master's Thesis, March 1976.

S. R. Olson, "A Computer Model to Assess Financing Provisions of Naval FPIF Shipbuilding Contracts," Master's Thesis, September 1975.

Title: Modeling a Defense Contractor

Investigator: Carl R. Jones, Associate Professor, Operations
                Research and Administrative Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To refine a model of a representative defense
                contractor and characterize the contractor's
                responses to exogenous influences.

Summary: Based on an earlier development of a representative
                defense contractor model, the following
                refinements were studied: the inclusion
                of dividends as a corporate decision variable,
                the market structure of subcontractors,
                and the contractor expectations of future
                events. Each of these phenomena were modeled
                and included in the refined version of the
                representative defense contractor. In addition,
                effort was devoted to the characterization
                of the contractor's responses to exogenous
                influences. While complicated mathematical
                expressions are derived, simple sign (plus
                or minus) results were not obtained. Thus,
                the contractor's responses require quantitative
                (magnitude) information to obtain simple
                direction of change (plus or minus) results.
                This suggests the need for a somewhat more
                abstract model to provide insight into contractor
                behavior.

Publications: None.

Thesis
Directed: W. C. Ridder and M. K. Heinz, "Structure,
                Conduct and Performance of the U.S. Aerospace
                Industry," Master's Thesis, March 1976.

Title: A Systems Engineering Management Analysis of
                  the Standard Missile Program

Investigators: M. B. Kline, Professor of Administrative Sciences,
                  CDR C. M. Garverick, USN, LCDR G. A. Bush, USN,
                  LCDR M. K. Heinz, USN, R. W. Doncette, NWC-China
                  Lake, and D. C. Gay, NWC-China Lake

Sponsor: Naval Sea Systems Command

Objective: To develop a history of the evolution of the
                  standard missile family and to analyze the
                  management of systems engineering trade-offs of
                  the SM-1.

Summary: This effort was undertaken as part of the project
                  research effort by students in NPS Course SM 4301.
                  Starting with a history of the evolution of the
                  standard missile family, the research report
                  documents systems engineering trade-offs made
                  in the acquisition of the SM-1 version in the
                  areas of system effectiveness (reliability, main-
                  tainability, performance effectiveness), produc-
                  tion (producibility, environment, packaging),
                  logistic support (supportability, compatibility,
                  standardization, safety, human factors, operability,
                  performance capability and flexibility.

Publications: None

Title: Conceptual Phase Requirements Determination
                  Methodology and Its Application to the Advanced
                  Naval Gun System

Investigators: Melvin B. Kline, Professor of Administrative Sciences,
                  William C. Giauque, Assistant Professor of Adminis-
                  trative Sciences, and James P. Hynes, Associate
                  Professor of Administrative Sciences

Sponsor: Naval Sea Systems Command

Objectives: To assist the sponsors in the development of the
                  conceptual phase methodology to be used for
                  determining Advanced Naval Gun System requirements
                  and in structuring a decision analysis model to be
                  used for estimating military worth in terms of
                  threat, mission, and effectiveness parameters.

Summary: The Naval Postgraduate School (NPS) research effort
                  to date has been involved with three main areas of
                  concern. These are (1) development of the basic
                  conceptual phase methodology for ANGS, (2) develop-
                  ment of a threat analysis methodology to determine
                  weapon characteristics necessary to defeat enemy
                  threats and to establish a target classification
                  hierarchy to be used for establishing decision
                  criteria, and (3) review of the status of existing
                  warfare and damage models and their applicability
                  to the ANGS problem.

                  Accomplishments to date have been the following:
                  (1) a generalized conceptual phase methodology has
                  been developed leading from intelligence, opera-
                  tional need, and technological inputs to the de-
                  fining of a quantified operational requirement.
                  (2) An ANGS decision model derived from the basic
                  methodological model has been structured. (3) An
                  inventory has been made of existing damage models
                  and their applicability to strike warfare. As a
                  result of this examination it was discovered that
                  existing damage models start with a description of
                  the target and our weapon capability and determine
                  the damage that occurs when these are opposed in
                  combat. What is needed is the inverse of this,
                  i.e., given the target parameters and the damage
                  (mission kill) we would like to effect, what
                  weaponry does it take to effect this damage. In
                  other words, existing models flow from attack to
                  results, we want to go from desired results back
                  to weapon requirements. We have termed this an
                  "inverse damage model." (4) Development of a model
                  relating mission effectiveness to target damage to
                  kill mechanisms and finally to weapon payload re-
                  quirements has been started along with an example
                  of its application to a specific target--a bunker.

Conference
Presentations: William C. Giauque, "Conceptual Phase Require-
                  ments Determination Methodology and Its Applica-
                  tion to the Advanced Naval Gun System," Presented
                  at Military Operations Research Society, El Paso,
                  Texas, June 1976.

Publications: Melvin B. Kline, William C. Giauque, James P.
                  Hynes, "Conceptual Phase Requirements Determi-
                  nation Methodology and Its Application to the
                  Advanced Naval Gun System," Technical Report
                  NPS 55Kx75121, December 1975.

Title: Advanced Naval Gun System (ANGS) Studies

Investigators: M. B. Kline, Professor of Administrative Science,
W. C. Giauque, Assistant Professor of Administrative
Science, and J. P. Hynes, Associate Professor of
Administrative Science

Sponsor: Naval Sea Systems Command and Naval Surface Weapon
Center

Objective: To assist the sponsors in the development of the
conceptual phase methodology to be used for deter-
mining ANGS system requirements and in structuring
a decision analysis model to be used for estimating
the military worth in terms of threat, mission, and
effectiveness parameters. To assess the application
of the methodology to SIRLS.

Summary: The Naval Postgraduate School (NPS) research effort
to date has been involved with three main areas of
concern. These are (1) development of the basic
conceptual phase methodology for ANGS, (2) develop-
ment of a threat analysis methodology to determine
weapon characteristics necessary to defeat enemy
threats and to establish a target classification
hierarchy to be used for establishing decision
criteria, and (3) review of the status of existing
warfare and damage models and their applicability
to the ANGS problem.

Accomplishments to date have been the following:
(1) a generalized conceptual phase methodology
has been developed leading from intelligence,
operational need, and technological inputs to the
defining of a quantified operational requirement,
(2) ANGS decision model derived from the basic
methodological model has been structured, (3) an
inventory has been made of existing damage models
and their applicability to strike warfare. As a
result of this examination it was discovered that
existing damage models start with a description
of the target and our weapon capability and
determine the damage that occurs when these are
opposed in combat. We are looking for the inverse
of this, i.e., given the target parameters and the
damage (mission kill) we would like to effect,
what weaponry does it take to effect this damage.
In other words, existing models flow from attack
to results, we want to go from desired results
back to weapon requirements. We have termed this
an "inverse damage model," (4) development of a
model relating mission effectiveness to target
damage to kill mechanisms and finally to weapon

payload requirements has been started along with
an example of its application to a specific target.
It is recommended that the methodology be applied to
SIRLS.

Publications: Melvin B. Kline, William C. Giauque and James P.
Hynes, "Conceptual Phase Requirements Determination
Methodology and Its Application to the Advanced
Naval Gun System," Technical Report, NPS55Kx75121,
December 1975.

Title: Determination of Maximal Flows in Nonplanar
                    Networks by Using Dual Graphs

Investigator: Alan W. McMasters, Associate Professor,
                    Administrative Sciences Department

Sponsor: Foundation Research Program (6.2)

Objective: To develop a "dual graph" algorithm for
                    determining the maximal flows in a nonplanar
                    flow network having finite capacities on
                    the arcs. This is a continuing project.

Summary: The introduction of pseudo nodes at intersection
                    points of the arcs of a two-dimensional
                    projection of a nonplanar flow network allows
                    a dual graph to be constructed. The solution
                    to the primal flow problem can then be obtained
                    by solving for the shortest route through
                    the dual graph subject to special constraints
                    associated with dual arcs circumscribing
                    each pseudo node. These constraints, although
                    simple in form, are extremely difficult
                    to combine with the shortest route algorithm
                    to obtain a solution to the dual. An algorithm
                    has been proposed which appears promising
                    and proof of its validity is currently being
                    sought.

Publications: None

Title: Analysis of Program Structure and Error
                Characteristics

Investigators: N. F. Schneidewind, Professor of Administrative
                Science, G. T. Howard, Associate Professor of
                Operations Research

Sponsor: Naval Air Development Center

Objective: To determine the relationship between a computer
                program's structure and the amount of effort
                required in the testing phase of software develop-
                ment. In addition, a study is underway to identify
                program complexity measures which may be related
                to the ability to find errors in a program. This
                is a continuing project.

Summary: A simulation model was developed to explore the
                relationship between program structure and the
                error characteristics of computer software. The
                software is represented as a directed graph con-
                sisting of arcs (portions of software) and nodes
                (merging or branching points). A single test of
                the software is viewed as a traversal through the
                software from the input node until either an error
                is encountered or the terminal node is reached.
                The path taken by an arbitrary input is selected
                randomly in the simulation. The original place-
                ment of errors in the software can be random or
                user selected. When randomly placed, the number
                of errors in each arc is drawn from a Poisson
                distribution, the parameter being dependent on the
                arc length. Several measures of program complexity
                were considered and the number of errors detected
                versus the number of inputs was examined. The
                simulation model has been used to analyze the error
                characteristics of some NTDS programs for which
                error history is available.

Publications: G. H. Bradley, G. T. Howard, N. F. Schneidewind,
                T. F. Green, and G. W. Montgomery, "System Test
                Methodology," Vol. 1, Technical Reports, NPS55Ss75072A
                and Vol. II, NPS55Ss75072B, July 1975.

                G. H. Bradley, T. F. Green, G. T. Howard and N. F.
                Schneidewind, "Structure and Error Detection in
                Computer Software," Proceedings AIIE Conference,
                pp. 54-59, 1975.

                N. F. Schneidewind and T. F. Green, "Simulation of
                Error Detection in Computer Programs," Proceedings
                of the Symposium on the Simulation of Computer
                Systems, National Bureau of Standards, pp. 101-105,
                1975.

                T. F. Green, N. F. Schneidewind, G. T. Howard, and
                T. Pariseau, "Program Structures, Complexity and
                Error Characteristics," Proceedings of the Computer

Engineering Conference, Microwave Research
Institute, Polytechnic Institute of New York, 1976.

Title: A Study of Age and Race Related Attitudes To-
                ward Supervisory and Peer Leadership in the
                United States Navy

Investigator: John Senger, Professor of Administrative Sci-
                ences

Sponsor: Naval Personnel Research and Development Center

Objective: To determine if the attitudes of younger sailors
                are relatively more influenced by their peer
                (work) group than are older sailors, and to
                further ascertain if the individual's race
                also affects these attitudes. Results of the
                study could provide useful information relative
                to the supervision of younger sailors.

Summary: A review of the literature suggests the general
                hypothesis that the attitudes and perceptions
                of young people differ from those of their
                elders, particularly in relationship to their
                peers. To examine this hypothesis an attitude
                survey data for a large sample of Navy person-
                nel is being examined to determine if, indeed
                such differences do exist.

                From the data examined to date it appears that
                there is generally a steady increase in the
                positiveness of attitude toward peers and
                supervisors as age increases. This holds for
                survey attitude questions referring to both
                supervisors and peers. It was found that both
                older and younger sailors answer more positively
                the questions relating to supervisors than they
                do those relating to peers with the following
                exceptions: in those questions not relating
                to work, e.g., friendliness, listening, en-
                couragement of ideas, the younger sailor reacts
                more positively to his peer leadership than to
                his supervisory leadership. This trend is
                particularly marked among the youngest (17-20
                year old) group.

                Racial differences between Whites and Blacks
                show the Black attitudes to be consistently
                less positive than those of the Whites. This
                difference tends to decrease consistently
                with age, except among the 30-35 age group
                whose attitudes to be somewhat less positive
                than expected.

                There appears to be some evidence to support
                the hypothesis that the younger sailors'

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
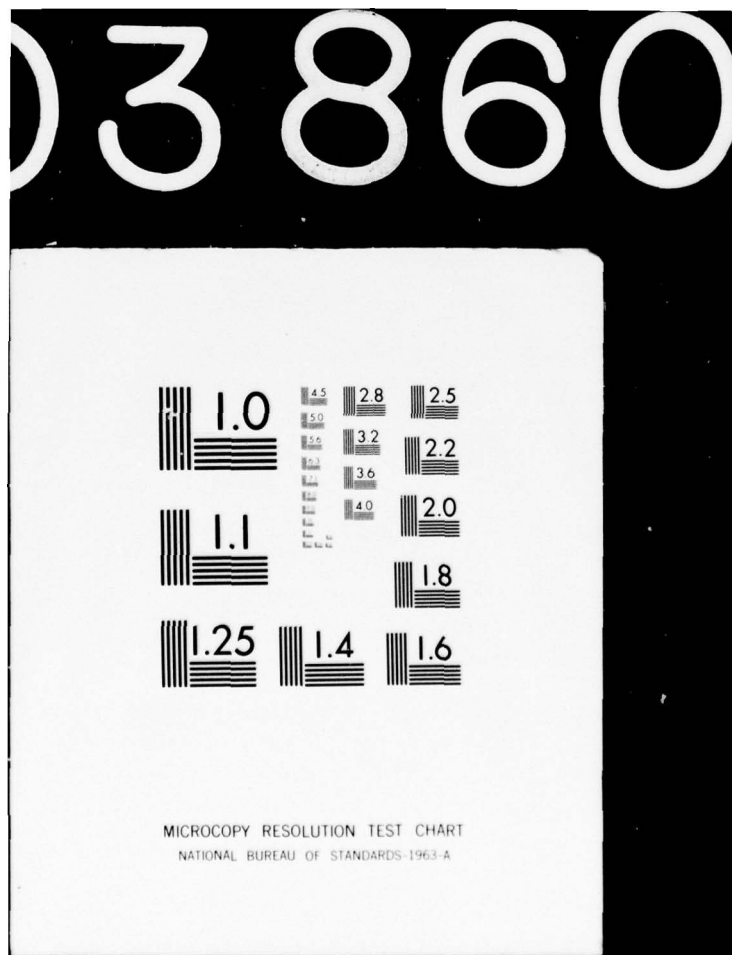
attitudes toward their peers differ from
those of older sailors.

Publications: None

Title: Occupational Structures and Methodologies

Investigator: R. A. Weitzman, Associate Professor of Administrative
                  Science

Sponsor: Naval Personnel Research and Development Center

Objective: To compare methods of selecting item sets that
                  maximize predictive validity (Part of a continuing
                  program).

Summary: Methods exist for the stepwise selection of binary
                  test (correct/incorrect) or biographical (yes/no)
                  items to maximize predictive validity. Sequin
                  (in which the predictor score is the total number
                  of correct answers to the selected items) and PAIN
                  (in which the predictor score for the pattern of
                  binary responses to the selected items) are
                  examples. This research will compare the efficiency
                  and effectiveness of sequin and pain as well as
                  other methods (already developed) on biographical
                  and test data obtained from Navy enlisted men.

Publications: None

Thesis   Jackson, J. Q., "A Programme for the Tailored
Directed: Selection of Response Patterns," Master's Thesis,
                  1976.

Title: Officer Career Continuance

Investigator: R. A. Weitzman, Associate Professor Administrative
                     Sciences
Sponsor: Naval Personnel Research and Development Center

Objective: To estimate retention probabilities for Naval
                     officers classified according to both commission
                     source and first and second billet assignments.

Summary: This research will prepare and apply a computer
                     program to the data on 16,000 Naval officers in
                     order to evaluate a method already developed for
                     achieving the objective described above when the
                     number of officers falling in specific three-way
                     classification cells may be too small for
                     reliable estimation by ordinary means.

Publications: None

Title: Superiority of Fit

Investigator: R.A. Weitzman, Associate Professor of Adminis-
                  trative Science

Sponsor: Naval Postgraduate School

Objective: To develop and illustrate a method for testing
                  the relative accuracy of different numerical
                  predictions.

Summary: Achievement of the objective described above
                  required reformulation of the traditional
                  structure of a statistical test. The method
                  developed is sequential and yields a decision in
                  favor of one prediction or the other with a
                  total probability of error specifiable in advance
                  of the test.

Publications: Weitzman, R. A., "Superiority of Fit," Technical
                  Report NPS54Wz76091, 1976.

Title: Pattern Analysis Applied to Retention Data: Comparison of PAIN and STRAIN

Investigator: R. A. Weitzman, Associate Professor, Administrative Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To develop STRAIN, which estimates pattern scores, and compare it with PAIN (already developed), which calculates pattern scores directly.

Summary: A "pattern score" is a score assigned to an individual who has a specific pattern of responses to a set of binary items. The acronyms PAIN and STRAIN stand for Pattern Analysis Item Nominator and STRuctural Analysis Item Nominator, respectively. The method of estimation used by STRAIN is to set mth- (and perhaps lower)-order covariances $E(X_1-M_1)(X_2-M_2)\ldots(X_m-M_m)$ among the binary items equal to zero. Different from PAIN, STRAIN can obtain estimates of pattern scores for response patterns that no member of the estimation sample has. The results, obtained from retention data on Navy enlisted men, suggest that these estimates may be quite reliable. Further research is necessary, however, to strengthen this conclusion.

Publications: None

Title: Analysis of Elements of the Military Health Care
                    Delivery System

Investigators: David Whipple, Associate Professor of Administrative
                    Science, Assistant Professor Carson Eoyang, Associate
                    Professor C. B. Derr, Assistant Professor K. L.
                    Terasawa, Associate Professor William Raike, Assistant
                    Professor Tom Wyatt,all of Administrative Science

Sponsor: Naval Bureau of Medicine and Surgery

Objective: To provide guidance to BUMED, and to the staff of
                   the newly instituted Planning, Programming and Analysis
                   Directorate (PPA) of the Bureau relevant to the
                   effective and efficient achievement of their stated
                   organizational objectives. Additionally, to the
                   extent feasible given the agreed upon budget and the
                   demands that timely response to the above tasks would
                   place upon the available NPS resources, we were to
                   identify and execute appropriate research projects
                   which would serve as inputs to the PPA agenda for
                   their future activities.

Summary: We may describe the substance of this effort under
                   three headings describing the different types of
                   effort involved:

                   1. The "management analysis" function which dominat-
                   ed efforts during these months of the contractual
                   relationship with BUMED. The major elements of this
                   vector include:

                   (a) The team Building Seminar held by the Study
                        Group for the entire PPA staff at Bethesda,
                        July 1975;

                   (b) The follow-up Conflict Management Workshop
                        held in Arlington, January 1976;

                   (c) The production of our "Quick and Dirty
                        Analysis of the Phase I Boeing Report" for
                        Code 023, (April 1975);

                   (d) Evaluation and input regarding the use and
                        value of Management by Objective (MBO) in
                        BUMED and PPA throughout 1975;

                   (e) Construction of a suggested set of "short
                        course" possibilities for PPA staff to be
                        given by Postgraduate School personnel;

                   (f) Provision of analysis, suggestions, and
                        evaluations of the Code 022 efforts to
                        develop the most appropriate Management
                        Information System (MIS) for BUMED under
                        PPA auspices;

(g) A Preliminary Analysis of the Military
Health Care Study (MHCS) report for
logical consistency, September 1975;

(h) Our in-depth analysis of the final version
of the MHCS report and our suggested
positive responses to it in terms of
possible changes in the management and
operational structure of the Navy's health
care delivery system, April 1976;

(i) Assistance in organizing the PPA/BUMED Long
Range Planning Session to be held in
Virginia in June, 1976.

2. Our more traditional research projects were
limited by the short run needs of PPA to the pro-
duction of the following reports:

(a) "On the Comparative Costing of Military vs
Civilian Models of Health Care Delivery,"
NPS Technical Report NPS55WpTc, by
Professors Whipple and Terasawa, November
1975;

(b) "Analytical Aspects of a Multi-Regional
Health care Voucher System," by Professors
Whipple and Terasawa, April 1976.

3. The support activities performed include the
monitoring of the dynamic literature and unpublished
suggestions of health care systems researchers per-
taining to the analysis and management of health care
delivery systems, public and private sector, and the
investigators and institutions involved. To this end
we initiated new, and maintained former, contacts with
those who may at present, or in the near future, be
able to provide direct assistance and ideas to pro-
jects upon which we may embark. Additionally, we,
in many instances,identified potential sources of
data and operational experiences in both the military
and private health care sectors, which we believe will
prove valuable in our work for BUMED.

Conference
Presentations: D. Whipple and K. Terasawa, "Analytical Properties
of A Multi-Regional Health Care Voucher System" pre-
sented at Eastern Economics Association Meetings,
April 1976, Bloomsburg, PA. and at the Mid-West
Regional Science Association Meetings, May 1976,
Bowling Green, Ohio.

D. Whipple, "Revolution vs. Evolution in Health Care Delivery," presented at Association for Humanistic Psychology Meeting, August 1975, Estes Park, Colorado.

D. Whipple and K. Terasawa, "On the Comparative Costing of Military vs. Civilian Models of Health Care Delivery," presented at NATO Conference on Systems Science in Health Care Delivery, July 1976, Paris, France.

Publications: None

Thesis
Directed:
W. C. Truesdell and M. S. Duny, "An Analysis of National Health Planning and Resource Development Act of 1974 and Its Impact on Health Care Delivery," Master's Thesis, June 1976.

Title: User Satisfaction Survey

Investigator: E. A. Zabrycki, LCDR, SC, USNR, Assistant Professor
                  of Administrative Sciences

Sponsor: Office of the Assistant Secretary of Defense

Objective: To develop, administer, and analyze the results
                  of a survey to measure the satisfaction of users
                  with the contract administration services pro-
                  vided by both the Defense Contract Administration
                  Services (DCAS) and Plant Cognizance activities.

Summary: In June 1975, the OASD (I&L) requested that a
                  study be performed to improve current contract
                  administration policies and procedures because of
                  the changing DOD procurement environment. There
                  were indications that manpower resources might be
                  more effectively used and greater demands and
                  responsibilities placed on the Defense contractors.
                  This research project was the third part of the
                  OASD (I&L) study. It involved the development
                  of a questionnaire which was determined as the best
                  method to efficiently sample a large number of
                  government buying activities. This approach per-
                  mitted identification of specific problem areas,
                  and provided a broad response of general attitudes
                  and opinions toward CAS services. Such an approach
                  also highlighted fundamental/recurring problems
                  in each functional area that could be characterized
                  as DOD-wide or service-intensive. With the
                  printing of 1,000 questionnaires, 274 were allocated
                  for each Service's buying offices and 130 question-
                  naires to the Defense Supply Agency (DSA) buying
                  acitvities. The 274 questionnaires for each
                  Service were distributed based on a proportion of
                  frequency they appeared on the contract adminis-
                  tration activities users' listings. The DSA
                  questionnaires were allocated to three DSA activi-
                  ties, DPSC, Philadelphia--60, DESC, Dayton--36, and
                  DCSC, Columbus--34. The percentage of return was
                  96.7%, and the large population sampled offers
                  confidence of the questionnaire results.

Summary of Survey Results

Functions	Performance Rating	
	DCAS Favorable	Service Cog. Favorable
Contract Administration	72%	79%
Production Management	67%	73%
Quality Assurance	64%	70%
Engineering Support	47%	56%

On satisfaction surveys of this type, a favorable performance rating of 70% or higher would be desirable to achieve adequate confidence to support an overall favorable response. The DOD procuring activities ratings of the four primary CAS functions indicated that the engineering support area received the least favorable user response; however, it also reflects that their overall confidence in CAS performance was low.

Recommendations: An informational device of this type be regularly employed to achieve better user feedback and improve CAS performance.

Certain traditional CAS tasks be performed by buying activities, particularly in areas of technical support and financial reporting.

Upgrade the CAS work force to cope with today's technology through a program of formal education and on-the-job training.

Establish a rotational/interchange program between DOD buying offices and Contract Administration activities for procurement personnel.

Publications: Department of Defense Study, "Forward Look," 23 November 1976.

Thesis Directed: Brian T. Hogan, Gary H. Monteith, "A Survey and Analysis of the Users' Evaluation of Contract Administration Services," Master's Thesis, June 1976.

DEPARTMENT OF OPERATIONS RESEARCH

Operations Research is a multi-disciplinary field, a fact which is reflected by the variety of areas covered by the sponsored research of the faculty. The topics can be grouped into the broad areas of basic research in the techniques of operations research and it's applications to military problems. The techniques are mathematical programming and stochastic modeling. The applications areas are computers and information processing, combat models, manpower and personnel, human factors and resource allocation.

MATHEMATICAL PROGRAMMING

Mathematical programming represents the major deterministic tool of operations research and the Naval Postgraduate School contributes to the profession through its basic research in the area.

Joint research by Professor Gordon Bradley and Professor Gerald Brown sponsored by the Office of Naval Research and of Professor Bradley by the National Science Foundation has led to the development of extremely fast mathematical programming codes which exploit the special structure of certain optimization problems. The researchers are now investigating application to problems of approximately one million variables.

Under foundation funding, Professor James Hartman has extended his previous work in non-linear, non-convex mathematical programming to include the case when roundoff errors are significant and also to include non-separable problems. Professor Gerald Brown has tested the GNET code developed above with a variety of network optimization problems with 20,000 equations and has added the capability to deal with fixed charges, non-linear costs and multi-commodity problems.

STOCHASTIC MODELING

The other major approach in Operations Research is probabilistic model building and statistical analysis. Several faculty contribute to this area.

Professor Donald Gaver, under National Science Foundation funding, has developed several models using a diffusion approximation technique for communication and computer systems and maintenance and repair systems. Professor James Esary has

continued his study of transformation techniques for analyzing networks of components which fail randomly. This work, under ONR support, led to his invitation to a major symposium on nuclear safety. Under foundation funding, Professor Harold Larson pursued development of optimal techniques for selecting the bias parameter in ridge regression, a new statistical technique.

Finally, Professor Peter Lewis derived properties for new stochastic point processes based on similarities to time series which he has previously examined. This work was supported by ONR.

COMBAT MODELS

The application of operations research to the development and employment of weapons reflects both the origin of the profession and the special role of the Naval Postgraduate School in the field.

Professor James Taylor has continued his fundamental studies of warfare via Lanchester-type differential equations and the optimization thereof for ONR. Several of his numerous publications won the yearly prize of the Military Applications Section of the Operations Research Society of America along with Professor Parry. Professor Sam Parry has been working directly with the Army Armor and Engineer Board on computer simulations of mobility's effect on tank survivability.

Professor Neagle Forrest has directed the Strategic Systems Project Office research program at the Naval Postgraduate School. In addition, he has produced programmable calculator routines for magnetic anamoly based on a new detection model for the Naval Air Development Center.

Search models for a moving target were developed by Professor Alan Washburn under foundation funding.

Professor Donald Barr developed models for evaluation of a Marine system for position locating.

HUMAN FACTORS

The application of operations research to man-machine systems is known as human factors study. The Human Factors Laboratory is a major resource for student thesis work as well as Navy research. Professor Gary Poock investigated aircraft accident factors for the Navy Safety Center. Additional work in that area under CDR L. E. Waldeisen was supported by the Naval Air Development Center.

COMPUTER AND INFORMATION PROCESSING

The computer has made possible large-scale examination of operational problems. Research in this area is of concern to several faculty.

Professor Donald Gaver has developed a model of the operating system of a multi-programming computer for the Defense Communication Agency.

Professor Gilbert Howard has cooperated with Professor Norman Schneidewind of the Administrative Sciences Department in studies of software reliability for the Naval Air Development Center.

Professor Bruno Shubert with Professor Gerald Brown has examined the structure of sorting and information retrieval processing under foundation funding.

MANPOWER AND PERSONNEL

The major cost of the U. S. military is for personnel. Planning and analysis of the personnel system is, therefore, of considerable interest.

Professors R. W. Butterworth, P. R. Milch and R. R. Read have developed interactive computer systems for analyzing Navy enlisted personnel data for the Bureau of Personnel. Related work for the Marine Corps has been carried out by Professor Kneale Marshall.

Professor Donald Gaver along with Professor William Giauque of the Administrative Sciences Department has pursued studies of the personnel retention system for the MARDAC organization of OSD.

Professor Robert Read, under foundation funding, has cooperated with Professor Richard Elster of the Administrative Sciences Department on a structure and data for describing Navy officer billets.

RESOURCE ALLOCATION

Many of the tools of operations research are applicable to the question of how to allocate resources in the military.

Professor Kneale Marshall was asked by the Chief of Naval Education and Training to devise indices for measurement of the training curricula of the Navy. He also worked with Professor

Russell Richards on modeling budget processes as queueing systems. Professor Richards has also devised inventory control procedures for the Naval Electronics Command.

Professor M. G. Sovereign has participated with Professor Jones of the Administrative Sciences Department in the ONR supported study of the impact of inflation on Navy budgeting. Professor Sovereign also directed the Conceptual Analysis Project supported by the Operations Research/Systems Analysis curriculum sponsor, OP-96.

Title: Statistical Models for Evaluating Position Location
                    Systems and Bombing Systems

Investigator: D. R. Barr, Professor of Operations Research

Sponsor: Naval Electronic Systems Command

Objective: To develop evaluation methodology and models for
                    use in assessing performance characteristics of
                    certain hardware systems being developed for use
                    by the Marine Corps.

Summary: Data obtained in tests of two PLRS (Position
                    Location and Reporting System) configurations at
                    Camp Pendleton, California, were analyzed. Some
                    characteristics of the two systems were determined,
                    including identification of factors significantly
                    affecting system errors. Methods of using the
                    TPQ-27 bombing system for radar bomb scoring were
                    investigated, and several problems requiring
                    further research were identified.

Conference   D. R. Barr and T. D. Burnett, "A Sequential Test
Presentation: Based on Sample Medians," Paper delivered at the
                    annual meeting of the American Statistical Asso-
                    ciation, Boston, Mass., August 1976.

Publications: D. R. Barr and T. D. Burnett, "A Radar Bomb
                    Scoring Method," Technical Report NPS55Bn76031,
                    March 1976.

Theses
Directed: W. Sevon, "An Analysis of the Position Location
                    and Reporting System's Performance Characteristics,"
                    Master's Thesis, March 1976.

                    T. Chen, "Relative Robustness of Several CEP
                    Estimators," Master's Thesis, March 1976.

Title: Large Scale Optimization in Network Models

Investigators: Gordon Bradley, Associate Professor of Operations Research, Gerald Brown, Associate Professor of Computer Science

Sponsor: Office of Naval Research

Objective: To extend the usefulness of highly efficient minimum cost pure network optimization systems by improving the mathematical treatment of the underlying algebraic theory. Data structures responsible for the efficiency of primal network codes such as GNET are not intrinsically suggested by the mathematical notation commonly used for optimization models. Development of a coherent mathematical context within which to view pure network models should lead naturally to generalization of network results to more complicated optimization models with imbedded networks, or other special problem structure.

Summary: The highly efficient network package GNET was extended to incorporate several new advances in data structures promoting the exploitation of special network structure. Two common examples with special structure are problems with many more sinks than sources, and pure transportation problems: The highly rectangular problems arise in production-distribution models with a few factories and many outlets, and transportation problems are a fundamental specialization of network distribution models. The new extensions to GNET (formerly the fastest code known) improved solution times by as much as 300 percent. In concert with the development of new data structures, the mathematical approach to primal networks was critically examined, and several fundamental theoretical results were derived with widely varying algebraic techniques. The usefulness of these alternate viewpoints was tested by implementation of several non-pure network applications with imbedded network structure. A nonlinear objective function was accommodated both by separable and local linearization methods. These two packages were used for solution of a goal programming model for (Army officer) personnel assignments. A version of GNET was provided as a subroutine for researchers developing optimization software for distribution system design with multiple commodities. One version of this system is now being used by the DOD Material Distribution System Study Group. The success of these, and other applications is due in part to the unprecedented economy and feasible problem sizes of these network codes. The network package GNET has been distributed to many universities and to several Federal agencies. Attention is now focused of solution of extremely large problems (in the one million variable range) and on further

development of more general models exploiting network substructure. This is a continuing research project.

Conference Presentations: G. Gradley, G. Brown and G. Graves, "A Comparison of Storage Structures for Primal Network Codes," presented at the Joint National Meeting of the Operations Research Society of America and the Institute for Management Sciences, Chicago, May 1975.

G. Bradley, G. Brown and G. Graves, "Tailoring Primal Network Codes to Classes of Problems with Common Structure," presented at the Joint National Meeting of ORSA/TIMS, Las Vegas, November 1975.

G. Bradley, G. Brown and G. Graves, "Surrogate Programming Approach to Solution of Large Scale Network Problems," presented at the Joint National Meeting of ORSA/TIMS, Philadelphia, March 1976.

Publications: G. Bradley, "Survey of Deterministic Networks," (Special Report) AIIE Transactions, 7, 3, September 1975.

G. Bradley, G. Brown and G. Graves, "GNET, A Primal Network Computer System for Solution of Capacitated Network Flow Problems," copyright 1975.

Thesis Directed: Y. P. Cheong, "Network Transformations and Some Applications," Master's Thesis, December 1975.

Title: Integer Linear Programming and Network Optimization

Investigator: Gordon H. Bradley, Associate Professor of Operations
                    Research

Sponsor: National Science Foundation

Objective: To investigate the algebraic structure of integer
                    linear programming problems and to develop algo-
                    rithms to compute optimal solutions to these
                    problems. To investigate algorithms to solve large
                    scale network optimization models including the
                    capacitated transshipment, transportation and
                    assignment problems.

Summary: Fixed order enumeration methods for integer linear
                    programming problems are simple and often effective
                    for solving practical size problems. This class of
                    algorithms can be improved by studying the structure
                    of the enumeration path as the algorithm proceeds.
                    Computational testing of these ideas has shown that
                    this approach can significantly improve performance
                    of the algorithms.

                    The capacitated transshipment, transportation and
                    assignment problems model many important defense
                    and commercial applications including the transport
                    of goods, assignment of personnel, and bid evalua-
                    tion. Data structures, algebraic and graph theoretic
                    methods were investigated for the efficient solution
                    of large-scale problems. For these network models an
                    extremely efficient algorithm was developed. The
                    results of this investigation were used to develop
                    a FORTRAN program for capacitated pure network
                    problems. Test results with problems with 10,000
                    nodes and 35,000 arcs show that the program is as
                    much as 50 times faster than commercial linear pro-
                    gramming algorithms. The copyrighted program is
                    available to other researchers and Department of
                    Defense agencies.

Conference
Presentations: G. Bradley, "Fixed Order Enumeration Methods," pre-
                    sented at the Joint National Meeting of ORSA/TIMS,
                    Las Vegas, November 1975.

                    G. Bradley, G. Brown and G. Graves, "A Comparison of
                    Storage Structures for Primal Network Codes,"
                    presented at the Joint National Meeting of the
                    Operations Research Society of America and the
                    Institute for Management Sciences, Chicago, May 1975.

                    G. Bradley, G. Brown and G. Graves, "Tailoring
                    Primal Network Codes to Classes of Problems with
                    Common Structure," presented at the Joint National
                    Meeting of ORSA/TIMS, Las Vegas, November 1975.

G. Bradley, G. Brown and G. Graves, "Surrogate Programming Approach to Solution of Large Scale Network Problems," presented at the Joint National Meeting of ORSA/TIMS, Philadelphia, March 1976.

Publications: G. Bradley, "Survey of Deterministic Networks," (Special Report) AIIE Transactions, 7, 3, September 1975.

G. Bradley, G. Brown and G. Graves, "GNET, A Primal Network Computer System for Solution of Capacitated Network Flow Problems," copyright 1975.

Theses Directed: Y. P. Cheong, "Network Transformations and Some Applications," Master's Thesis, December 1975.

J. J. Timar, "Modeling, Transformations and Scaling Decisions in Constrained Optimization Problems," Master's Thesis, March 1976.

R. J. Waterman, "An Evaluation and Comparison of Three Nonlinear Programming Codes,"Master's Thesis, March 1976.

Title: Navy Enlisted Personnel Modelling Project

Investigators: R. W. Butterworth, Paul R. Milch and Robert R.
                    Read, Associate Professors and Professor of
                    Operations Research

Sponsor: Naval Personnel Research and Development Center
                    and Bureau of Naval Personnel

Objective: To improve existing management tools, and to
                    introduce new tools, for the Navy's enlisted
                    personnel system. Specific objectives were
                    concentrated on the Navy's FAST model for strength
                    and advancement planning, namely evaluating po-
                    tential improvements in this model, and developing
                    alternate models to augment the Navy's capability
                    in this area.

Summary: The advancement process for the enlisted Navy was
                    studied in order to understand how this process
                    might be better modelled. This task was done to
                    support the Navy's FAST model. Preliminary data
                    analysis of the promotion process historically
                    has indicated a wide variation in practices,
                    year to year.

                    A modified regression model was found to be suf-
                    ficiently accurate to predict advancements by LOS
                    using the volume of advancements and the inventory
                    by LOS as predictor variables. This model was
                    then used to find a relationship between the mean
                    LOS of advancements and the volume of advancements.
                    Such relationship was not readily verifiable from
                    the data. Somewhat contrary to expectation, it
                    was found that the mean LOS of advancements may be
                    either a decreasing or an increasing function of
                    volume. Whether it is the former or the latter
                    depends on the pay grade, rating and fiscal year
                    in question. A possible explanation for both the
                    decreasing and increasing type of behavior is also
                    offered.

                    An interactive personnel planning model, MINIFAST,
                    was formulated, coded, and delivered for
                    operational testing and evaluation. The model,
                    beginning with the selection of a subject rating,
                    calculates an estimate of the yearly gains and
                    losses of personnel, the promotions within, and
                    the new recruits to the rating. A policy affecting
                    the personnel system can be quickly evaluated for
                    its effect on overages and shortages of personnel,
                    its effect on the advancement system, and the need
                    for new personnel, for multiple years in the future.

Thus MINIFAST is an interactive planning model for rapid policy evaluation.

A preliminary investigation of ridge regression as a technique for predicting personnel system losses and gains was completed, and a further study is now scheduled.

Publications: Richard W. Butterworth, "Minifast, An Interactive Model of the Navy's Enlisted Personnel System," Technical Report, NPS-55Bd76081, August 1976.

Thesis   A. R. Walker, "An Analysis of the Naval Personnel
Directed: Pay Predictor (Enlisted Model) A Basic Pay Projection Model," Master's Thesis, September 1975.

Title: Probability Models for Reliability Analysis

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

Sponsor: Office of Naval Research

Objective: To refine and develop the probability models
                    which are the basis for practical methods of
                    reliability analysis and prediction.

Summary: Phased Missions: In a phased mission the
                    pertinent system configuration (block diagram,
                    fault tree, etc.) changes as the mission proceeds
                    through a sequence of distinct phases (periods in
                    which the operational requirements on the system
                    and possibly the stresses on its components are
                    different). Computing the probability of success
                    for a phased mission is more complex than doing a
                    series of standard reliability calculations, one
                    for each phase. A principal result previously ob-
                    tained is a transformation which makes the
                    analysis of a phased mission equivalent to the
                    analysis of a single-phase mission, so that (at
                    least in principal) existing computer programs
                    can be used. The transformation has been used to
                    study various approximations to the probability of
                    mission success.

                    Subsequent work has included provision in the
                    analysis of phased missions for an "operational
                    readiness" phase, i.e. a phase of uncertain
                    duration prior to the inception of the active
                    mission in which maintenance can be performed.
                    Phased missions with phased sub-missions branching
                    away from the main mission trunk have also been
                    considered. The mission of an FBM submarine has
                    "operational readiness" and branching sub-mission
                    aspects.

                    The methods are being applied to reactor safety
                    systems by the Aerojet Nuclear Company under an
                    ERDA contract.

                    Mixtures of Life Distributions: Mixtures of life
                    distributions arise when manufacturing processes
                    produce items with different innate survival po-
                    tentials, or when the service environments of
                    identical items vary. The properties of mixtures
                    of life distributions are relevant to the use of
                    "burn-in" as a quality control measure. This
                    study has presumed an initial population of
                    devices with constant failure rates, and has
                    focussed on the composition of the population of
                    survivors after a period of service or burn-in.

The principal results have been a strong technical interpretation of how the "fittest" items survive. These results contain some previously known properties of such mixtures.

Recent work has been concerned with the effect of improving the initial population mixture on the mixture to be found in the populations of survivors. A kind of improvement that does persist has been found. Others prove to be surprisingly transient.

Publications: J. D. Esary and H. Ziehms, "Reliability Analysis for Phased Missions." Edited by R. E. Barlow, J. B. Fussell, and N. D. Singpurwalla, published by the Society for Industrial and Applied Mathematics, 1975.

H. Ziehms, "Approximations to the Reliability of Phased Missions," Technical Report, NPS55Ey75091, September 1975.

M. G. Bell, "Multi-Phase-Mission Reliability of Maintained Standby Systems," Technical Report NPS55Ey75121, December 1975.

Thesis
Directed: M. G. Bell, "Multi-Phase-Mission Reliability of Maintained Systems," Doctoral Dissertation, December 1975.

Title: Naval Effectiveness and Vulnerability Studies

Investigators: R. N. Forrest, J. D. Esary, B. O. Shubert, R. H.
                Shudde, and A. R. Washburn, Professors of Opera-
                tions Research

Sponsor: Department of the Navy

Objective: To develop and improve specific Navy effectiveness
                and vulnerability models.

Summary: This work dealt with the following subjects: Phased
                Mission Reliability: In a phased mission, the
                relevant system configuration changes during conse-
                cutive time periods (phases). Several important
                Navy systems are required to perform phased missions
                for which reliability considerations are significant.
                Search Detection and Localization Modeling: Work
                was done on the problem of analytically modeling
                submarine search detection, and localization.
                Attention was given to non-acoustic sensors.

Publications: B. O. Shubert, "Modeling a Random Search", Technical
                Report NPS 55SY 75071, July 1975.

                R. N. Forrest, "A Submarine Magnetic Anomaly Signal
                Model with Programs for A Hewlett-Packard 65 Calcu-
                lator", Technical Report NPS 55Fo 75101, October 1975.

                M. G. Bell, "Multi-Phase-Mission Reliability of
                Maintained Standby Systems", Technical Report
                NPS 55EY 75121, December 1975.

                R. H. Shudde, "Nonsymmetric Ballistic Range, Height,
                Time-of-Flight and Optimal Flight Path Angle Compu-
                tations with Programs for a Hewlett-Packard 65
                Calculator", Technical Report NPS 55Su 76031, March
                1976.

Title: Magnetic Anomaly Detection Studies

Investigators: R. N. Forrest, Associate Professor of Operations Research and G. L. Sackman, Associate Professor of Electrical Engineering

Sponsor: Naval Air Development Center

Objective: To analyze and model magnetic noise and magnetic anomaly detection and localization systems.

Summary: This work dealt with the following subjects:

Geologic Magnetic Noise: Space-dependent geologic magnetic noise sources contribute to the magnetic noise background of magnetic anomaly detection and localization systems. A geologic magnetic noise model has been constructed for use in the development and evaluation of automatic signal detection algorithms. Experimental validation of the model is currently underway.

Magnetic Anomaly Detection Models: An evaluation of proposed magnetic anomaly detection systems can be based in part on magnetic anomaly detection models. A detection model which describes a magnetometer detection system has been developed for this purpose. A model which describes a gradiometer system is to be developed.

Publications: R. N. Forrest, "A Magnetic Anomaly Signal Model with Programs for a Texas Instruments SR-52 Calculator, Technical Report NPS 55Fo76021, February 1976.

Theses Directed: W. F. Burdick and J. J. Sheridan, "Modeling Geologic Noise for MAD Applications,"Master's Thesis, March 1976.

J. L. Harford and P. L. Reed, "A Comparison of the Signals Received by a Magnetometer Mounted on an Aircraft Flying Circular Patterns Versus Straight Line Paths," Master's Thesis, March 1976.

D. A. Pignotti and T. P. Winters, "A Feasibility Study for a Magnetic Anomaly Detection (MAD) Test Range," Master's Thesis, March 1976.

Title: Sensitivity of Gordon and Newell, and Buzen
                       Models of Computer Configurations

Investigator: D. P. Gaver, Professor of Operations Research

Sponsor: Defense Communications Agency

Objective: To test the sensitivity of the GNB model of
                       computer operation by comparison to a new model
                       with different properties.

Summary: A probability model has been developed to
                       describe the flow of programs of two types
                       through a multiprogramming computer (CPU and
                       peripherals). The model is solved numerically,
                       using a variation of the Gauss-Seidel iteration
                       technique. A program that carries out this
                       program, and computer system measures of
                       effectiveness (system element utilizations, queue
                       lengths) has been written and submitted to the
                       sponsor.

Conference   D. P. Gaver, "Sensitivity of Gordon and Newell,
Presentations: and Buzen Models of Computer Configurations,"
                       presented, by invitation, at the International
                       Symposium on Computer Performance Modeling,
                       Measurement, and Evaluation, Harvard University,
                       March 1976.

Title: Stochastic Systems Analysis and Modelling

Investigator: D. P. Gaver, Professor of Operations Research

Sponsor: National Science Foundation

Objective: To develop realistic stochastic (probability)
                     modelling techniques that are capable of yielding
                     numerical results in a variety of applied areas.

Summary: Several models have been developed, using a
                     diffusion approximation technique, communications
                     systems, time-shared computing systems, maintenance
                     and repair systems, and pharmacokinetic (compart-
                     ment) systems. Papers have been prepared, and are
                     in the process of being published.

Publications: D.P. Gaver, "Probability Models in Logistics,"
                     Chap. 12 of Modern Trends in Logistics Research.
                     Proc. of a conference sponsored by ONR, ed. by
                     W. H. Marlow, published by MIT Press, 1976.

                     D.P. Gaver and G. Humfeld, "Multitype Multi-
                     programming: Probability Models and Numerical
                     Procedures." Proc. of the Int. Symp. on Computer
                     Performance Modelling, Measurement, and Evalua-
                     tion; Harvard University, Cambridge, Mass., March
                     1976.

Title: Global Optimization of Nonlinear Programming
                Problems

Investigator: J. K. Hartman, Associate Professor, Operations
                Research Department

Sponsor: Foundation Research Program (6.1)

Objective: To continue investigation of a class of
                linear approximating problems for nonconvex
                nonlinear programs.

Summary: In previous work the "Grid Linearization"
                algorithm for nonlinear optimization was
                extended to apply to separable nonconvex
                nonlinear programming problems.
                    Current research has focused on the
                properties of the method when roundoff errors
                are present in the computations and has
                resulted in an approximate optimality theorem
                in these circumstances.
                    A related effort has formally extended
                the method to nonseparable nonconvex problems.
                Although the mathematics of the nonseparable
                case is straightforward, it is believed
                that the method would be very difficult
                to use computationally.

Publications: J. K. Hartman, "Extension of the Grid Lineariza-
                tion Algorithm for Convex Optimization to
                Nonconvex Nonlinear Programs," Technical
                Report NPS55Hh75071, July 1975.

                J. K. Hartman, "Epsilon Optimality for a
                Global Optimization Algorithm," Technical
                Report NPS55Hh75121, December 1975.

                J. K. Hartman, "A Branch & Bound Method
                for Nonseparable Nonconvex Optimization,"
                Technical Report NPS55Hh75102, October 1975.

Title: Ridge Regression

Investigator: H. J. Larson, Professor, Operations Research
Department

Sponsor: Foundation Research Program (6.1)

Objective: To review the current literature and examine
the distribution of the ridge regression
estimator over repeated samples.

Summary: Ridge regression is a subjective biased estimation
technique whidh seems to give more sensible
numerical estimates of unknown regression
parameters than does ordinary least squares,
in certain circumstances. A study was made
of the variations on ridge regression described
in the literature, and their applications.
Some properties of an iterative Bayesian
ridge regression estimation technique were
derived. Several procedures for getting
the distribution of the ridge estimator,
over repeated samples, were investigated.
None of these leads to simple methods of
comparing the classical properties of ordinary
least squares estimators with those of ridge
estimators.

Publications: None

Theses Directed:

E. B. Lewis, "An Investigation of the Probability
Distribution of the Ridge Regression Estimator
for Linear Models," Master's Thesis, March
1976.

Title: Manpower Planning and Budgeting Models

Investigator: K. T. Marshall, Professor of Operations Research

Sponsor: Headquarters Marine Corps and Navy Personnel
                Research and Development Center

Objective: To continue previous studies in manpower policy
                planning with emphasis on on-line interactive
                computer models.

Summary: Two areas were emphasized, a) enlisted force
                year-end strength planning and forecasting under
                alternative recruitment policies and budget con-
                straints, and b) officer force structure planning,
                with determination of promotion policies and budget
                requirements. The theory of manpower modelling
                progressed simultaneously and is published in the
                following reports. A book, entitled "Manpower
                Planning Models," is to appear in January 1977.

Publications: K. T. Marshall and R. C. Grinold, "Manpower Plan-
                ning Models - III, Longitudinal Models," Technical
                Report NPS55Mt75081, August 1975.

                K. T. Marshall and R. C. Grinold, "Manpower Planning
                Models - IV, Snythesis of Cross-sectional and
                Longitudinal Models," Technical Report NPS55Mt75111,
                November 1975.

                K. T. Marshall and R. C. Grinold, "Manpower Planning
                Models - V, Optimization Models," Technical Report
                NPS55Mt75101, October 1975.

Title: CNET Efficiency Indicators

Investigator: K. T. Marshall, Professor of Operations Research

Sponsor: Chief of Naval Education and Training

Objective: To investigate and develop certain indicators of education and training efficiency for use by CNET staff for internal management.

Summary: The use of economic-type indicators, such as the Laspoyeres, Paasch and Fisher Indices, by CNET for internal monitoring of their education and training operations was investigated. Their use was demonstrated using data from SSC San Diego. It is expected that these preliminary studies will be continued.

Publications: None

Title: Analysis of Discrete Time Resource Allocation
                    Policies with Applications to Budgeting

Investigators: K. T. Marshall, Professor, and F. R. Richards,
                    Associate Professor, Operations Research

Sponsor: Foundation Research Program (6.1)

Objective: To analyze the stochastic properties of
                    the sequence of deficits produced over time
                    with various budgeting policies which lead
                    to correlated supplies and demands. Such
                    policies are commonly observed in government
                    budgeting procedures.

Summary: A set of policies in which current and future
                    budgets are determined as convex linear
                    combinations of past demands was postulated,
                    and the properties of the resulting deficits
                    and surpluses were determined. The sequence
                    of deficits was shown to be related to the
                    sequence of waiting times in a single-channel
                    queue. However, the usual assumptions of
                    independence made for queueing systems are
                    unrealistic in the context of many resource
                    allocation problems. Our results show that
                    certain strongly correlated systems can
                    be analyzed. Our results have applications
                    in correlated queueing systems as well as
                    a wide variety of resource allocation problems.

Publications: K. T. Marshall and F. R. Richards, "Analysis
                    of Deficits in Discrete Time Resource Allocation
                    Problems with Correlated Supplies and Demands,"
                    Technical Report NPS55MtRh76051, May 1976.

Conference
Presentations: K. T. Marshall, "Analysis of Deficits and
                    Surpluses Under Various Budgeting Policies
                    with Relation to Queueing and Scheduling
                    Problems," presented to Operations Research
                    Seminar Series at Bell Telephone Laboratories,
                    Holmdel, New Jersey, March 1976.

Title: Analysis of Mobility, Agility and Survivability in the Land of Combat Environment

Investigator: Samuel H. Parry, Assistant Professor of Operations Research

Sponsor: U. S. Army Armor and Engineer Board

Objective: To assist in the experimental design and analysis of the S-Tank Agility/Survivability Test conducted at Fort Knox in 1975-76. To determine the relationship between apparent target motion parameters and gunner performance variables. This is a continuing project leading into the High Mobility/ Agility Vehicle Test scheduled for 1977.

Summary: One of the most important questions being posed by the Armor community today is "What is the effect of mobility and agility on tank survivability on the battlefield?" The overall goal of this continuing research is to formulate a viable quantification of mobility and agility that can be directly related to induced tracking errors (and hence to probability of hit).

The data base for this research consists of approximately 1500 trials utilizing four fire vehicles, seven target vehicles, three courses, five maneuvers, and two test sites. At this time, data reduction has been accomplished for approximately 300 trials. The investigator formulated a split plot design for conducting analysis of variance (reference 1 under Publications). Programs were developed to determine apparent target motion profiles for each trial in a variety of modes (references 1, 2, 3). Several statistical techniques, such as partial correlation, canonical correlation, factor analysis, and multiple regression are being employed to determine the relationship between gunner errors and target motion parameters. Preliminary analysis indicates that significant positive correlation exists between apparent velocity and tracking errors. The relationships between apparent acceleration, aspect rate of change, and tracking performance are unclear at this time.

It is anticipated that data analysis from the STAGS Test will be completed by November 1976. These results will be instrumental in the design of the subsequent High Mobility/Agility Test to be conducted in 1977.

Publications: Parry, Samuel H., "Studies of Mobility, Agility, and Survivability in the Land Combat Environment," Technical Report NPS-55Py75091, September 1975.

Parry, Samuel H., "Land Combat Studies, Task Order No. 76-148," Battelle Columbus Labs, Durham, N. C., December 1975.

Parry, Samuel H., "The Effects of Apparent Target Motion of Battlefield Survivability, Task Order No. 76-0059," Battelle Columbus Labs, Durham, N. C., June 1976.

Title:	An Investigation of the Causes of Increased Major Aircraft Accidents in Specific Months
Investigator:	G. K. Poock, Associate Professor of Operations Research
Sponsor:	Naval Safety Center
Objective:	To identify reasons, if any, for high major aircraft accident rates in some months of the year versus other months.
Summary:	In FY 76, the main effort was devoted to analysis of data by specific command and by specific type of aircraft. There appear to be no specified trends in either commands or aircraft types.
Publications:	G. K. Poock, "Trends in Major Aircraft Accident Rates," Technical Report NPS 55PK76061, June 1976. G. K. Poock, "Factors Involved in the Variability of Monthly Major Aircraft Accident Rates," Technical Report NPS 55PK76071, July 1976.
Theses Directed:	J. S. Maxwell and L. V. Stucki, "Analysis of the Variable Behavior Manifested in all Navy/Marine Major Aircraft Accident Rates," Master's Thesis, September 1975. G. F. Johnson, "Analysis of U.S. Navy Major Aircraft Accident Rates by Aircraft Type," Master's Thesis, September 1976. L. C. Bucher, "Analysis of U.S. Navy Aircraft Accident Rates in Major Aviation Commands," Master's Thesis, September 1976.

Title: Conceptual Analysis Program

Investigators: M. G. Sovereign, D. R. Whipple and M. K. Block,
                      Associate Professors of Operations Research and
                      Administrative Sciences

Sponsor: Chief of Naval Operations

Objective: To introduce faculty members to CNO level problems
                      and provide conceptual approaches to analysis of
                      these problems.

Summary: This year the program's major effort was continu-
                      ation of the previous year's work on the study of
                      the military health care system. In particular,
                      data was analyzed to determine the factors which
                      determine the supply of physicians to the military.
                      This work was done by Professors Whipple and Block.
                      A smaller effort on costing was undertaken by
                      Professor Sovereign.

Publications: M. G. Sovereign, "A Conceptual Model for Setting
                      Design-to-Cost Goals." Proceedings of the 37th
                      MORS, July 1976.

Title: Optimal Fire-Support Strategies

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

Sponsor: Office of Naval Research

Objective: To develop methodology for determining the optimal time-sequential fire-support allocation policy in several situations of tactical interest and to examine its dependence on such factors as the model of combat dynamics, quantification of combatant objectives, and battle termination conditions (i.e. unit breakpoints). Attention to be also given to modelling the combat attrition process and extracting information from such models (e.g. solving the associated Lanchester-Type equations for warfare).

Summary: The reporting of previously obtained results on optimal fire-support strategies was completed. In this previous work, deterministic optimal control theory was used to study the structure of optimal fire-support policies for some time-sequential tactical allocation problems with combat described by Lanchester-type equations of warfare. Numerous specific problems for determining optimal time-sequential fire-distribution policies for supporting weapon systems were studied. A sequence of the one-sided time-sequential tactical allocation problems was examined to study how the optimal fire-support policy depends on the nature of the combat model (in particular, maneuver element interactions). The modelling of the suppressive effects of supporting weapons and their inclusion in such allocation optimization problems were considered briefly. The dependence of the structure of optimal time-sequential fire-support policies on the quantification of military objectives was examined. The splitting of supporting fires between enemy units in an optimal policy was shown to depend on whether the objective is to attain an "overall" military advantage or a "local" advantage.

Additionally, some new work was done on obtaining insights into the dynamics of combat between two homogeneous forces modelled by Lanchester-type equations of modern warfare with time-dependent attrition-rate coefficients. It was shown that much new information about such models could be obtained by considering Liouville's normal form for X and Y force-level equations. New victory-prediction conditions that allow one to forecast the battle's outcome without explicitly solving the deterministic combat equations and computing

force-level trajectories were developed for *fixed-force-ratio-breakpoint* battles. These particular victory-prediction conditions involve only the initial force ratio and simple algebraic functions of the attrition-rate coefficients and their derivatives, whereas other such results of the author have involved higher transcendental functions. An important new canonical set of functions for solving Lanchester-type equations of modern warfare for combat between two homogeneous forces with power attrition-rate coefficients with "no offset" was developed. Tabulations of these functions, which we call Lanchester-Clifford-Schläfli functions, allow one to study this particular variable-coefficient combat model almost as easily and thoroughly as Lanchester's classic constant-coefficient one.

Publications: J. G. Taylor, "Optimal Fire-Support Strategies," Technical Report NPS 55 Tw 76021, February 1976.

Title: Study of Variable-Coefficient Lanchester-
                Type Equations of Warfare

Investigator: J. G. Taylor, Associate Professor, Operations
                Research Department

Sponsor: Foundation Research Program (6.1)

Objective: To extend the state-of-the-art for developing
                and analyzing solutions to Lanchester-type
                equations of warfare in order to develop
                insights into the dynamics of combat (by
                explicitly showing the dependence of combatant
                force levels on the physical parameters of
                the combat attrition process and on initial
                conditions) and also in order to facilitate
                sensitivity and other parametric analyses.
                In particular, a specific objective is to
                develop techniques for predicting the outcome
                (e.g., force annihilation) in variable-coefficient
                Lanchester-type combat from initial conditions
                without explicitly solving the attrition
                equations.

Summary: A mathematical theory was developed for predict-
                ing force annihilation from initial conditions
                without having to explicitly compute force-
                level trajectories for Lanchester-type equations
                of modern warfare for combat between two
                homogeneous forces with temporal variations
                in fire effectivenesses. It was shown that
                prediction of force annihilation involves
                a single parity-condition parameter, which
                depends on only the model's attrition-rate
                coefficients. A canonical auxiliary parity-
                condition problem was introduced for determining
                this parity-condition parameter. Further
                research was performed on constructing the
                solution to variable-coefficient Lanchester-
                type equations of modern warfare from so-
                called hyperbolic-like general Lanchester
                functions. The force-annihilation results
                provided further information about the mathematical
                properties of these Lanchester functions.
                Important new results were obtained on how
                the parity-condition parameter depends on
                the intensity of combat and the relative
                fire effectiveness of the combatants. Approximate
                solutions were also examined, and new error
                bounds were developed for the Liouville-Green
                approximation to initial-value problems.

This research also developed new "simple" victory-prediction conditions for two Lanchester-type models, one linear and the other nonlinear, of combat between two homogeneous forces with superimposed effects of supporting weapons not subject to attrition. These simple victory-prediction conditions involve only the initial conditions of battle and certain assumptions about the nature of temporal variations in the attrition-rate coefficients. They were developed for fixed-force-ratio-breakpoint battles by studying the force-ratio equation for the linear combat model. The inadequacy of previous victory-prediction results was explained by examining (for the linear combat model without the supporting fires) new "exact" victory-prediction conditions, which show that even the range of possible battle outcomes may be significantly different for variable-coefficient and constant-coefficient models.

Previous results on the optimal allocation of military resources to battle and associated optimization theory were revised for publication. For example, the committing of forces to battle was examined as a mathematical programming problem. It was shown that one can determine whether or not it is "beneficial" for the victor to initially commit his entire force by considering the instantaneous force-change ratio for Lanchester-type combat equations.

Publications: J. G. Taylor and C. Comstock, "Force-Annihilation Conditions for Variable-Coefficient Lanchester-Type Equations of Modern Warfare, I: Mathematical Theory," Technical Report NPS55Tw76081, August 1976.

Conference Presentations:

G. G. Brown and J. G. Taylor, "An Examination of the Effects of the Criterion Functional on Optimal Fire-Support Policies," Operations Research Society of America and The Institute of Management Sciences (ORSA/TIMS) Joint National Meeting, Las Vegas, Nevada, November 1975.

G. G. Brown and J. G. Taylor, "Canonical Methods in the Solution of Variable-Coefficient Lanchester-Type Equations of Modern Warfare," ORSA/TIMS Joint National Meeting, Las Vegas, Nevada, November 1975.

J. G. Taylor, "On the Relationship Between the Force Ratio and the Instantaneous Casualty-Exchange Ratio for Some Lanchester-Type Models of Warfare," ORSA/TIMS Joint National Meeting, Philadelphia, PA, April 1976.

Theses Directed:

J. Craig, "The Effect of Uncertainty on Lanchester-Type Equations of Combat," Master's Thesis, 1975.

B. G. Baskerville, "The Significant Parameters Affecting the Modeling of Target Acquisition of Ground Combat Targets from Tactical Helicopters," Master's Thesis, 1976.

D. W. Brewer, "A Parametric Analysis of the Dismounted Final Assault," Master's Thesis, 1976.

J. N. Carpenter, "A Numerical Evaluation of the Liouville-Green Approximation of Variable-Coefficient Lanchester-Type Equations of Modern Warfare," Master's Thesis, 1976.

Y. Lee and Y. Pi, "The Estimation of Lanchester Attrition-Rate Coefficients for an Aggregated Combat Model," Master's Thesis, 1976.

R. A. Martray, "Development of an Aggregated Lanchester-Type Combat Model for the Evaluation of Air-War Allocation Strategies in a Theater Sector," Master's Thesis, 1976.

Title: Cost Effectiveness Considerations for Navy Harbor Spill Removal/Recovery Program

Investigators: Marlin Thomas, Associate Professor of Operations Research, Alan McMasters, Associate Professor of Administrative Sciences

Sponsor: Naval Facilities Engineering Command

Objective: To review the operations engineering considerations and to assist NAVFAC in the technical evaluation phase for the Harbor Oil Spill Removal/Recovery System Development Program. This is a continuing project.

Summary: A working conference on cost effectiveness of harbor oil spill removal/recovery systems was held at the Naval Postgraduate School on 3 and 4 November 1975. Specifically addressed were the defining of expected mission profiles for systems operational scenarios for the technical evaluation occurring in March, 1976, and performance capabilities and environmental goals, and the identifying of alternative systems.

A cost effectiveness analysis was conducted on oil containment boom which made use of life cycle performance data obtained from approximately twenty Naval facilities. This data allowed estimates to be made on equipment useful lifetime as a function of the levels of maintenance costs and oil spill business. A report to the sponsor is being prepared.

Publications: None

Title: On Search for a Diffusing Target

Investigator: Alan R. Washburn, Associate Professor of Operations Research

Sponsor: Department of the Navy

Objective: To provide guidelines for the distribution of search effort when the target being sought is itself moving.

Summary: It is known that a modification of the heat equation describes the density function of the position of a target moving about randomly. By employing the adjoint equation, a necessary condition for a search to be optimal is found, as well as a computational technique for finding a locally optimal search plan.

Publications: None

DEPARTMENT OF NATIONAL SECURITY AFFAIRS

The Department of National Security Affairs has expanded the research program during the past 1976 Academic Year in sponsored and unsponsored programs. These programs are directed to research investigations concerning national and international security affairs, strategic planning, and naval intelligence. Some of the research projects underway provide the foundation for additional research by individual students with thesis requirements.

Among the categories of competence and interest, investigations are pursued in the following general areas: U. S. national security interests and problems in the Middle East, Soviet Union, Western Europe, or Asia; military escalation in international conflict; politico/military decision-making; methodology for forecasting technological threat; military balances, and measuring perceptions about them; data analysis in national security policymaking; the presidency and national security; and the course of U.S. decisions.

It is noteworthy that the majority of both sponsored and unsponsored projects result in publication. Project sponsors include the Naval Intelligence Command, the Technology Assessment Office, OSD, OJCS, Plans and Policy Division, Naval Intelligence Support Center, U. S. Army, Ballistic Research Laboratory, Office of Defense Research and Engineering, and the Hoover Institution on War, Revolution, and Peace. The national stature of project sponsors, the technical research expertise of faculty, and published documentation of completed projects are indicative of the continuing expansion in research endeavors in the Department of National Security Affairs.

Title: The October War: A Study in the Politics of
                    Escalation

Investigator: John W. Amos, II, Assistant Professor of National
                    Security Affairs

Sponsor: Naval Intelligence Command

Objective: To analyze the factors correlated with military
                    escalation in the Arab/Israeli conflict.

Summary: Revised version of the original study prepared
                    for NAVINTCOM. A comparison of the factors
                    leading to the 1967 and 1973 Wars; and analysis
                    of Arab strategy, training, and tactical doctrines;
                    a summary of factors effecting Arab politico/
                    military decision-making. Draws extensively on
                    Arab world sources. Includes a series of esca-
                    lation scenarios. (377 pages & appendix).

Publications: None

Title: The Middle East: The Problem of Quarantine

Investigator: John W. Amos, II, Assistant Professor of National
                  Security Affairs

Sponsor: None

Objective: Analysis of U.S. national security interests and
                  problems in the Middle East.

Summary: Statement of U.S. interests in the Middle East;
                  summary of the problems involved in securing
                  these interests; examination of several alternative
                  strategies available to U.S. policy-makers.
                  Analysis is set against the background of post-1973
                  changes within the Arab world, and in the relative
                  positions of the U.S. and U.S.S.R. in the area.

Publication: J. W. Amos, "Foreign Policy and U.S. National
                  Security: Major Post-Election Issues," Published
                  as a chapter in: William W. Whitson, ed., Praeger
                  Publishers, Inc., 1976.

Title:	The United States and the Philippines
Investigator:	Claude A. Buss, Professor of National Security Affairs
Sponsor:	The Hoover Institution and the American Enterprise Institute for Public Policy
Objectives:	To study the background of United States - Philippine relations; to state clearly the respective perceptions of national interests and policies; to analyze current problems between the two nations; and to present alternatives for future action; with conclusions, and recommendations as appropriate.

Summary: This research has been completed and is in the hands of the publishers. It is a part of a long-term and continuing study of the position of the United States in the Western Pacific and East Asia after the conclusion of the Vietnam affair. Results obtained will be published in forthcoming book to be brought forth by the sponsors. It will be most useful in the analysis and description of the problems and in presenting the diplomatic record in a readily accessible form. It endeavors to explain the objectives of the two countries in their foreign relations, and in so doing exposes the roots of conflict. Separate sections deal with security arrangements including the bases and military assistance and with economic relations after the expiration of the Laurel-Langley agreement in 1974. Due attention is given to the influence of the martial law situation and the temporary denial of civil rights on the traditional good relations between the United States and the Philippines. This research involved study trips to Washington and to the Philippines, the better to judge the respective role of the two in the evolving balance of powers in the Pacific.

Publications: None

Title: The 1974 Soviet Merchant Marine

Investigator: D. C. Daniel, Assistant Professor of National
                      Security Affairs

Sponsor: None

Objectives: (1) To document the size, growth, and major
                      characteristics of the Soviet merchant fleet.

                      (2) To compare its size, growth, and characteris-
                      tics with those of the world merchant fleet as a
                      whole.

                      (3) To highlight 1974 ship construction, fleet
                      operation, and port development trends.

Summary: Conclusions as to size, growth, and inventory
                      characteristics of both the Soviet and world
                      fleets were based on data aggregated by this writer
                      from Lloyd's Register of Shipping, Western shipping
                      journals and Soviet sources provided additional
                      necessary information to meet the objectives laid
                      out above.

                      Among some of the major conclusions are that the
                      Soviet Merchant Marine is one of the world's
                      largest; it is continuing to grow; it differs
                      significantly from the world fleet in many ways
                      though it is tending closer toward world "norms" in
                      many areas. The Soviets are conscious of the need
                      to improve their port facilities and eliminate
                      port-associated problems which restrict the efficiency
                      of their fleet. They continue to use their fleet as
                      an auxiliary arm of their military system.

Publication: D. C. Daniel, "The 1974 Soviet Merchant Marine,"
                      published in D. R. Jones, Ed. The Soviet Military
                      Affairs Review, Academic International Press, 1977.

Title:	French Perceptions of U.S. - Soviet Military Balances as Revealed in Défense Nationale.
Investigator:	D. C. Daniel, Assistant Professor of National Security Affairs
Sponsor:	Advanced Research Project Agency
Objectives:	In conjunction with ARPA Order 3117, I am coding twenty years (1955-1974) of selected articles and and chronical items from the French journal Défense Nationale. At the focus of inquiry are balance comparisons made by the authors of the journal relative to U.S. - Soviet and certain East-West military capabilities. I am seeking to answer the following questions:

(1) What are the perceptions of the authors as to which side is ahead in the balance comparisons?

(2) What reasons do they give for justifying their views?

(3) What sources do they mention as providing them information for reaching their conclusions?

(4) What events do they acknowledge as triggering their thinking on a particular balance?

(5) What do they say should be done in light of the state of a particular balance as they percieve it?

(6) Which balances most/least frequently provided the basis for comparisons.

Summary:	This study applies a quantitative technique (content analysis) to coding the journals in order to ascertain trends. The study is still in progress, and final results will be available 1 October 1976.
Publications:	D. C. Daniel, "Défense Nationale Perceptions of the U. S.-Soviet Military Balances," Technical Report 56D176111, November 1976.

Title:	The U.S. Navy in the Indian Ocean: The Surface Ship Naval Presence Issue
Investigator:	D. C. Daniel, Assistant Professor of National Security Affairs
Sponsor:	None
Objective:	To evaluate various arguments for and against increasing the U.S. naval surface ship presence in the Indian Ocean.
Summary:	The arguments were grouped into three major schools of thought as to what U.S. policy should be. These recommendations and their rationale were compared and contrasted. The study ended with this writer making his own recommendations based upon his analysis and evaluation of the differing rationale.
Publication:	D. C. Daniel, "South Asia: The Problem of Secure Lines of Communication," published in W. W. Whitson, Ed. Foreign Policy and National Security, Praeger (Special Studies Series), 1976.

Title: The President and National Security, Vol. II

Investigator: Stephen Jurika, Adjunct Professor of National
                 Security Affairs

Sponsor: None

Objective: Prepare, with co-author Malcolm Smith, volume two
                 of The President and National Security. (Volume
                 one was published by Kendall/Hunt, Dubuque, Iowa
                 in 1972.

Summary: The two volumes document the records of American
                 presidents from Washington to Nixon with respect
                 to "national security" in its many facets. More
                 especially, it is seldom that both the "how" and
                 the "why" of decision-making is released to the
                 public, including much that is new from sources
                 that have been classified over the years.

                 The thesis of both books is that so long as
                 American elections are scheduled AND HELD no
                 President can gather into his hands the absolute
                 power that so tends to corrupt. Since Volume one,
                 the Watergate affair and the limitations on
                 presidential power corroborate our thesis.

Publications: None

Title: Arthur W. Radford, Admiral of the Skies

Investigator: Stephen Jurika, Adjunct Professor of National
                  Security Affairs

Sponsor: The Hoover Institution on War, Revolution, and
                  Peace

Objective: To continue in the Hoover Institution tradition of
                  publishing scholarly books.

Summary: The papers of Admiral Arthur W. Radford are now
                  in the possession of the Hoover Institution.
                  The Publications Committee of the Hoover Institute
                  selected me to:

                       a. Select, arrange, and annotate the 1493
                  pages of typed manuscript, select and obtain
                  photographs, charts, tables, and maps.

                       b. Write and edit some 500 pages (printed) of
                  final manuscript to be published as a hardcover
                  book.

                       c. Provide many other services which need not
                  be noted.

                  Admiral Radford was one of the most important naval
                  aviators in the history of the United States Navy.
                  He was present at numerous high-level meetings and
                  conferences as an advisor to James Forrestall,
                  Presidents Truman and Eisenhower, and was Chairman
                  of the Joint Chiefs of Staff for seven years.
                  During those cold war years, his impact on the
                  course of U. S. decisions was immense, and the
                  Admiral was meticulous and clear at writing down
                  notes and memoranda, in addition to a daily journal.
                  From the material in the Hoover archives, and from
                  the Admiral's sharp observations, there flow new
                  light and perspectives--even major differences,
                  between his well documented records and the published
                  memoirs of two Presidents and a host of major
                  officials such as Dean Acheson.

Publications: None

Title: Data Analysis in National Security Policymaking

Investigator: E. J. Laurance, Assistant Professor of National Security Affairs, R. G. Sherwin, Assistant Professor (Research Associate) of National Security Affairs

Sponsor: Office of the Joint Chief of Staff, Plans and Policy Division

Objective: For 1975 - 76, the objective of this project has been to devise a data-based scheme for researching and monitoring international transfers of conventional arms. The project has also been concerned with linking conventional wisdom about arms transfers with other international relations phenomena such as political interaction, recent conflicts, trade, alignment, and the flow of strategic commodities, and so forth.

Summary: The conclusion reached after the first phase of the project is that statistical analysis of arms transfer data is difficult due to a paucity of cases, the measurement problem, and the inadequate distribution and organization of relevant data. Significant progress was made in the development of a valid measure of the arms transfer concept through the application of multiple attribute utility theory.

Conference Presentations: Laurance, Edward J., "Arms Transfers and Influence in Latin America." Presented to International Studies Association, February 1976.

Sherwin, Ronald G., "International Commitments and Arms Transfers: A Conceptual Discussion." Presented to the International Studies Association, March 1976.

Laurance, Edward J., "The Changing Nature of Conventional Arms Transfers: Implications for U.S. National Security Planning and Policy Research." Presented to the 1976 Senior Conference, U.S. Military Academy, May 1976, West Point, New York.

Laurance, Edward J., and Sherwin, Ronald G., "Understanding Arms Transfers Through Data Analysis." Conference on the Implications of the Military Build-Up in Non-Industrial States. Fletcher School of Law and Diplomacy, May 1976.

Thesis Directed: Le Grow, Allan Wesley, "Measuring Aircraft Capability for Military and Political Analysis," Master's Thesis, March 1976.

Title: A General Methodology for Forecasting the
                Technological Threat from the Soviet Navy

Investigator: R. H. S. Stolfi, Associate Professor of National
                Security Affairs

Sponsor: Office of Naval Research and Naval Intelligence
                Support Center

Objective: The investigator working as part of a team with
                Associate Professor Peter C. C. Wang, Department
                of Mathematics, was tasked to develop a methodology
                for forecasting the technological threat from the
                Soviet Navy.

Summary: A technological threat forecasting methodology
                was developed, which has been tested by naval
                intelligence students at the Naval Postgraduate
                School and a group of analysts from NISC, and
                has proven to be realistic and capable of useful,
                practical application. The methodology is presently
                being expanded to include application to weapons
                platforms (as distinguished from weapons) and
                application to other navies of the Eurasian
                Communist Countries.

                Fourteen class projects are being edited and
                modified to appear as either Naval Postgraduate
                School research reports or research memoranda
                from the recently proposed Naval Postgraduate
                School Center for Research in Intelligence. Each
                project consists of an actual forecast of a
                particular category of weapons comprising a
                ten-page executive summary, systematically
                arranged forecast, and various appendices.

Publications: None

Title: Weapons Threat to the United States from the Armed Forces of the Eurasian Communist Countries (ECC)

Investigator: R. H. S. Stolfi, Associate Professor of National Security Affairs

Sponsor: U. S. Army, Ballistic Research Laboratory (BRL)

Objective: In 1973, the Department of Defense under the earlier insistance and guidance of John Foster, published the eight-volume work representing the state of weapons technology in the United States entitled, "Weapons Technology Coordinating Paper." At that time, I had been responsible for presenting the ECC Technological Threat, Volumes I - VII, and putting together the general picture of the threat in Volume VIII. The BRL, as executive agent for DOD in keeping the work current, gave me the task in January 1976, to edit and update Volumes I - VII from the viewpoint of the weapons threat from the Eurasian Communist Countries.

Summary: From January - August 1976, the eight volumes of the Weapons Technology Coordinating Paper were (1) edited for clarity and (2) changed substantively where necessary to reflect the latest information and intelligence.

Publications: R. H. S. Stolfi, "Weapons Technology Coordinating Paper," Eight Volumes, Office of the Director of Defense Research and Engineering, Washington, D. C., October 1976.

Title: Gun Systems Aquisition in the United States

Investigator: R. H. S. Stolfi, Associate Professor of National
                 Security Affairs

Sponsor: Director of Defense Research and Engineering

Objective: Under the prompting of the Secretary of Defense
                 (James Schlesinger) late in 1974, the Director
                 of Defense Research and Engineering (Dr. Malcom
                 Currie) brought together under the Defense Science
                 Board, a special panel to examine the process of
                 gun systems acquisition in the United States and
                 to advise DDR&E and the Secretary of Defense on
                 the state of the process and the means by which
                 it could be improved. I served as primary consul-
                 tant to the panel, attended most of its meetings,
                 and accomplished various gun systems historical
                 and technical research in support of its members.

Summary: The Panel published a two-volume report in which
                 the principal finding was that the process for
                 acquiring advanced gun systems in the United
                 States has ground virtually to a halt. The report
                 elaborates that the management system executing
                 the process of gun systems acquisition has pro-
                 vided neither an overall sense of direction,
                 clear incentives, nor adequate stimuli to affect
                 the process.

Publications: R. H. S. Stolfi, "Report of the Task Force on
                 Gun System Acquisition," Defense Science Board,
                 Office of the Director of Defense Research and
                 Engineering, Washington, D. C. Two Volumes,
                 1 August 1975.

DEPARTMENT OF PHYSICS AND CHEMISTRY

The research program in the Department of Physics and Chemistry has continued along several main lines: (1) Acoustics and Fluid Dynamics, (2) Atmospheric Optics, (3) Laser and Plasma Physics, (4) Atomic Physics, (5) Nuclear Physics, (6) Physical Chemistry, and (7) Solid State and Surface Physics. Under these headings, there are a number of related investigations being pursued by various faculty members as described below.

ACOUSTICS AND FLUID DYNAMICS

Influence of the upper ocean fluctuations on the propagation of sound by H. Medwin; Processing of ocean acoustic signals in response to the ocean fluctuations by H. Medwin; High intensity acoustic phenomena by A. Coppens and J. V. Sanders; Drag and noise reduction of underwater vehicles by J. V. Sanders and K. E. Woehler; Underwater acoustic range studies involving O. B. Wilson, J. V. Sanders, H. Dahl, A. Coppens; (Sound propagation on wave guides with time varying rough surfaces)(shallow water Anti-Submarine Warfare (ASW)) by A. Coppens.

ATMOSPHERIC OPTICS

This activity has evolved to be one of the strongest in the department and is done in cooperation with the Meteorological Department: Study of the optical propagation in the marine boundary layer as a function of turbulence and aerosols/fog at militarily important atmospheric window wavelengths, by E. C. Crittenden, A. W. Cooper, E. Milne, W. Rodeback, S. H. Kalmbach, and R. Armstead; Development and Calibration of Diagnostic Tools and Field Studies of Atmospheric Turbulence in the Presence of Marine Fog, by G. E. Schacher and C. Fairall.

LASER AND PLASMA PHYSICS

In the Laser and Plasma Laboratory the dynamics of plasma production by impact of pulsed laser radiation on solid targets is investigated by F. Schrwirzke and A. Cooper, using neodymium glass and carbon dioxide lasers. Generation of spontaneous magnetic field, emission of x-rays and momentum transfer to the target are studied in detail. Laser development is carried out in conjunction with this program. Coherent Anti-Stokes Raman Scattering (CARS) as an analytical probe is under study by W. Tolles. A compilation of mostly classified data on effects of high energy laser irradiation of materials is made by J. R. Neighbours.

ATOMIC PHYSICS

Our spectroscopic data center's compilation of vacuum ultraviolet spectral lines in continuing, emphasizing at present rocket borne stellar spectroscopy, R. L. Kelly.

NUCLEAR PHYSICS

F. R. Buskirk, J. N. Dyer and R. Pitthan are continuing their investigations of giant multipole resonances in various nuclei by inelastic electron scattering at the LINAC.

PHYSICAL CHEMISTRY

Continuing investigation of the reaction kinetics and catalytic properties of palladium complexes by R. A. Reinhardt; thermodynamics of internal explosion processes by G. E. Kinney.

SOLID STATE AND SURFACE INTERACTION PHYSICS

Investigation by means of computer simulation of ion-surface interactions by D. E. Harrison, Jr.

Title: Measurement of Nuclear Giant Resonances
by High Energy Electron Scattering

Investigators: F. R. Buskirk, E. B. Dally, J. N. Dyer and
R. Pitthan, Professors, Physics and Chemistry
Department

Sponsor: Foundation Research Program (6.1)

Objective: To investigate the collective modes of oscilla-
tion (giant resonances) of medium and heavy
nuclei by means of inelastic electron scattering,
using the electron linear accelerator (Linac)
as the source of high energy electrons.
Specific objectives include: (a) more positive
identification of the monopole (breathing
mode) resonance; (b) a systematic investigation
of the isovector and isoscalar quadrupole
resonances for nuclei ranging in mass from
58 to 238; and, (c) identification of the
octupole mode.

Summary: The efforts have fallen into two broad categories,
(a) Giant Resonance Research, and (b) Improvements
in Spectrum Analysis.

(a) Giant resonance measurements were
made in ^{89}Y at 90 MeV and scattering angles
of 75°, 90°, 105° and 120°. Nine resonances
were observed in a range of excitation energy
from 6 to 38 MeV, and the results are listed
in the thesis (9). One very important result
of this experiment concerns the width of
the isoscalar E2 resonance (14.86 MeV).
In an early (1972) electron scattering experiment
by the Sendai group (Japan) with the neighboring
nucleus ^{90}Zr, a very large width of 4.8
MeV was found. This result was not surprising
at the time, but subsequent experiments
with many other nuclei in the ensuing years
would make this result hard to understand.
Our results indicate that the broad resonance
actually consists of two resonances, M1
at 13.6 MeV and E2 at 14.9 MeV.

(b)   The Radiation Tail refers to the
continuous spectrum of electrons which accompanies
inelastic electrons scattering, and in fact
accounts for 90% or more of the electrons
seen in a spectrum.   To obtain a nuclear
spectrum the radiation tail must be subtracted
and knowledge of its energy dependence is
essential.   In the present spectrum analysis
procedure, the observed spectrum is fit
to adjustable resonances and a constant
time the radiation tail function.   The constant
would be 1.0 only if the radiation tail
function were known exactly, but the experimental
values of the constant ranging from 0.9
to 1.1 indicate that the function is known
more accurately than had been expected (2).

(c)   Related research is described in
the report on the NSF project.

Publications: G. L. Moore, F. R. Buskirk, E. B. Dally,
J. N. Dyer, X. K. Maruyama and R. Pitthan;
"The Widths of the E2 (T = 0 and T = 1)
Giant Resonances in ^{165}Ho," Zeit Schrift fur
Naturforschung, 31a, 668 (1976).

R. Pitthan and F. Buskirk, "Line Structure
and Resonant Structure in ^{208}Pb," Bulletin
of the American Physical Society, 21, 516
(1976).

Theses Directed:

D. H. DuBois and G. M. Bates, "Electro-Excitation
of Giant Resonances in ^{60}Ni Between 5 and
30 MeV Excitation Energy," Master's Thesis,
June 1976.

J. O. Shannon and W. H. Smith, "Electro-
Excitation of Giant Resonances Between 6.1
and 38 MeV Excitation Energy in ^{89}Y," Master's
Thesis, June 1976.

E. F. Gordon, "An Investigation of the Natural
Line Shape of the Giant Dipole Resonance,"
Master's Thesis, 1975.

Title: Electro-Excitation of the Collective Hydro-dynamic Oscillation of Nuclei: The Giant Resonances

Investigators: F. R. Buskirk, E. B. Dally, J. N. Dyer and R. Pitthan, Professors of Physics and Chemistry

Sponsor: National Science Foundation

Objectives: The overall objective is the survey of giant resonances in medium and heavy nuclei, from mass 50 to 238. A specific objective has been the study of the isotope pair ^{58}Ni and ^{60}Ni, to see if the isospin splitting of the giant dipole resonance, measured by (γ,n), could be verified and to see if corresponding isospin effects occur for the isovector quadrupole resonance.

Summary: Experiments with Nickel isotopes have been done in the past, but many questions remain unanswered. The El resonance has been measured with (γ,n) and (γ,p) in both ^{58}Ni and ^{60}Ni. While ^{60}Ni fits in the systematic behavior of the El resonance, ^{58}Ni showed an abnormally large $(\gamma,p)/(\gamma,n)$ ratio, i.e. a very small percentage of the sum rule is exhausted by (γ,n). In contrast, our results, which show the total giant dipole resonance strength, and in ^{58}Ni it is significantly larger than in ^{60}Ni, which is difficult to understand.

Information concerning the isovector E2 resonance is generally scarce and most of the work reported so far has been done in our laboratory. One specific question, which may influence our concept of isospin very much, is the question if, and how, the $\Delta T = 1$ E2 resonance splits into T< and T> components. Direct comparison of the T = 1 nucleus ^{58}Ni with the T = 2 nucleus ^{60}Ni may offer the best possibility to learn about this effect. Our preliminary data indicate the possibility of such splitting, but more measurements are necessary.

Another surprising feature is a pair of E3 lines (or group of states) at 6.1 MeV and 7.0 MeV, which change their relative strength in going from ^{58}Ni to ^{60}Ni.

Knowledge of the energy dependence or shape
of the giant resonance lines is needed when
experimental spectra are fitted with several
overlapping resonance forms, and a not exactly
known background. To test line shape functions,
(γ,n) spectra, which have little background
ambiguity were fitted to various possible forms.
It was found that the strength function was fit
best by a Breit-Wigner resonance shape, and
this result should aid in the analysis of our
(e,e') spectra which involve many more
resonances.

Related results for ^{89}Y and the radiation tail
structure are described in the corresponding
report for the NPS Foundation Research Program.

Publications: G. L. Moore, F. R. Buskirk, E. B. Dally,
J. N. Dyer, X. K. Maruyama and R. Pitthan:
"The Widths of the E2 (T = 0 and T = 1) Giant
Resonances in ^{165}Ho", Zeitschrift für
Naturforschung, 31a, 6.8 (1976).

R. Pitthan and F. R. Buskirk: "Line Structure
and Resonant Structure in ^{208}Pb", Bulletin of
the American Physical Society, 21, 216 (1976).

Theses Directed: E. F. Gordon: "An Investigation of the Natural
Line Shape of the Giant Dipole Resonance",
Master's Thesis, 1975.

D. H. DuBois and G. M. Bates: "Electro-
Excitation of Giant Resonances in ^{60}Ni between
5 and 30 MeV Excitation Energy," Master's
Thesis, June 1976.

J. O. Shannon and W. H. Smith: "Electro-
Excitation of Giant Resonances Between 6.1 and
38 MeV Excitation Energy in ^{89}Y", Master's
Thesis, June 1976.

Title: Laser Produced Plasmas

Investigators: A. W. Cooper and F. Schwirzke, Associate
                   Professors, Physics and Chemistry Department

Sponsor: Foundation Research Program (6.1)

Objective: In this continuing project the interaction
                   is investigated between intense laser pulses
                   and targets. The dynamics of the laser
                   produced plasma and self-generated magnetic
                   fields are studied.

Summary: In the interaction of high-power pulsed
                   laser radiation with a solid target, gas
                   breakdown and subsequent plasma formation
                   in the vicinity of the surface dominate
                   the later transfer of energy and momentum
                   to the solid. The interaction of 20-nsec
                   300-MW pulses of 1.06-μm laser radiation
                   with aluminum targets in vacuum has been
                   studied. The time history of the target
                   impulse has been measured with a Sandia
                   quartz gauge. A time sequence of plasma
                   density maps constructed from floating double-
                   probe data has been used with measured expansion
                   velocities to estimate the plasma momentum.
                   The results show that the stress wave is
                   predominantly produced by about 10% of the
                   evaporated target material which is ionized
                   and expands from the surface in the form
                   of a hot plasma during and shortly after
                   the laser pulse. Initial measurements were
                   also made of target impulse in layered materials
                   (solar cell models) in air and vacuum environ-
                   ment using 5-10 J 250 μsec pulses from a
                   CO_2 TEA laser.

Publications: A. W. M. Cooper, F. Schwirzke, and K. M.
                   Brooks, Sr., "Time Development and Symmetry
                   of a Laser-Produced Plasma Plume on a Plane
                   Target," Bulletin of American Physical Society,
                   20, 1266 (1975). Presented by A. W. Cooper
                   at the Annual Meeting of the Division of
                   Plasma Physics of the American Physical
                   Society, St. Petersburg, Florida, November
                   1975.

F. Schwirzke, A. W. M. Cooper and P. Krehl, "Correlated Measurements of Laser Induced Stress Waves and the Dynamics of the Laser Produced Plasma," Bulletin of the American Physical Society, 20, 1266 (1975). Presented by F. Schwirzke at the Annual Meeting of the Division of Plasma Physics of the American Physical Society, St. Petersburg, Florida, November 1975.

R. S. Case, Jr. and F. Schwirzke, "Background Gas Pressure Dependence and Spatial Variation of Spontaneously Generated Magnetic Fields in Laser-Produced Plasmas," Journal of Applied Physics 46, 1493 (1975).

P. Krehl, F. Schwirzke and A. W. Cooper, "Correlation of Stresswave Profiles and the Dynamics of the Plasma Produced by Laser Irradiation of Plane Solid Targets," Journal of Applied Physics, 46 4400 (1975).

Theses Directed:

Francis T. Williamson, "Laser Generated Magnetic Fields," Master's Thesis, June 1976. (Thesis Advisor: F. Schwirzke)

Daniel J. Callahan, "Laser Plasma Particle Velocities," Master's Thesis, June 1976. (Thesis Advisor: F. Schwirzke)

Sydney A. Shewchuk, "X-Ray Diagnostics of Laser-Produced Aluminum Plasmas," Master's Thesis, June 1976. (Thesis Advisor: A. W. Cooper)

John F. Jacobson, "Examination of Laser-Produced Pressure Pulses in a Gallium Arsenide Solar Cell," Master's Thesis, June 1976. (Thesis Advisor: A. W. Cooper)

Title: Finite Amplitude Acoustic Waves in Cavities

Investigator: A. B. Coppens, Associate Professor of Physics
                   and Chemistry

Sponsor: None

Objective: To obtain a physical understanding of the
                   behavior of high amplitude acoustical standing
                   waves in cavities with rigid boundaries. The
                   goal is to be able to predict the nonlinear
                   acoustical effects which arise in real cavi-
                   ties where boundary irregularities and
                   physical imperfections of the system cannot
                   be ignored.

Summary: This work represents a continuing effort over
                   several years to obtain solutions to an
                   emphirical nonlinear wave equation describing
                   the behavior of nonlinearly-distorted standing
                   waves in real tubes and cavities. Present
                   efforts are devoted to solving this wave
                   equation for standing waves in rigid-walled
                   cavities of rectangular geometry. The
                   Theoretical predictions of the bahavior of the
                   nonlinearly-generated harmonics of a driven
                   standing wave in the cavity are in agreement
                   with experiment for cavities with very good
                   geometry. The frequency dependence of the
                   amplitudes of the harmonics depends on the
                   exact relationships between the observed
                   resonance frequencies and absorption coeffi-
                   cients of the real cavity. This means that
                   calculated resonance frequencies and absorp-
                   tion coefficients of the cavity are not
                   sufficiently accurate to predict the observed
                   behavior of the standing wave. We are now
                   investigating solutions of the nonlinear wave
                   equation for cavities containing simply per-
                   turbed boundaries. The results look promising,
                   and demonstrate the possibility of coupling
                   energy into normal modes (otherwise unexcited)
                   by means of finite-amplitude perturbation
                   corrections to the finite amplitude solution
                   in the unperturbed cavity.

Publications: A. B. Coppens and J. V. Sanders, "Finite Am-
                   plitude Standing Waves Within Real Cavities".
                   Journal of the Acoustical Society of America
                   (1975).

Theses Directed: Milo J. Kilmer II, "Finite Amplitude Effects
                   in Rectangular Cavities with Perturbed
                   Boundaries", Master's Thesis, December 1975.

141

Winfield S. Slocum IV, "Finite Amplitude
Standing Waves in Real Cavities Containing
Degenerate Modes", Master's Thesis, December
1975.

John J. Donnelly, "Investigation of Sub-
harmonic Generation by Finite Amplitude
Waves in a Rigid-Walled Tube", Master's
Thesis, June 1976.

Title: Optical Propagation in the Marine Boundary Layer (Optics)

Investigators: E. C. Crittenden, Jr., A. W. Cooper, S. H. Kalmbach, E. A. Milne, G. W. Rodeback, and R. L. Armstead, Professors of Physics and Chemistry

Sponsor: Naval Sea Systems Command

Objective: To develop methods for predicting the optical propagation properties in the marine boundary layer on the basis of the bulk properties of the atmosphere, and to determine the dependence of the optical properties on the micrometeorology in the marine boundary layer.

Summary: Knowledge of the optical properties of the atmosphere over land has been sketchy, and over the ocean has been almost nonexistent. Such knowledge is vital for the design, and prediction of performance in the marine environment, of a wide range of military applications of electro-optics - specifically for target detection, ranging, pointing, tracking, homing, imaging and communications. The major properties of interest are the "seeing" or resolution through the atmosphere, as it is degraded by turbulence and aerosols, the "scintillation" or intensity fluctuations and the angle-of-arrival fluctuations (image wander) of a transmitted beam, and the extinction, or loss of energy from a beam, by absorption and scattering of radiation by fog and aerosol particles. The "seeing" is characterized by the Modulation Transfer Function (MTF) and the closely related Mutual Coherence Function (MCF) which also determines the signal-to-noise ratio in a coherent detection receiver. Image wander and its frequency spectrum are also involved in determination of seeing. The scintillation is characterized by the Optical Turbulence Structure constant C_n. Measurement of scintillation over a horizontal path yields a value for C_n averaged over the path; point values of C_n^2 can be obtained by meteorological methods. During the past three years techniques have been developed for measuring these parameters under open-ocean conditions with both shore-to-shore and ship-to-shore paths, using the Naval Postgraduate School (NPS) research vessel, ACANIA, for ranges up to 20 km. Optical measurements of scintillation, image wander and

MTF are made simultaneously with meteor-
logical measurements.

Measurements have been made under a variety
of conditions with lasers at wavelengths of
.488 μm (blue), .6328 μm (red), 1.06 μm
(near IR) and 10.6 μm (far IR). Broad band
detection with black body sources has been
carried out in the middle IR band from 3-5 μm.
On-line data reduction is in operation for
the determination of C_n from scintillation.
MTF is determined by Fourier analysis of the
line spread image function obtained with a
telescope. The data is recorded for later
processing by computer. An on-line data re-
duction system is under construction to yield
direct MTF results in the field. A portable
compact system has been developed for measuring
the MTF on-site in connection with other
optical experiments elsewhere.

Extinction, the loss of light from a beam as
as a result of aerosol scattering, has been
measured over the same optical paths as for
MTF and C_n, in order to incorporate the effects
of scattering in the prediction of MTF.
Measurements of fog/aerosol parameters are
simultaneously made on shipboard during the
optical measurements, in a companion research
project headed by Professor Schacher. The
micrometeorology is simultaneously measured
in another companion research project headed
by Professor Davidson in the Department of
Meteorology. Comparison of the experimental
results with theory indicates a substantial
inadequacy of the capability of current theo-
retical models to predict MTF of an optical
path on the basis of C_n values obtained either
from scintillation over the same path or from
thermal fluctuation measurements at points
along the path. Experimental work is in
progress to determine the cause of this
inadequacy. MTF measured by a shearing inter-
ferometer in a joint experiment with MIT
Lincoln Lab gave essential agreement with the
NPS values, and corroborated the inability of
theory to predict MTF from C_n on present models.

Publications: E. C. Crittenden and K. L. Davidson, "Laser
Transmission in the Marine Environment",
Naval Research Review, February 1976.

Title: Development of an Improved Ray-Tracing
Algorithm for Underwater Acoustic Ranges

Investigator: Harvey A. Dahl, Assistant Professor of
Physics and Chemistry

Sponsor: Naval Tropedo Station

Objective: The purpose of this work was to produce and
test an improved computer program by means
of which the position of a sound source in
an underwater range could be determined
accurately using only the signal arrival
times at the four hydrophones of a single
array on the range. Current programs which
do this were known to produce significant
errors, particularly in the depth coordinate.

Summary: The calculation of position is broken into
two steps. The first of these is the deter-
mination of the angle of elevation of the
arriving ray and of the effective time of
flight to the center of the given array of
sensors. A new algorithm has been produced
which caculates these quantities on the
assumption that sound speed varies linearly
with depth (isogradient case). The calcu-
lation involves hyperbolic functions of the
travel times to the four hydrophones and is
slightly more cumbersome than the old
algorithm which was based on the assumption
that sound speed in the water is a constant
(isovelocity case).

The second part of the calculation is the
actual tracing back along the ray from the
array center, starting with the angle of
elevation from step one, and proceeding
until all the time is consumed and the
predicted source position is reached. The
new traceback program considers the water
to be composed of horizontal, ten-foot
thick isogradient layers. The traceback
occurs along a ray composed of circular
segments with different radii in the suc-
cessive layers, with matching slopes at the
layer boundaries.

The complete program has been tested on
models of the range in which the water is
broken into one, two, or three horizontal
isogradient layers. Current NTS isovelocity
programs used on these models produce depth
errors of about 1 ft due to elevation angle
error alone and another 1.7 ft due to trace-
back errors, for a total depth error of 2.7

145

ft, all at 3,000 ft horizontal range from
the array. Use of the new NPS algorithm,
on the other hand, results in depth errors
of less than 0.05 ft total for the same
horizontal range in these models. Horizon-
tal position errors, though not very large
in either development, are reduced by a
factor of about 5 to a value of about 0.01
ft by use of the new program.

Motivation for this study and a slightly
expanded description of the effort may be
found in the Ray-Tracing Task Group portion
of the following report.

Publications: O. B. Wilson (Editor),"Annual Summary Report
of the Range Study Program", NPS-71W176081,
August 1976.

Title: Torpedo Tracking

Investigator: H. A. Dahl, Assistant Professor of Physics
                    and Chemistry

Sponsor: Naval Torpedo Station

Objective: The application of Kalman Filtering to
                    torpedo range tracking.

Summary: The application of Kalman filtering to the
                    on-line real-time tracking problems at
                    Keyport as well as for improving the post-run
                    data analysis is underway. Two thesis students
                    are involved in the project. A workshop in
                    Kalman filtering has been presented to engineers
                    at Keyport. A tape of a torpedo track has
                    been obtained and is presently being used to
                    check out our computer tracking algorithm for
                    this application. When a sufficient confidence
                    in the program is obtained we will put the
                    program on the computers at Keyport and test
                    it in a real-time environment. The two thesis
                    students will complete their work this fall
                    and a report is in progress.

Publications: None

Title: Computer Simulation of Sputtering III

Investigator: Don E. Harrison, Jr., Professor, Physics
and Chemistry Department

Sponsor: Foundation Research Program (6.1)

Objective: To prepare for publication previous investigations
of the formation of clusters of particles
sputtered by atomic ions, and to pursue
the investigation, by computer simulation,
of the sputtering of a copper surface by
diatomic molecular ions.

Summary: (1) The paper was prepared and has been
published, see Publications below.
(2) The main thrust of the molecular sputtering
effort has been suspended while further
details of the atomic sputtering process
are examined. A careful examination of the
sputtering ratio, atoms sputtered per incident
ion, as a function of the ion mass indicates
that the momentum transfer mechanisms are
quite different for small and large mass
ratios. There are now clear indications
that a light bullet sputters atoms near
the impact point while heavy ions produces
a liquid droplike effect. For heavy ions
the near atoms do not sputter, but a ring
of atoms approximately 5 Å from the impact
point do. This effect must be studied in
greater detail. An immediate consequence
is that computation will be more time consuming
for heavy ions because the target microcrystallite
must be larger. The project will continue
in FY77.

Publications: Don E. Harrison, Jr. and C. D. Delaplain,
"Computer Simulation of the Sputtering of
Clusters," Journal of Applied Physics, 47,
2252-59, (1976).

Title: Compilation of Vacuum Ultraviolet Spectra

Investigator: R. L. Kelly, Professor of Physics and
                      Chemistry

Sponsor: National Aeronautics and Space Adminis-
                      tration, Goddard Space Flight Center

Objective: To prepare a complete and accurate compilation
                      of atomic spectrum lines with wavelengths
                      less than 3000 Angstroms, based on publica-
                      tions in the open literature.

Summary: An important part of any field of science
                      is the utilization of measurements which
                      have already been made. Frequently, however,
                      the available information is fragmentary, of
                      questiononable value, or is not easily
                      located in the various journals. The
                      Spectroscopic Data Center is a repository of
                      all available information on optical transi-
                      tions in atoms and ions of the elements
                      through Krypton. These data are contin-
                      ually up-dated and evaluated, so that frag-
                      mentary information is put into the larger
                      picture, and doubtful information is elimi-
                      nated.

                      Compilations are published from time to time,
                      the latest being NRL 7599, "Atomic and Ionic
                      Emission Lines Below 2000 Angstroms," June
                      1973. This report contains the wavelength,
                      intensity, and classification of 34,700
                      spectrum lines with wavelengths in the
                      vacuum region, from all observed stages of
                      ionization. Entries are arranged by element
                      and spectrum, with a separate finding list.
                      Following the publication of this report,
                      up-dating the data files has continued. More
                      than 200 new publications with relevant infor-
                      mation have appeared. Evaluation of the new
                      and old data is a continuing task, certainly
                      one of the most important. In addition to
                      the compilations published, the files are
                      available to users as magnetic tapes and
                      punched cards. These forms of data file have
                      been used by astrophysicists and plasma
                      physicists.

                      A specific task nearing completion of data on
                      the 2000-3000 Angstrom region. Approximately
                      30,000 lines have been observed in this region
                      of the spectrum. Lack of information on
                      several inportant ions indicates the need for
                      more laboratory observations.

Publications: None

Title: Thermodynamics Calculations for Internal Blast

Investigator: G. F. Kinney, Professor Emeritus, Department of
                Physics and Chemistry

Sponsor: Naval Weapons Center

Objective: To make theoretical thermodynamic calculations
                for the pressure and temperature rises developed
                in the internal blast produced by an explosion
                in a confined space. This is a continuing
                program.

Summary: An explosion in a confined space such as a
                ship or aircraft compartment produces an internal
                blast by pressure rise as energy release raises
                the temperature of confined air and as gases are
                formed in the explosion. Important here is
                chemical dissociation in the reaction zone which
                acts as an energy sink and so limits the pressure
                rise that can be produced.

                A computer program for characterizing these
                effects has been developed. This involves the
                solution of twelve simultaneous non-linear
                equations. Its results have been found to agree,
                within experimental uncertainty, with observed
                values for TNT as reported in the literature.
                These calculations show that an explosion with
                an ordinary fuel such as fuel oil has a maximum
                peak overpressure at a fuel-air ratio that is
                intermediate between the CO_2-H_2O and CO-H_2O
                stoichiometric points. For explosive fuels such
                as TNT or PETN the internal blast pressure
                increases monatonically with the amount of fuel.

Publications: None

Title: Environmentally Adjusted Signal Enhancement

Investigator: H. Medwin, Professor of Physics and Chemistry

Sponsor: Naval Seas Systems Command

Objective: To study means for adjusting an ocean
                    acoustics signal in response to the fluctu-
                    ating medium in order to enhance its strength
                    and to improve its stability.

Summary: Recent research has shown that significant
                    improvement in passive signal strength and
                    reliability can be achieved by appropriately
                    applying phase shifts. To optimize this
                    technique the dependence of the improvement
                    on the size and location of the hydrophone in
                    the incoherent field, and the acoustical
                    roughness of the surface will be investigated
                    for a broad range of frequencies.

Publications: None

Title: Upper Ocean Parameters Affecting Sound
                  Propagation

Investigator: H. Medwin, Professor of Physics and
                  Chemistry

Sponsor: Office of Naval Research

Objective: To characterize the statistical relations
                  between ocean wave spectra, underwater
                  turbulence temperature microstructure bubble
                  populations, and propagation of acoustic energy
                  near the sea surface.

Summary: Computerized equipment has now been used to
                  obtain data on sound speed dispersion, atten-
                  uation and inferred microbubbles in the upper
                  ocean. The experiment is continuing in
                  search of the interrelations between physical
                  and biological ocean parameters, bubble presence,
                  and sound propagation under various ocean condi-
                  tions.

Publications: H. Medwin, "Acoustical Probing for Micro-
                  bubbles at Sea", Proceedings of a Conference
                  on Oceanic Acoustic Modelling. SACLANT ASW
                  Research Center La Spezia, Italy, 15 October
                  1975.

Title: Preparation of Laser Effects Handbook

Investigator: John R. Neighbours, Professor of Physics and Chemistry

Sponsor: Naval Surface Weapons Center

Objective: This continuing project is to present the effects of high energy laser irradiation of materials in a single source. Much of the data results are from the NRL Materials Effects portion of the Optical Radiation Program, but all three services and the civilian sector are surveyed.

Summary: The principal investigator receives directly a large number of pertinent classified reports which serve as a beginning data base. Several faculty members have participated with the principal investigator serving as Editor. Procedure has been for each participating faculty member to have responsibility for a particular topic. After becoming familiar with recent work in the field, the participating faculty member has made field trips to visit important research workers. This method allows personal interaction with a research worker as well as transmittal of information.

Publications: John R. Neighbours and A. J. Perkins, "NPS Laser Effects Handbook," Technical Report NPS-61-61Nb75091, August 1975.

Title: Homogeneous Catalysis by Palladium Complexes

Investigator: R. A. Reinhardt, Professor, Physics and Chemistry Department

Sponsor: Foundation Research Program (6.1)

Objective: To study the kinetics of olefin oxidation by a series of palladium complexes. This is part of the continuing research into ligand substitution processes.

Summary: As a continuation of experiments begun previously, the rate of oxidation of trans-2-butene to 2-butanone by $PdBr_4^{2-}$ in acidic aqueous media is being studied. The use of gas chromatography to follow the reaction permits monitoring the actual concentrations of both reactant and product as functions of time. From data thus far obtained over a limited range of concentrations of acid and bromide, the reaction mechanism appears to be the same as that found in chloride solutions, with nearly the same value found for the formation constant of the precursor complex, but a rate of reaction of this precursor to product an order of magnitude less with bromide than with chloride.

Future plans: once the $PdBr_4^{2-}$ study is properly completed, we shall examine the reaction with other complexes, using the stopped-flow apparatus when appropriate for the more rapid processes, as is expected with the tetraaquo complex.

Conference Presentations: R. A. Reinhardt (presenter) and K. J. Graham, "Kinetics of Oxidation of Olefins by Palladium (II) Complexes." Paper presented to the 31st Meeting of the Northwest Region of the American Chemical Society, Reno, Nevada, 15 June 1976.

Publications: None

Title: Characteristics of Resistance Wires Used
for Atmospheric Turbulence Measurements
in the Marine Environment

Investigators: Gordon Schacher, Associate Professor, and
C. W. Fairall, Assistant Professor, Physics
and Chemistry Department

Sponsor: Foundation Research Program and Naval Air
Systems Command

Objective: The purpose of this project is to determine
the effect of marine aerosols on resistance
wires which are used to measure fluctuations
in wind speed and temperature. This is
a continuing project.

Summary: Resistance wires are used as sensors to
measure fluctuations in air temperature
and wind speed. Such measurements are being
made at NPS in the marine environment where
the wires are impacted by marine aerosols,
primarily saline droplets, resulting in
sea salt encrustation. It is possible for
thick layers of salt to change the calibration
of the wires and measurements of the responses
of wires that have been encrusted in the
laboratory. The laboratory coatings are
much thicker than that normally produced
by sea spray in the field, and enabled a
change in wire sensitivity to be measured.
Both the dc and ac response of hot wires
used for wind speed measurements have been
investigated and it is found that naturally
occurring levels of encrustation are rarely
sufficient to significantly affect wire
calibration, and that it is possible to
easily test to determine if the wires are
severely coated. Measurements on temperature
wires are in progress and the effects of
fog droplet impaction will be investigated
in the future.

Publications: Gordon Schacher and C. W. Fairall, "Use
of Resistance Wires for Atmospheric Turbulence
Measurements in the Marine Environment,"
Review of Scientific Instruments, 47, No. 6,
703, 1976.

C. W. Fairall and Gordon Schacher, "Frequency
Response of Hot Wires Used for Atmospheric
Turbulence Measurements in the Marine Environment,"
Review of Scientific Instruments, 47, No.12,
0065, 1976.

Title: Plasma - Surface - Interaction

Investigator: F. Schwirzke, Associate Professor of Physics and Chemistry

Sponsor: Energy Research and Development Administration, Division of Magnetic Fusion Energy

Objective: To perform an independent review of impurity studies and diagnostics in tokamak systems, make recommendations and submit a comprehensive plan for action.

Summary: Since adequate magnetic confinement and heating of a deuterium-tritium plasma seems possible, impurity evolution due to plasma-wall interaction and impurity control are recognized now as being the critical remaining obstacles on the way to magnetic fusion energy. Impurities adversely influence almost every aspect of plasma behavior in the toroidal magnetic confinement system tokamak. Most tokamaks lose a large fraction of the power input by impurity radiation. High-Z impurities are particularly harmful since they are only partially stripped of electrons in the hot plasma and therefore radiate strongly. The tolerable impurity level for ignition of fusion reactions is so low that active impurity control is imperative for future fusion reactors.

Conference Presentation: (1) "Laser-Induced Desorption of Gas from Metallic Surfaces" presented by F. Schwirzke, IEEE Conference Record, 75CH0987-8-NPS, Second International Conference on Plasma Science, Ann Arbor, Michigan, p. 121 (1975).

Publications: F. Schwirzke, H. Brinkschulte and M. Hashmi, "Laser-Induced Desorption of Gas from Metallic Surfaces," Journal of Applied Physics, (1975).

Title: The Influence of Coatings and Self-Generated
                      Magnetic Fields on X-ray and Particle Emission
                      from a Laser Produced Plasma.

Investigator: F. Schwirzke, Associate Professor of Physics
                      and Chemistry

Sponsor: Air Force Office of Scientific Research

Objective: To investigate the processes which influence
                      the emission of x-rays and fast particles
                      from a laser produced plasma.

Summary: Measurements have been made of the expansion
                      of a laser produced plasma, and the data
                      have been correlated to the target impulse
                      measured with a quartz pressure gauge. Also,
                      a number of experiments were conducted to
                      assess the effects of thin coatings with
                      varying optical properties on the stress wave
                      generation at the surface of targets. Stress
                      enhancement of up to a factor of 10 has been
                      observed with transparent coatings. The
                      results suggest that the enhanced stress is
                      caused by temporarily trapping of the plasma
                      at the target coating interface.

                      The proper use of magnetic fields represents
                      another promising method to enhance the
                      x-ray emission from a laser produced plasma.
                      Magnetic fields are generated in a laser
                      produced plasma by nonaligned density and
                      temperature gradients. These magnetic fields
                      may be quite large near the focal spot region
                      and thus can influence the dynamics and heat
                      conduction of the electrons. After successive
                      burst of laser energy on the same spot a
                      crater is formed in a metal target. In this
                      case the lateral excape of plasma to the walls
                      of the crater will be reduced by the existence
                      of strong self-generated magnetic fields which
                      can not diffuse into the conducting walls of
                      the crater during the short time of the laser
                      pulse. Due to limited expansion and heat
                      conduction loss in radial direction the
                      electrons can be heated to higher temperatures,
                      and consequently the x-ray emission from the
                      plasma in the crater can escalate to higher
                      values.

Presentation: F. Schwirzke, A. W. M. Cooper, and F. T.
                      Williamson, Jr., "Spontaneous Magnetic Fields
                      in Laser-Impact Craters," Bulletin of the
                      American Physical Society, 21, 1029 (1976).

Title: An Analysis of the Performance Limits of Coherent Anti-Stokes Raman Spectroscopy (CARS) as an Analytical Technique

Investigator: W. M. Tolles, Professor of Physics and Chemistry

Sponsor: Office of Naval Research

Objective: CARS is currently undergoing development as a means of gathering molecular spectroscopic information. This study was to determine quantitative estimates of the signal-to-noise ratio expected for specified experimental conditions.

Summary: The signal-to-noise relationships are obtained for Coherent Anti-Stokes Raman Spectroscopy (CARS) in addition to two commonly employed spectroscopic tools: absorption and Raman scattering. Similar assumptions are included for laser performance and other parameters affecting each spectroscopic technique. CARS offers the greatest signal-to-noise advantage when utilized to obtain high resolution spectra of gases at low pressure for species that do not have a dipole moment. For mixtures of gases at one atmosphere total pressure, ordinary Raman scattering appears to offer greater signal-to-noise ratios than CARS except for the notable exception of hydrogen gas, which has substantially narrower lines. Other experimental arrangements are simulated.

Publications: None

Thesis Directed: R. Turner, "An Analysis of Coherent Anti-Stokes Raman Spectroscopy as an Analytical Tool," Master's Thesis, June 1976.

Title:	Range Studies Program
Investigator:	O. B. Wilson, Jr., Professor of Physics and Chemistry
Sponsor:	Naval Torpedo Station
Objective:	To provide support for the Long Range Development Program of the Naval Torpedo Station, Keyport, Washington.
Summary:	This is a continuation of a program initiated in 1973 for participation by NPS and NTS in projects of mutual interest and benefit. NTS personnel present, on an irregular basis, seminars at NPS on subjects of mutual interest. NPS faculty members and their students participate in studies of long range problems in the development of the NTS facilities and capabilities.

Nineteen members of the NPS faculty participated in the program during FY76. The total effort was divided into eight parts each which was attacked by a task group consisting of from one to eight faculty plus students. The work of these groups is reported individually elsewhere in this document under the name of the task leader as Investigator. The name of each participant in these task groups and reports and theses resulting from their work is also listed. The task groups for FY76 were as follows:

Task Group	Task Leader
1. Range Requirements	Assoc. Prof. D. A. Stentz
2. Signal Coding	Prof. D. B. Hoisington
3. Transducers	Prof. O. B. Wilson, Jr.
4. Ray Tracing	Ass't. Prof. H. A. Dahl
5. Range Concepts	Assoc. Prof. A. R. Washburn
6. Non-Acoustic Sensors	Assoc. Prof. G. L. Sackman
7. Data Transmission, Processing and Display	Ass't. Prof. V. M. Powers
8. Electromagnetic Propagation	Assoc. Prof. J. B. Knorr

Publications:	O. B. Wilson, Jr., "Annual Summary Report, Range Studies Program", Technical Report NPS-71WL76081, August 1976.

DEPARTMENT OF ELECTRICAL ENGINEERING

The Electrical Engineering research program encompasses a variety of areas, including: (1) Acoustics and Electro-Optics; (2) Bioengineering; (3) Electromagnetics; (4) Electronic Warfare Systems; (5) Information Processing Systems--Communications, Computer Applications, Estimation and Control, and Signal Processing; (6) Naval Tropedo Station Range Studies; and (7) Solid State Devices. The projects in each of these areas generally involve one or more faculty members working with several thesis students. A summary of the projects follows.

ACOUSTICS AND ELECTRO-OPTICS

Computer-aided acoustic imaging has been investigated by Professor John Powers with the objectives of implementing scalar diffraction integrals on a computer and magnetically recording the ultrasonic planar diffraction pattern. Professor Donald Stentz has studied seawater properties that cause scattering and absorption of light beams in order to determine factors which affect the operation of the Optical Ranging Identification and Communication (ORIC) System.

BIOENGINEERING

The neurophysiological research program directed by Professor George Marmont involves an investigation of human electroencephalogram characteristics of a subject performing a task in order to provide real time feedback signals to improve task performance.

ELECTROMAGNETICS

Techniques for measuring surface currents on ship-shaped objects were developed by Professor Richard Adler in his shipboard electromagnetic compatibility study. Professor Robert Burton has measured electromagnetic pulse (EMP) effects on aircraft communications systems. These measurements, when used with analytical results, provide a means of evaluating EMP simulation programs. Professor George Sackman has initiated a study of magnetic background noise with the objective of improving Navy systems for magnetic detection and degaussing of submarines.

ELECTRONIC WARFARE SYSTEMS

Techniques for phase-front distortion jamming of monopulse tracking radar systems have been investigated by Professor David Hoisington. The purpose of the project is to develop a feasible hardware implementation of the jammer.

COMMUNICATIONS

Professor Glen Myers has begun an investigation of interval modulation--a new technique for signal transmission--with the objective of determining the characteristics of this method. Professor Myers also studied the use of frequency division in demodulating FM carrier signals. Shipboard radio frequency interference (RFI) in the UHF SATCOM System has been the subject of a research program directed by Professor John Ohlson. The objectives of the study have been to characterize the RFI shipboard environment and to develop a simulator to be used in improving future SATCOM receivers.

COMPUTER APPLICATIONS

An adaptation of the USAF noise analysis program NOISEMAP was developed by Professor John Duffin who also devised computer programs to perform air emission analysis and to provide aircraft noise contour data plotting.

ESTIMATION AND CONTROL SYSTEMS

Professor Harold Titus has investigated tracking algorithms for military systems, including techniques for acoustic tracking, optimal scanning for two-dimensional tracking, Kalman filtering algorithms for the Position Locating Reporting System (PLRS), and an improved Kalman filtering algorithm for optimally resetting strap-down laser gyros. Professors George Thaler and Alex Gerba have continued validating and updating a digital simulation program for captured air bubble type surface effect ships. This simulation program will be utilized in predicting dynamic characteristics and control strategies for this new class of ship.

SIGNAL PROCESSING

Various aspects of Signals Intelligence (SIGINT) systems and Tactical Airborne Signal Exploitation Systems (TASES) were investigated by Professor Stephen Jauregui. Professor George Marmont continued development of his tegulometric analysis technique which can be applied to detection of frequency signatures in a complex multi-source signal. Professor Tien Tao investigated the application of recursive comb filters, synthesized using Charge Transfer Devices (CTD's) to Moving Target Indicator (MTI) radar signal processing. Procedures for designing recursive filters using CTD's have also been developed.

RANGE STUDIES

Several faculty members in the Electrical Engineering Department have participated in the Range Studies Program. Professors Hoisington and Myers participated in the development of a phase-coded transmission system used for position location of range vehicles. Professor Jeffrey Knorr initiated an electromagnetic propagation study for determining tropospheric path loss for transmission of voice and data communications in support of range activities. An electrical circuit was designed by Professor Glen

Myers to simulate the attenuation and phase shift characteristics of seawater over a distance of 1000 yards in the frequency range 50 kHz to 100 kHz. Professor Sackman led a task group investigating magnetic sensors and magnetic "silencing." Professor Harold Titus investigated the application of Kalman filtering to torpedo range tracking.

SOLID STATE DEVICES

Fabrication of a high dielectric constant insulator by a low temperature process compatible with non-silicon semiconductors has been carried out in a project directed by Professor Tien Tao. This fabrication process has applications in the area of infrared charge coupled imaging systems.

Title: Shipboard Electromagnetic Compatibility study

Investigator: Richard W. Adler, Electrical Engineering

Sponsor: Naval Electronics Laboratory Center

Objective: To develop techniques for measuring surface
                currents on ship-shaped objects such as
                rectangular prisms with monopole antennas.

Summary: The Navy is currently developing an Inte-
                grated Technique for Electromagnetic Analysis
                which will provide a computer modeling capa-
                bility for shipboard electromagnetic compa-
                tibility studies. To validate the computer
                codes, a set of measurements must be made.
                This project provides these unique measure-
                ments as a deliverable item.

Publications: C. T. Ristorcelli with R. W. Adler, "Elec-
                trical Characteristics of Monopole Antennas
                above a Rectangular Prism", Technical Report
                NPS52A675121, December 1975.

Title: Experimental and Theoretical Investigation of Electromagnetic Pulse (EMP) Effects on Aircraft Communication Systems

Investigator: R. W. Burton, LT COL, USAF, Associate Professor of Electrical Engineering

Sponsor: Air Force Weapons Laboratory and Rome Air Development Center

Objective: To determine by measurement the charge and current densities on analytically tractable models of aircraft which are exposed to electromagnetic pulse (EMP) radiation. From a study of measured and analytic results, insight may be gained to evaluate actual aircraft EMP simulator programs.

Summary: The work during this reporting period extended the measurement techniques and methods of analysis developed in the study of electrically thin (ka= .2) receiving crossed monopoles reported earlier to electrically thick (ka = 1) crossed monopoles which are respectively the low frequency and high frequency models used to study aircraft structures exposed to the broadband electromagnetic pulse. Measurement of charge and current distributions on scattering flat plates have been completed which give insight into analysis of aircraft wing structures. A complete characterization of charge and current distributions in the area of electrically thick wing junction regions has been accomplished.

Publications: Burton, R. W., "On Measuring Elliptically Polarized Surface Currents," Published in <u>Proceedings of National Conference on Electromagnetic Scattering</u>, June 1976

McDowell, E. J.; Burton, R. W., "Charge and Current Distributions on, and Input Impedance of Moderately Fat Transmitting Crossed-Monopole Antennas," Technical Report NPS-52Zn76031, March 1976.

Wiedemann, H. J.; Burton, R. W., "Measured Surface Charge and Current Distributions on Scattering Rectangular Plates," Technical Report NPS-52Zn76051, May 1976.

King, R. W. P.; Burton, R. W.; Shen, L. C., "Electric and Magnetic Fields Induced on the Surfaces of Electrically Thin and Thick Cylinders and Crossed Cylinders by an Incident Plane Wave," published in <u>Proceedings of National Conference on Electromagnetic Scattering</u>, (invited paper) June 1976.

Title: Adaptation of USAF Computerized Noise Analysis Program "NOISEMAP 3.2" to IBM System 360-Mod 67 Located at NPS, Monterey, California

Investigator: J. H. Duffin, Professor of Electrical Engineering

Sponsor: Naval Air Rework Facility

Objective: The U. S. Air Force noise analysis program "NOISEMAP 3.2" be adapted to the NPS system 360 computer. This program had been changed from CDC type Fortran to IBM type by Bolt, Beranek and Newman. The changed program contained many "bugs" which were to be removed to make the program operational. The program was then to be used for production type runs using noise survey data from various Naval Air operations centers.

Summary: Program NOISEMAP 3.2 was set up on the NPS system 360. A number of program bugs were found and eliminated but by no means all of them. Due to size and complexity of the program, it was necessary to have NARF-NORIS personnel come to Monterey to make runs. An effort to eliminate these visits involved an attempt to exchange information with NARF-NORIS via data communication lines with Monterey's System 360 "talking" to North Island's Wang 2200C. It was found that the data transmission rate was too slow to be useful - mainly due to hardware limitations on the Monterey end.

In view of these difficulties, NARF-NORIS decided to look elsewhere for high-speed data transfer/time-share-console type use. They found what they needed with Tymshare Corp. of Cupertino, California. As a result all effort on this project has been discontinued as of March 1976. NOISEMAP 3.2 is still in the NPS computer system and may be used again but it is not likely.

Publications: None

Title: Creation of Various Wang 2200C Minicomputer
                  Programs

Investigator: J. H. Duffin, Professor of Electrical Engine-
                  ering

Sponsor: Naval Air Rework Facility

Objective: There were several relatively small problems
                  in the areas of noise analysis, air emissions
                  analysis etc., that NARF-NORIS needed to have
                  computerized. In addition, their Wang
                  2200-C had just had a large flat-bed plotter
                  added into its hardware configuration and
                  the Wang supplied software plotting package
                  needed to be customized for NARF-NORIS use.
                  Therefore, it was the objective of this work
                  to create various software packages to meet
                  the diverse needs of the Air Emissions
                  Support Office (AESO) located at NARF-NORIS.

Summary: This work was performed during the investiga-
                  tors intersessional period of approximately
                  15 October 1975 to 15 December 1975. No
                  further work was or will be done after the
                  latter date.

                  A series of 12 software packages were created,
                  tested and put into use to cover the various
                  needs of the NARF-NORIS AESO group. The
                  major part of the time was spent in adapting
                  the Wang plotting package to the general
                  plotting needs. Specific applications of
                  the plotting software were in air craft
                  noise data contour plotting. Others were in
                  general data plotting. Editing and report
                  generation software packages were created.
                  All software packages operated successfully
                  and were acceptable to all parties concerned.

Publications: None

Title: Range Studies Program; Phase-Coded Clock

Investigators: D. B. Hoisington, Professor of Electrical Engineering and G. A. Myers, Associate Professor of Electrical Engineering

Sponsor: Naval Torpedo Station

Objective: To provide consulting services in the development of a phase-coded acoustic transmission system to be used for locating vehicles on the Naval Torpedo Station Tracking ranges.

Summary: The Naval Torpedo Station is developing a phase coded system to replace the present uncoded 75 kHz synchronous pulse transmitters for the 3-D tracking ranges operated by the Station. Objectives are improved tracking accuracy through improved use of available bandwidth, and the ability to transmit telemetry signals on the pulse. During Fy 76 a number of system tests were conducted on the NTS ranges, and improvements made in the system. The final result is a system that fully meets the requirements laid down for it. Improved tracking accuracy results in smoother tracks of vehicles with fewer data point drop outs. The telemetry system is highly reliable. NPS personnel participated in system tests during the year, and provided consulting service for NTS personnel. To facilitate testing of systems involving transmission of signals through water in the vicinity of 75 kHz, a transmission simulator was designed. This device approximates the phase shift and attenuation vs frequency transmission characteristics of water in the range from 50 to 100 kHz over a path length of 1000 yards. Sections can be cascaded to simulate greater path lengths.

Publications: O. B. Wilson (Editor), "Annual Summary Report of the Range Studies Program," Technical Report NPS-71w1 76081, August 1976.

Title: Jamming of Monopulse Tracking Radars

Investigator: David B. Hoisington, Professor, Electrical
                    Engineering

Sponsor: None

Objective: To investigate phase-front distortion jam-
                    ming of monopulse tracking radars.

Summary: At the present time no practical jammers
                    exist for providing angular deception of
                    monopulse tracking radars. Phase-front
                    distortion generated by an interferometer
                    pair has been proposed. Although some
                    success has been achieved in tests, it has
                    not been possible to convert this into use-
                    ful equipment. The purpose of this research
                    is to find techniques that can be used to
                    construct a viable phase-front distortion
                    deceptive monopulse jammer. Computer simu-
                    lation was first used to investigate the
                    effects of amplitude and phase deviations
                    from optimum values, and the effects of
                    amplitude and phase modulation. A range
                    was constructed using the NPS Nike-Ajax
                    monopulse radar for validation of the simu-
                    lation results. Significant angular errors
                    were induced in the radar tracking system.
                    This work is continuing in FY 7T-FY-77 with
                    NAVSEA sponsorship.

Thesis   M. J. Ducan, "Design of a Repeater-Jammer
Directed: Experiment for a Monopulse Radar," Master's
                    Thesis, September 1975.

Title: Range Studies Program: Electromagnetic
                  Propagation Task

Investigator: J. B. Knorr, Associate Professor of
                  Electrical Engineering

Sponsor: Naval Torpedo Station

Objective: The Electromagnetic Propagation study is
                  one of several tasks included in the Range
                  Studies Program sponsored by the Naval
                  Torpedo Station at Keyport, Washington. The
                  objective of this study is to determine path
                  loss for tropospheric circuits, both existing
                  and proposed, for the transmission of voice
                  and data communications in support of Key-
                  port range activities.

Summary: Work was begun on this task in January 1976
                  and during the first phase of the study the
                  Naval Postgraduate School computer Program
                  TROPOPLOT was used to determine long term
                  median values of basic path loss for the
                  troposhere curcuits of interest. TROPOPLOT
                  is based on the ESSA technical report ERL
                  79-1TS67. This work has been reported as
                  described below. During AY 76-77, work will
                  be continued with the objective being the
                  definition of the short term and long term
                  variations in loss for the tropospheric
                  paths. It is anticipated that both theor-
                  etical and experimental studies will be
                  carried out.

Thesis   R. M. Cassidy, "Computer Prediction of
Directed: Tropospheric Radio Transmitted Loss for
                  Selected Paths in the Pacific Northwest,"
                  Master's Thesis, June 1976

Title: Neurophysiological Research Program

Investigator: G. Marmont, Professor of Electrical Engine-
                ering

Sponsor: Naval Electrical Systems Command

Objective: The objectives of the Neurophysiological
                Research have been:

                (1) To detect and analyze the human electro-
                encephalogram (EEG) taken while a subject is
                performing a mental task.

                (2) To develop from the analysis a feedback
                signal, in real time, which would, when pre-
                sented to the subject, reinforce him in his
                task effort.

Summary: The research has been successful in meeting
                the above objectives. A distinctive type
                of EEG signature, the "tegule" was discovered.
                A tegule is a waxing and them waring sinusoid
                of a distintive frequency, seen as one of the
                components of the complex EEG record. When
                a subject is engaged in a demanding task, a
                sequence of tegnlic in a certain preferred
                frequency range are detected. The tegule
                frequencies tend to center in the 70 to 100
                H_Z range.

                A biofeedback signal has been derived (in
                real time, with a 1/4 second up date) from
                the cross-correlation of the digitally fil-
                tered response from two closely spaced EEG
                electrodes. Subjects respond to the signal,
                which is presented as a varying degree of
                ambient illuminations, as an indication of
                of their performance.

                Because of the multi-demensional nature of
                the EEG signal, much further investigation
                of the effects observed is called for.
                Various aspects of this research area are
                the subjects of current thesis effort by
                several students.

                A spin off from this research has been the
                tegulometric method of frequency signature
                analysis.

O3 860

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MICROCOPY RESOLUTION TEST CHART
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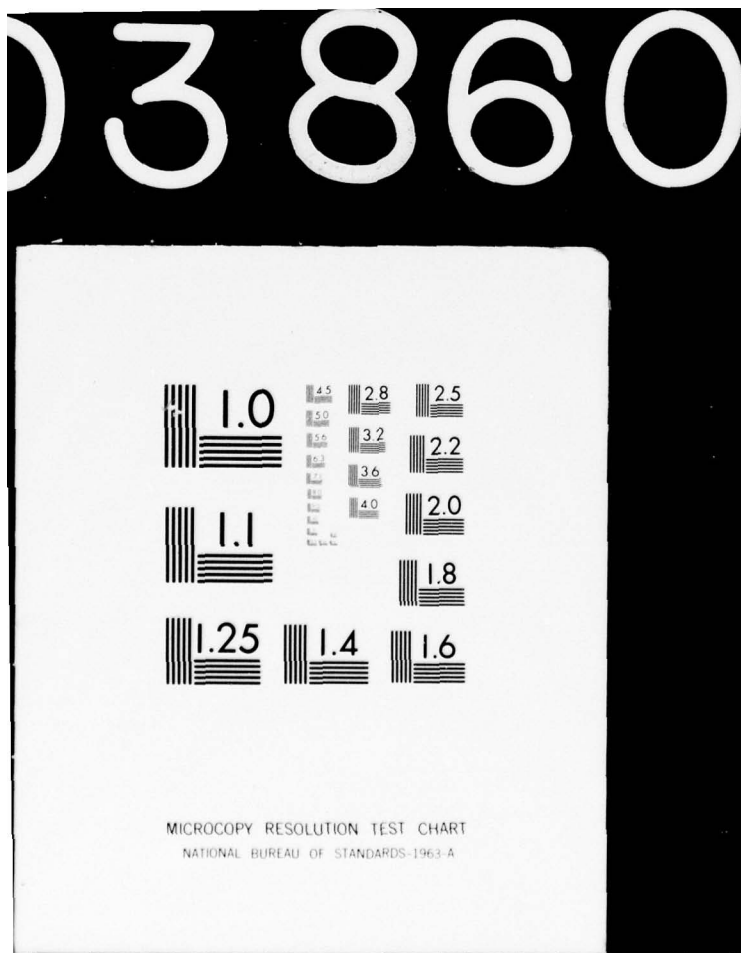
Theses
Directed: Nizamettin Cetinyilmaz, "Application of the Computer for Real Time Encoding and Decoding of Cyclic Block Codes," Master's Thesis, December 1975.

Robert E. Dzialo, "An Analysis of Motor Function and Control in the Human Nervous System," Master's Thesis, December 1975.

Douglas D. Frisbie, "Preferred Frequencies in the Human Electroencephalogram," Master's Thesis, December 1975.

Dennis C. Marvel, "A Versatile System for Interfacing Subject to Task in EEG Analysis with Biofeedback," Master's Thesis, December 1975.

Peter S. Pierpont, "Improvement and Testing of 40 KHZ FM Modulated Underwater Communications System for Free Swimming Divers," Master's Thesis, December 1975.

Dennis C. McCormich, "Preferred Frequencies of the Human Electroencephalogram in Response to Auditory Stimuli," Master's Thesis, June 1976.

Hugh P. Parsons, "Frequency Analysis of Human Electroencephalogram in the Process of Performing Specific Tasks," Master's Thesis, June 1976.

Title: Tegulometric Analysis

Investigator: G. Marmont, Professor of Electrical Engine-
                     ering

Sponsor: Naval Electronics Laboratory Center

Objectives: The tegulometric method of analysis has
                     proved to more sensitive, by an order of
                     magnitude, in detecting frequency signatures
                     present in a complex, multi-source signal
                     as compared to more conventional methods
                     such as discrete fourier transform analysis.
                     The priciple objectives are:

                     (1) To apply the method effectively in anal-
                     ysis of such signals as ASW sonograms and
                     electroencephalograms.

                     (2) To further develop techniques for de-
                     tection of very weak signals buried in noise.

                     (3) To apply the method to other types of
                     signals, using frequency translation tech-
                     niques where required.

                     It is expected that NELC will continue sup-
                     port of this research effort, with the goal
                     of leading to operational devices.

Summary: Tegulometric analysis implies the dissection
                     of a complex signal which is a summation of
                     signatures from many sources and contamin-
                     ation with "noise". When one examines a
                     time domain representation of the signal
                     having a narrow frequency range, a tegular
                     structure becomes apparent. (A "tegule" is
                     defined as a waxing and then waring sinusoid).
                     Because the tegules from the same or from
                     several sources overlap in an irregular man-
                     nar, there are many times when a momentarily
                     stronger tegule "captures" its weaker neigh-
                     bors. Identification of the frequency of
                     the momentarily stronger tegule can be mea-
                     sured via a zero-crossing algorithm. Each
                     new frame of data is scanned with a narrow
                     band frequency operating the relative occur-
                     rence of component frequencies determined,
                     and the counts deposited in a histogram
                     block having frequency as the abscissa.

                     New developments of the method include test-
                     ing of the method on ASW phonogram recordings
                     and a comparison of the results versus those

using current operational FFT types of analysis. Tegulometric analysis shows about an order of magnitude improvement in sensitivity.

Further development, still under way, is the extension of the method to the detection of very weak signals buried in noise. Additional computational techniques, only feasible with fast digital processing, have helped reveal S/N ratios of -24db, the noise being measured on a 1 HZ bandwidth basis.

Publications: None

Title:	Use of Frequency Division in Demodulating FM Carrier Signals
Investigator:	G. A. Myers, Associate Professor of Electrical Engineering
Sponsor:	Naval Electronics System Command
Objective:	To measure the performance of frequency demodulators that use frequency division before demodulation.

Summary: Binary digital data was used to frequency modulate (FM) a carrier. Noise was added to this FM signal. The sum of signal and noise voltages was applied to a divide-by-N circuit which reduced the carrier frequency and signal bandwidth by factors of $\frac{1}{N}$. A pulse counting demodulator (PCD) was used to recover the binary data. Errors were counted to form a plot of probability of error vs signal-to-nose ratio. Results for values of N = 1, 2, 6, 8 and 12 are tabulated. From these experimental results, it is concluded there is no significant improvement in system performance with frequency division.

Publications: Duong Tuan Viet, "Measured Effects of Frequency Division on the Performance of Pulse Counting Frequency Demodulators," Master's Thesis, July 1976

Title: Range Studies Program; Range Display and
                    Water Simulator Studies

Investigator: G. A. Myers, Associate Professor of Elec-
                    trical Engineering

Sponsor: Naval Torpedo Station

Objective: To become familiar with a 3-D instrumented
                    range and to relate such a system to the
                    future requirements of the ranges of the
                    Naval Torpedo Station.

                    To design an electrical circuit which would
                    simulate the effects of the propagating
                    medium on a sonar signal.

Summary: A visit was made to Miramar Naval Air Station,
                    San Diego to observe the display subsystem of
                    the Air Combat Maneuvering Range (ACMR).
                    Both in-flight and taped exercises were
                    viewed. Information on system cost and capa-
                    bility was obtained and documented. It
                    appears a system like the ACMR could be effec-
                    tively used for the following Naval Torpedo
                    Station Functions: real time control/safety/
                    recovery and measurement of parameters re-
                    quired in proofing torpedoes and in research
                    and development; playback and simulation in
                    WSAT training and in other fleet exercises.

                    A circuit is synthesized which approximates
                    the attenuation and phase shift vs frequency
                    characteristics of sea water in the range
                    50 kHz to 100 kHz over a distance of 1000
                    yards. Component values are specified.
                    Simulation can be achieved for ranges of M
                    kiloyards be cascading M such networks (M
                    is a positive integer). The chosen design
                    provides an excellent simulation of the ab-
                    sorption of the assumed propagating medium
                    in the frequency range 50 kHz to 100 kHz.

Publications: None

Title: An Investigation of Interval Modulation

Investigator: G. A. Myers, Associate Professor of Electrical Engineering

Sponsor: Naval Electronics Systems Command

Objective: To determine the effect of varying the time between bursts of a sinsusoidal carrier in accordance with a message to be transmitted, and to study means of recovering the message from such an interval modulated (IM) carrier.

Summary: Effort to date indicates that a phase - locked loop can be used to recover the message from a particular IM carrier. Present work is concerned with developing a versatile modulating circuit. Spectral analysis of the IM carrier is being initiated. Other work on this continuing area of research will include the measurement of effects of noise and the transmission of human speech.

Publications: None

Title: Shipboard RFI in UHF SATCOM

Investigator: J. E. Ohlson, Associate Professor Electrical Engineering

Sponsor: Naval Electronic Systems Command

Objective: This study is to characterize the radio-frequency-interference (RFI) environment on ships of the Fleet. Susceptibility to interference of the SATCOM receivers is to be evaluated. A simulator is to be built to test improvements in receivers. Anti-RFI techniques are to be developed and tested.

Summary: A test instrumentation package was developed and was used to measure RFI on board several ships during at-sea operations. The bit-error-rates of the AN/WSC-3 and AN/SSR-1 SATCOM sets have been measured. Desensitization characteristics of the two radios have also been determined. A shipboard RFI simulator has been built and is now an operational laboratory tool. The shipboard RFI environment has been characterized. Anti-RFI techniques are now being evaluated.

Publications: R. W. Adler, J. E. Ohlson, B. K. Hollar, "Evaluation of the AS-3018/WSC-1(V) Shipboard Satcom Antenna," Technical Report NPS-52AB76031, March 1976.

R. F. Carlson and J. E. Ohlson, "Receiver Desensitization of the AN/WSC-3 Satellite Communications Set, "Technical Report NPS-620L76091, September 1976.

R. F. Carlson and J. E. Ohlson, "Receiver Densensitization of the AN/SSR-1 Satellite Communications Receiver," Technical Report NPS-620L76101, October 1976.

R. F. Carlson and J. E. Ohlson, "Bit-Error Rate Measurements on the AN/WSC-3 and AN/SSR-1 Satellite Communications Sets," Technical Report NPS-620L76102, October 1976.

J. E. Ohlson and T. C. Landry, "Shipboard Radio Frequency Interference in UHF Satellite Communications," Technical Report NPS-620L76103, October 1976.

T. D. B. Menlo and J. E. Ohlson, "ITU Registrations and Navy UHF SATCOM," Technical Report NPS 620L76104, October 1976.

G. B. Parker and J. E. Ohlson, "Deck Boxes for UHF SATCOM Radio Frequency Interference Study," Technical Report NPS-620L76105, October 1976.

F. E. Mace, Jr., and J. E. Ohlson, "A High Level Noise Blanker and RF Amplifier System for the UHF Band," Technical Report NPS-620L76106, October 1976.

D. C. Arneson and J. E. Ohlson, "A Level Density Analyzer for Shipboard RFI Measurements," Technical Report NPS-620L76107, October 1976.

A. R. Shuff and J. E. Ohlson, "Instrumentation Package for Measurement of Shipboard RFI," Technical Report NPS-620L76108, October 1976.

E. S. Brick and J. E. Ohlson, "A Simulator for Shipboard Radio Frequency Interference in Satellite Communications," Technical Report NPS-620L76109, October 1976.

Title: Computer-Aided Acoustic Imaging

Investigator: John P. Powers, Associate Professor of Electrical Engineering

Sponsor: Foundation Research Program (6.2)

Objective: This study investigates the feasibility of using a computer to obtain images of objects from the amplitude and phase of the diffraction pattern caused by ultrasound reflected from or transmitted by an object. The specific objective of this period of research was to investigate the implementation of the scalar diffraction integrals on the computer and to design an experimental arrangement to magnetically record the ultrasonic diffraction pattern over a plane. This is a continuing project.

Summary: The study of the implementation of the diffraction integrals compared the Fresnel integral representation and a spatial frequency domain approach. Both techniques use two dimensional Fast Fourier Transform (FFT) algorithims but differ in their geometry and in other respects. Based on the considerations that a computer aided imaging technique would require several evaluations of the integrals at arbitrary distances and that the spatial frequency approach is compatible with all frequency domain operations (e.g., Weiner filtering), it was concluded that the implementation in the spatial frequency domain was advantageous for use in imaging systems that might include an image processing capability. During the course of study computer programs for both diffraction integrals were written. As part of the experimental verification of the imaging technique a mechanical raster scanning system was designed to cover a flat planar area while electronically sampling both the phase and amplitude of the ultrasonic diffraction pattern of various objects in the laboratory environment. When assembled in the future this data acquisition system will provide experimental verification of the results obtained in previous studies from computer simulated objects.

Publications: J. P. Powers, "Computer Simulation of Scalar
Linear Acoustic Diffraction," <u>Acoustical Holography</u>,
Vol. 7, Lawrence Kessler, Ed., <u>Plenum Press</u>,
New York.

Title: Magnetic Background Noise Studies

Investigator: George L. Sackman, Associate Professor of
                    Electrical Engineering

Sponsor: Foundation Research Program (6.2)

Objective: The long-term objective of this study is to
                    characterize the spectral density, amplitude
                    probability density, and spacial cross-correlation
                    of magnetic background noise. The immediate
                    objective is to establish a magnetometer data
                    acquisition system capable of recording simultaneous
                    measurements of total field, vector field,
                    and field gradient at several locations in
                    a form suitable for analysis by digital computer.
                    These studies are part of a continuing program
                    to agument Navy system R&D in magnetic detection
                    and degaussing of submarines.

Summary: This study is in its initial phase and the
                    major effort during the period covered by
                    this report was devoted to re-establishing
                    a magnetic observatory site, using the NPS
                    Cesium magnetometer. A data acquisition system
                    based on direct measurement of the Larmor
                    period was developed which has a response
                    time less than 2.5 milliseconds. However,
                    noise introduced by the FM tape recording
                    system limited resolution to 0.3 gamma. An
                    improved system using digital tape recording
                    is being developed.

Thesis Directed:

                    LT C. L. Xefteris, USN, "A Magnetometer Data
                    Acquisition System," Master's Thesis, June
                    1976.

Title: Range Studies -- Non-acoustic Sensors

Investigators: G. L. Sackman, Task Group Leader, Associate
                  Professor of Electrical Engineering
                  M. H. Bank, Assistant Professor of Aeronautics
                  D. B. Hoisington, Professor of Electrical
                  Engineering

Sponsor: Naval Torpedo Station

Objective: The overall objective of this study has
                  been to consider the implications of the
                  forthcoming Trident facility on non-acoustic
                  services which Naval Torpedo Station might
                  be called upon to provide.

Summary: The immediate objective is to survey the
                  area of magnetic silencing (deperming/degaus-
                  sing) and potentially available magnetic sen-
                  sors suitable for a magnetic testing range.
                  A review of the literature on deperming and
                  degaussing has been written, and an annotated
                  bibliography compiled. The state of art in
                  magnetometers has been assessed, including
                  visits to instrument manufacturers, and can-
                  didate sensors for magnetic range use have
                  been examined.

Publications: O. B. Wilson (Editor), "Range Study Program,
                  Annual Summary Report," NPS-71W176081,
                  August 1976.

Title: Seawater Properties that Cause Scattering and Absorption of the ORIC System Light Beam

Investigator: Donald A. Stentz, Associate Professor of Electrical Engineering

Sponsor: Naval Air Development Center

Objectives: The objectives of this task were to:
a. Locate and Catalog sources of optical scattering data for various kinds of seawater. b. Study the relationship of optical scattering to temperature profile, and other properties of the first 300 meters of the water column, and determine the validity of these relationships for predicting location and magnitude of optical scattering as it concerns the ORIC system. c. Determine the variability in terms of both spatial and temporal characteristics. d. Suggest a format for presentation of optical scattering data, and initiate an OEICS scattering atlas.

Summary: The literature concerned with the propagation of visible light through seawater has been reviewed. Much of this research, both theoretical and in situ measurements, have been carried out at wavelengths close to that of ORICS. Of particular interest is the absorption and scattering characteristics of seawater due to dissolved organic matter, chemical content (salts), temperature variations, and suspended particulates of all descriptions. This search has revealed a growing number of reports concerned with the determination of the scattering of light, both natural and artificial, when viewed from above the surface of the ocean. The principle thrust of this work is to find a satisfactory model of the water path from which a measure of the light radiated from the surface will correctly indicate the optical characteristics of the water column, and indirectly indicate the presence or abscence of certain kinds of dissolved organic matter, organic and inorganic suspended matter, and perhaps even temperature variations of the water column.

Investigators of the optical properties of the ocean have suggested at least four analytical approaches to approximate the absorption and scattering of radiant flux that

impinges upon the surface of a flat ocean.
The incident light energy is thought to
arrive normal to the surface for purposes
of ORICS, however, these investigators used
direct sunlight, sky light, and various kinds
of artificial light including the laser which
may arrive at any angle. Their sensors were
designed to accept light from all direction
on a Lambert surface. The four approaches
taken by these investigators are: a. Mult-
iple integration using the volume-attenu-
ation and scattering coefficients of the
water column. b. Radiative Transfer. A
method using iterative computation and
intergo-differential equations. This method
seems to be the most promising. c. Monte
Carlo computational procedures. This ap-
proach, as well as the radiative transfer
approach use Mie and/or Rayleigh scattering
functions to determine the angle of scatter
for each photon collision. d. Diffusion
theory.

The particular interest in the examination
of each approach was to obtain at least an
intuitive feeling for the water parameters
that affect the propagation (absorption and
scatter) of the photon as it travels between
light source and sensor. The reflection
characteristics of the target were not con-
sidered at this time. A number of inter-
esting conclusions can be made from these
models. None of the approaches perfectly
model the water column, however tests made
by the researchers indicate that some of
the methods are reasonably accurate if
certain things are known about the water
column such as the type of water, depth,
mixing, temperature, etc.

Future work will include an examination of
various types of seawater in regard to chem-
ical content, absorption and scattering co-
efficients, size and characteristics of
suspended particulate matter, and tempera-
ture variations that appear to have an influ-
ence on the ORICS light beam. The spatial
and temporal variation will be studied as
well. It the laser light is modulated in
intensity by these natural parameters of the
water column, then perhaps the ORIC system
can be used as a search instrument where
the natural characteristics of the column

have been shifted, mixed, or otherwise ad-
justed by the passage of a submarine. If
one of these models can be used as the sig-
nal processing approach, the ORIC system may
also be useful as an oceanographic instru-
ment.

Further work on this project has been dis-
continued because of funding, however a
final report is nearly completed which will
summarize the literature search and the op-
tical absorption and scattering of the ORICS
light beam.

Publications: Donald A. Stentz, "A Chronological Study of
the Measurement of the Optical Properties
of Ocean Water; and an Atlas of the Diffuse
Attenuation Coefficient, K, of Tropical
Atlantic Ocean Waters," Technical Report
NPS-52Sz75061, June 1975.

Title: Application of Recursive Comb Filter to MTI Radar Signal Processing

Investigator: T. F. Tao, Associate Professor of Electrical Engineering

Sponsor: Foundation Research Program (6.2)

Objective: To investigate the feasibility of using recursive comb filter as the canceller of a MTI radar.

Summary:
When a recursive filter uses delay devices of N delay stages, its frequency characteristics have a comb feature with a period of fs/N where fs = sampling frequency. By properly designing the feed forward and the feedback coefficients, the comb filter characteristics can be made to have high attenuations at a series of periodically spaced frequencies at d.c. and the multiples of fs/N and good transmission in between. If fs/N is matched to the pulse repetition frequency of a radar, this type of comb filter can be used as the canceller in a MTI radar. However, additional requirements must be met for bandwidth consideration. Altogether, three relations should be satisfied:

Canceller requirement $=$ fs/N = PRF

Bandwidth requirement $=$ $BW \geq \dfrac{1}{2\tau}$

Sampling frequency requirement = fs $\geq$ 2BW = $\dfrac{1}{\tau}$

where τ = radar pulse width

BW = electronic bandwidth

Several canceller type of comb filters have been studied both experimentally and theoretically using two types of delay lines: 8 bits CCD and 96 bits CTD delay lines. However, their bandwidth is not adequate for real MTI radar applications. Instead, simulated MTI radar signals with less demanding bandwidth requirement were used to investigate the feasibility of using this type of comb filter as cancellers.

The result is encouraging and is reported
in the following paper. Further investigation
is being continued because a new CCD of better
bandwidth and long enough delay time recently
became available (although its dynamic range
is more limited).

Publications: T. F. Tao, V. Iamsaad, S. Holmes, B. Freund,
L. Saltre and T. Zimmermann, "Sampled Analog
CCD Recursive Comb Filter," Proceedings of
1975 International Charge Coupled Device Applica-
tions Conference, San Diego, CA, October 1975,
pp. 257-266.

Theses Directed:

L. T. Saetre, "Sampled Analog Recursive Comb
Filters and Their Application to MTI Radar,"
Master's Thesis, December 1975.

S. V. Holmes, "Theory of Operation and Applications
of Sampled Analog Devices in Recursive Comb
Filters," Ph.D. Thesis, June 1976.

Title: Sampled Analog Signal Processing and
IV - VI MIS Study

Investigator: T. F. Tao, Associate Professor of
Electrical Engineering

Sponsor: Naval Electronics System Command

Objective: (1) To develop the theory and design
procedure of recursive filter using
charge transfer devices.

(2) To develop high dielectric constant
insulator fabricated by a low temperature
process compatible with non-silicon semi-
conductors.

Summary: (1) Sampled analog signal processing
using CTD devices are generally similar
to digital signal processing but with some
significant differences. This study is
concerned with the CTD recursive comb
filters. Two design procedures have been
used. One is indirect which first designed
a transfer function H(S) using the well
developed analog filter theory and then
transforms H(S) into H(Z) for implementation
using CTD devices. The other is direct which
obtains a transfer function H(Z) directly from
a specified frequency domain requirement.
Several filters designed by these procedures
were studied both experimentally and theoreti-
cally. It was found that the digital recur-
sive filter theory must be significantly
modified to explain the experimental behavior
of sampled analog recursive filters. The
major differences are the frequency dependence
of the filter coefficients and the multiple
delay stages of the delay line.

(2) High dielectric constant insulator is of
interest in the fabrication of Metal-Insulator
Semiconductor devices of IV-VI semi-conductors
for infrared charge coupled imaging applica-
tions. Because the material limitations of
these IV-VI semiconductors, fabrication process
can not exceed 300-500°C. During this period,
an electrolytic anodization process has been
used to make tantulum oxide, a high dielectric
constant insulator. Si of both n type and p
type have been used to develop this process.
Encouraging results have been obtained which
will be reported in detail upon the completion
of an engineer's thesis in December 1976.

Publications: T. F. Tao, V. Iamsaad, S. Holmes, B. Freund, L. Saetre and T. Zimmermann, "Sampled Analog CCD Recursive Comb Filter", Proceedings 1975 International Charge Coupled Device Applications Conference, San Diego, California, October 29-31, 1975, pp 275-266.

T. F. Tao and S. Holmes, "Hardware Signal Processor Development--Session Summary" Proceedings Ninth Asilomar Conference on Circuits, Systems and Computers, November, 1975, Asilomar, California, pp 289-299.

Theses Directed: S. V. Holmes, "Theory of Operation and Application of Sampled Analog Devices in Recursive Comb Filters," PhD. Thesis, June 1976.

M. Ang Vong, "Study of an Integrated Circuit Tapped Delay Line and its Applications to Signal Processing," Master's Thesis, June 1976.

Title:	Analytical Studies of Captured Air Bubble Type Surface Effect Ships
Investigator:	G. Thaler, Professor of Electrical Engineering
Sponsor:	Naval Sea Systems Command
Objective:	To validate and update the Digital Simulation Program developed by Oceanics, Inc. To develop techniques for applying this program to predict the dynamic behavior of a variety of captured air bubble boats including the XR-3, as well as extension to a 2000 ton size. To study problems of scaling habitability, dynamics and control which are of importance for future developments.
Summary:	Validation studies of the XR-3 program led to updating, studies of plenum pressure dynamics, and preliminary studies of the effect of introducing a membrane in the plenum wall (deck). Parallel studies of the frequency response of the XR-3 have led to good correlation with sea state behavior and better understanding of basic principles.
	Current studies include investigation of minimizing power consumption by control of plenum pressure and pitch angle. Studies of sealing problems are also being carried out, with particular attention to the interpretation of towing tank data in terms of full size ships.
Theses Directed:	Boggio, J. M., "A Study of Pressure-Volumn Rates and Plenum Membrane Additions to the Captured Air Bubble Surface Effect Ship XR-3 Digital Computer Loads and Motion Program," Master's Thesis, June 1976.
	Booth, B. F. III, "The Frequency Response and Operating Characteristics of the XR-3 Loads and Motions Program," Master's Thesis, June 1976.
	Menzel, R. F., "Study of the Roll and Pitch Transients in Calm Water Using the Simulated Performance of the XR-3 Surface Effect Ship Loads and Motions Computer Program, " Master's Thesis, December 1975.

Title: Torpedo Tracking

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Torpedo Station

Objective: The application of Kalman filtering to torpedo
range tracking made in the location of sensor
arrays.

Summary: The application of Kalman filtering to the
on-line real-time tracking problems at Keyport
as well as for improving the post-run data
analysis is underway. Two thesis students are
involved in the project. A workshop on Kalman
filtering has been presented to engineers at
keyport. A tape of a Mark 48 torpedo track has
been obtained and is presently being used to
check out our computer tracking algorithm for
this application. Two computer programs have
been implemented on the Naval Torpedo Station
computers and a briefing has been given to
their possible users. The software was pre-
sented with a summary of the two thesis projects
which were completed this December. Work is
continuing on this project and a report will be
presented in June.

Publications: None

Title: Naval Applications of Scanning Processor

Investigator: H. A. Titus, Professor of Electrical
                  Engineering

Sponsor: Naval Electronic Systems Command

Objective: To develop optimal techniques for scanning,
                  target tracking, and pattern recognition in
                  the application of CCD and CID devices to
                  target tracking.

Summary: A study is being made of the optimal scanning
                  techniques for target tracking, and pattern
                  recognition in the application of CCD and CID
                  devices to target tracking.

                  A study is also being made of the optimal
                  scanning techniques for target tracking in a
                  two-dimensional field and for the optimal
                  tracking thereof. Techniques for integration
                  of pattern recognition schemes and target
                  tracking algorithms are being looked at and
                  a computer simulation is being developed.

                  In addition, coherence functions are being
                  developed having two-dimensional axes of time
                  delay and doppler and the tracking of
                  significant parameters in this two-dimensional
                  plane is being addressed. This work is just
                  getting underway. One thesis student is
                  involved in this image processing effort.

Conference   H. A. Titus and M. Schacher, "Image Processing
Presentation: Algorithms for IR Target Tracking," presented
                  at Asilomar Conference on Circuits and Systems
                  Monterey, California, November 1976.

Publications: None

Title: Coherent and Incoherent Tracking and Undersea Surveillance

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Electronic System Command

Objective: It is our intent to demonstrate several techniques for coherent and incoherent acoustic tracking for both the near field problem (P3C) and for long-range applications.

Summary: The program for submarine tracking using extended Kalman filtering with single difar buoy or multiple buoys was previously developed for incoherent signals. This work has been extended to cover this potentiality coherent signal. A study has been made of the initialization problems involved therein. Three thesis students have completed work in this program.

Conference Presentations: H. A. Titus, D. E. Kirk and G. Mitschang, "Locating with Fixed Sensor Having Observations of Signal Angle of Arrival and Doppler Shifted Frequency," presented at Sixth Symposium on Nonlinear Estimation Theory and its Applications, San Diego, California, September 1975.

H. A. Titus and D. E. Kirk, "Evaluation of Linear Estimation for Nonlinear Systems," presented at Asilomar Conference, Monterey, California, November 1975.

Title: Computer Program Improvements for the Laser
Gyro Application in a Medium Range Missile

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Weapons Center

Objective: This study is to improve upon the Kalman
filtering algorithm presently proposed for a
laser-gyro system under study at the Naval
Weapons Center.

Summary: A thesis student has begun work on the Kalman
filter program for the optimal reset of a laser
gyro with updating. An attempt here is being
made to improve upon the algorithms developed
for inflight updating of strap-down inertial
mid-course guidance systems in the work by
Gregory Nazarof of the Weapons Development
Department at China Lake. The thesis student
developed the simulation and completed his work
in December. A second student is starting work
in this area and will continue his work at the
Draper Laboratories at MIT. This work is
presently unfunded.

Publications: None

Title: Integrated Aircraft Maneuver and Jamming for Missile Evasion

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Air Systems Command

Objective: This study involves the optimal use of jammers for missile evasion as well as the integration of optimal maneuvers.

Summary: Funding for this project was received on June 26, 1976, and work is presently in progress. Several simulations are being developed to evaluate optimum jamming techniques against specific missiles. The modulation schemes involved in the servo tracking loops of the sensors are being investigated. The sensitivity of several AGC circuits and doppler tracking circuits are being studied. In addition, optimal control theory is being applied to attempt optimal maneuvers to avoid the missile. A Ph.D. candidate student is involved in this project. Included in this study will be investigations of home on jam, AGC gate capture, velocity gate pull-off, angle gate steal, and J to S requirements for expendable and on-board jammers.

Conference Presentations: H. A. Titus with D. B. Hoisington, "Electronic Warfare and Missile Design," presented at the Naval Tactical Missile Colloquium, 20-30 April, 1976, Naval Postgraduate School, Monterey, California.

Title: Mission Planning for EA6B

Investigator: H. A. Titus, Professor of Electrical
                    Engineering

Sponsor: Naval Air System Command

Objective: To devise computer-aided display programs for
                    utilization in mission planning in EA6B.

Summary: Two thesis students are presently developing
                    a computer program to handle mission planning
                    problems involving hostile radar, missile and
                    gun placement. An EOB is placed in the
                    computer and a computer search is made for
                    optimal tracks to maximize the effectiveness
                    of the EA6B's jammers. A program will indicate
                    on the display the reduced radar environment
                    due to jamming and give quantitative measures
                    of potential effectiveness. Through the
                    display the operator may interact with the
                    system to improve upon the computer's solution
                    and through a process of evolution, optimum
                    mission plan for EA6B support will evolve. A
                    hard copy of mission profiles and stand-off
                    regions will be the output from the program.
                    The first student thesis work will be published
                    in June of 1977.

Publications: None

Title:	Position Locating Reporting System
Investigator:	H. A. Titus, Professor of Electrical Engineering
Sponsor:	Naval Electronic Systems Command
Objectives:	Kalman filtering techniques are applied to the Position Locating Reporting System involving many radio transponders ranging on each other in a computer controlled enviornment.

Summary:

In the PLRS system a master computer will keep track of some 350 radio transmitter-receiver units which may be placed in helicopters, aircraft, tanks, and with troops. The essential mechanism for locating is obtained by pulse transient time. Because of obvious problems to be encountered with terrain, the computer may connect to a unit which it desires to locate via several units. These units would act as relay units in the transferral of time pulses. In addition, in order to obtain an initial location, several units are required to be in contact with the unit to be located all via the computer. When a unit location is to be updated, the computer must determine which units it wishes to make contact through to obtain an optimum reduction in the covariance of error associated with the location of the unit in question. The problem is complicated additionally by the fact that these relay units themselves have uncertain location with associated covariance of error in position.

A simulation was performed involving an aircraft in a 3g turning maneuver and several ground relay stations. An effective algorithm was developed for the choice of which relay station is to be used. This simulation is now being extended to handle a multitude of ranging units each with appropriate dynamics and associated covariances of error in their position location.

Publications:	H. A. Titus and C. A. Ditmar Jr., "The Application of Extended Kalman Filtering to the Position Locating Reporting System (PLRS)," Technical Report NPS-52Ts-75121, December 1975.

Title: Nonlinear Sources of Harmonics in Power
                    Line Voltages and Currents

Investigator: M. Wilcox, Associate Professor of Electrical
                    Engineering

Sponsor: Naval Ship Engineering Center

Objective: Not well defined as yet but in general seems
                    to be to determine what can be done to recog-
                    nize and correct harmonies in the power
                    lines due to nonlinear electromagnetic
                    devices.

Summary: As indicated in the objective, this is in
                    the planning stage. Again literature
                    searches are being made, preparatory work in
                    the laboratory is being done depending on
                    availability of appropriate equipment. A
                    proposal has been submitted but no action
                    taken as yet.

Publications: None

Title: Dynamic Braking of Ships

Investigator: M. Wilcox, Associate Professor of Electrical Engineering

Sponsor: Naval Ship Engineering Center

Objective: To investigate the possibility of recovering and storing some of the ships kinetic energy when stopping a ship.

Summary: Since funding is unknown, the project is still in the beginning stage. So far information gathering is being attempted, appropriate literature searches are being made, equations of motion are being established and initial programming is being done.

Publications: None

DEPARTMENT OF METEOROLOGY

The research program in the Department of Meteorology has continued along several main lines as follows: (1) Numerical weather prediction, (2) Analysis and dynamics of tropical weather systems, (3) Marine boundary-layer turbulence, (4) Tropical cyclone prediction, (5) Marine fog observation and prediction. Under each of these headings, a number of related investigations are being pursued by various faculty members, as described briefly below.

NUMERICAL WEATHER PREDICTION

Under this heading are included: modeling of the large-scale weather systems by G. J. Haltiner and R. T. Williams; numerical prediction of ocean-hurricane interaction by R. L. Elsberry; ocean circulation modeling and prediction by R. L. Haney; solar and terrestrial transfer simulation by F. L. Martin; and boundary-layer parameterization by K. L. Davidson.

ANALYSIS AND DYNAMICS OF TROPICAL WEATHER SYSTEMS

C.-P. Chang, R. L. Elsberry and R. T. Williams are investigating various aspects of the dynamics of tropical weather systems, including development of hurricanes and typhoons by Elsberry, the dynamics and energetics of tropical wave disturbances and circulations by Chang and Williams, and the diagnostic analysis of tropical systems by Chang.

MARINE BOUNDARY-LAYER TURBULENCE AND TURBIDITY

This research area includes K. L. Davidson's observational studies of the air motion induced by ocean waves and its relation to boundary fluxes, and boundary-layer simulation for numerical weather prediction models. Turbulence plays an important role in the vertical transport of momentum, heat and water vapor which are essential processes in weather prediction. K. L. Davidson, in collaboration with other Naval Postgraduate School faculty, is involved in an interdisciplinary study of turbulence and aerosal effects on optical propagation in the marine boundary layer. This study includes observational experiments to obtain descriptions of the vertical distribution of small scale turbulence or properties which affect optical propagation and aerosal distributions.

TROPICAL CYCLONE CLIMATOLOGY PREDICTION

The climatology and prediction of movement of eastern North Pacific tropical cyclones has been pursued by R. J. Renard and J. D. Jarrell. The developed analog prediction technique, EPANALOG, is now being used operationally.

MARINE FOG OBSERVATION AND PREDICTION

An interdisciplinary project, involving R. J. Renard and K. L. Davidson, Department of Meteorology, and faculty members from the Departments of Oceanography, and Physics and Chemistry, is concerned with the observation, climatological analysis, and prediction of fog over open ocean and coastal regimes, both on a regional and hemispheric scale.

Title: Tropical Wave Dynamics

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

Sponsor: National Science Foundation

Objective: To study the dynamics of large-scale wave motions
in the tropical troposphere and lower stratosphere
in terms of theoretical interpretation of their
development, maintenance and structure and the
inter-relationship between them.

Summary: Many aspects of tropical waves are included in
this study, but the present emphasis is on the
excitation mechanisms of the various types of
waves. The main results obtained so far include: 1)
selection of stratospheric Kelvin waves can be
explained by randomly-distributed heat sources in
the troposphere; 2) wave-CISK (instability due to
internally-induced cumulus heating) would give rise
to very small growth rates and large vertical wave-
lengths; 3) inclusion of viscous damping comparable
to that derived from observational studies would
alter the equatorial wave theory greatly for slowly-
moving waves, and can explain the basic character
of the tropospheric waves; 4) first order effect
of a mean flow with varying barotropic instability
depends on the relative contributions of several
advective terms; and 5) CISK will not greatly alter
the barotropic instability selection mechanism.

Publications: C.-P. Chang, "Vertical Structure of Tropical Waves
Maintained by Internally-Induced Cumulus Heating."
Journal of Atmospheric Sciences, Volumn 33, 729-739,
1976.

C.-P. Chang, "Forcing of Stratospheric Kelvin Waves
by Tropospheric Heat Sources." Journal of Atmos-
pheric Sciences, Volumn 33, 1976.

C.-P. Chang, "Comments on Instability Theory of
Large-Scale Disturbances in the Tropics." Journal
of Atmospheric Sciences, Volumn 33, August 1976.

C.-P. Chang and R. T. Williams, "Barotropic
Instability of a Spatially-Varying Mean Flow."
Presented at the Conference on Atmospheric Waves
and Stability, Seattle, March-April 1976. Abstract
published in Bulletin of American Meteorological
Society, 57, 1976.

C.-P. Chang, "Viscous Internal Gravity Waves and
Low-Frequency Tropical Oscillations." Presented
at Tenth Technical Conference on Hurricanes and
Tropical Meteorology, Charlottesville, VA, July
1976. Abstract published in Bulletin of American
Meteorological Society, 57, 1976.

Title: Numerical Simulation of Monsoon Circulations

Investigator: C.-P. Chang, Assistant Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To simulate planetary-scale circulations and
                    associated synoptic-scale wave disturbances in a
                    global numerical model and to study the scale
                    interactions.

Summary: This study focuses on two aspects of the monsoonal
                    circulation during Northern Summer: the dynamics
                    of the synoptic-scale wave disturbances generated
                    by the instability of zonal-mean and planetary-scale
                    flows in the upper trosposphere, and the simulation
                    of the planetary- and synoptic-scale motions of the
                    monsoon in a numerical model. The first part is
                    studied as a theoretical problem by treating the
                    linearized barotropical vorticity equation both
                    analytically and numerically. The results are
                    compared to those obtained from the second part, in
                    which a numerical model essentially similar to the
                    UCLA general circulation model is used, but
                    presently the study involves specified heating only.
                    Testing of fully parameterized heating will be
                    continued in the following year.

Conference
Presentations: C.-P. Chang, R. T. Williams and J. B. Tupaz, "Study
                    of Planetary and Synoptic-Scale Waves of the
                    Northern Summer Monsoon." Presented at the GARP
                    Study Conference on tropical numerical modeling,
                    Exeter, England, April 1976.

Title: Interannual and Spatial Variation of Tropical
                Waves

Investigator: C -P. Chang, Assistant Professor of Meteorology

Sponsor: National Environmental Satellite Service,
                National Oceanic and Atmospheric Administration

Objective: The structure and properties of the tropical
                easterly waves have been found to vary considerably
                between different regimes and time periods. This
                study investigates the possible roles played by
                the temporal and spatial sea-surface temperature
                (SST) variations on the waves using radiosonde
                and satellite data and a tropical objective-
                analysis data set.

Summary: Time series of tropical western Pacific radio-
                sonde data during two contrasting eight-month
                periods of SST anomalies, May-December 1972,
                which has abnormally high SST in the central and
                eastern Pacific, and May-December 1973 which has
                below normal SST in the same region, have been
                analyzed. In both periods, the waves have the
                same periodicity of 4-5 days and a lower tro-
                pospheric zonal wavelength on the order of
                3300 km, but their vertical phase and amplitude
                distributions as well as the thermal structures
                are different. The results are discussed in
                terms of two possible influences the SST varia-
                tions may have on the waves: 1) direct effect,
                the warmer SST represents stronger thermal
                control through cumulus heating; and 2) indirect
                effect, the variation of SST changes the large-
                scale mean wind circulation which, in turn, has
                a strong impact on the wave vertical structure
                and the relative importance of energy sources
                other than cumulus heating. A schematic model
                of these influences was proposed which may be
                applied to both the temporal and the spatial
                variations of SST. Continuation of this work
                using satellite data is planned for next year.

Publications: C -P. Chang and C. R. Miller, III, "Spectrum
                Analysis of Easterly Waves in the Western Pacific
                During Two Contrasting Periods of Sea-Surface
                Temperature Anomalies," Fall Annual Meeting of
                American Geophysical Union, San Francisco,
                December 1975. Abstract published in Trans-
                actions, 57, 997, 1975.

C -P.Chang and C. R. Miller, III, "Spectrum Analysis of Easterly Waves in the Tropical Pacific During Two Contrasting Periods of Sea-Surface Temperature Anomalies," Technical Report NPS-63Cj76071, July 1976.

C -P. Chang and E. Maas, Jr., "A Case of Cross-Equatorial Displacement of a Vortex," Monthly Weather Review, Volumn 104, 1976.

Title: Tropical Wave Dynamics

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

Sponsor: Foundation Research Program (6.1)

Objective: To study the dynamics of large-scale wave
                 motions in the tropical troposphere and lower
                 stratosphere in terms of theortetical interpreta-
                 tion of their development, maintenance and
                 structure and the inter-relationship between
                 them.

Summary: Many aspects of tropical waves are included
                 in this study, but the present emphasis is
                 on the excitation mechanisms of the various
                 types of waves. The main results obtained
                 so far include: (1) selection of stratospheric
                 Kelvin waves can be explained by randomly-
                 distributed heat sources in the troposphere;
                 (2) wave-CISK (instability due to internally-
                 induced cumulus heating) would give rise to
                 very small growth rates and large vertical
                 wavelengths; (3) inclusion of viscous damping
                 comparable to that derived from observational
                 studies would alter the equatorial wave theory
                 greatly for slowly-moving waves, and can explain
                 the basic character of the tropospheric waves;
                 (4) first order effect of a mean flow with
                 varying barotropic instability depends on
                 the relative contributions of several advective
                 terms; and (5) CISK will not greatly alter
                 the barotropic instability selection mechanism.

Publications: C-P. Chang, "Vertical Structure of Tropical
                 Waves Maintained by Internally-Induced Cumulus
                 Heating," Journal of Atmospheric Sciences,
                 33 729-739, 1976.

                 C -P. Chang, "Forcing of Stratospheric Kelvin
                 Waves by Tropospheric Heat Sources," Journal
                 of Atmospheric Sciences, 33, 740-744, 1976.

                 C -P. Chang, "Comments on Instability Theory
                 of Large-Scale Disturbances in the Tropics,"
                 Journal of Atmospheric Sciences, 33, August
                 1976.

C -P. Chang and R. T. Williams, "Barotropic
Instability of a Spatially-Varying Mean Flow,"
presented at the Conference on Atmospheric
Waves and Stability, Seattle, March-April
1976. Abstract published in Bulletin of American
Meteorological Society 57, 1976.

C -P. Chang, "Viscous Internal Gravity Waves
and Low-Frequency Tropical Oscillations,"
presented at the Tenth Technical Conference
on Hurricanes and Tropical Meteorology, Charlottes-
ville, VA, July 1976. Abstract published
in Bulletin of American Meteorological Society,
57, 1976.

Title: Meteorological Effects on Optical Propagation
                 in the Marine Boundary Layer

Investigator: K. L. Davidson, Associate Professor of Meteorology

Sponsor: Naval Sea Systems Command

Objective: The long range objective of this research is to
                 develop methods for predicting optical propagation
                 properties in the marine boundary layer on the
                 basis of its bulk properties, e.g., wind speeds
                 and air-water temperature differences. The short
                 range objective is to obtain observational des-
                 criptions of coincident turbulent and mean pro-
                 perties, wind and temperature, from the sea surface
                 to 1km and also aerosol distribution. This is a
                 continuing project.

Summary: A specific goal of this study is to relate small
                 scale turbulent and aerosol properties to the
                 mean hydrostatic stability. Such stability is
                 definable from measures of the surface wind speed
                 and the near surface air-water temperature differ-
                 ence. Small scale turbulent properties are ex-
                 pected to vary differently with height under
                 different conditions of stability. Results from
                 multi-level shipboard and kiteborne measurements
                 under several conditions of stability reveal
                 distinct differences in height variations of the
                 small-scale parameters under different conditions
                 of stability. The observed height dependencies
                 approximate those predicted on the basis of over-
                 land investigations. The variations from the
                 predictions will be examined for possible wave
                 influence when more data become available.

Publications: K. L. Davidson, "Descriptions for Wind Profiles
                 and Wind Fluctuation (gust) Statistics Over Ocean
                 Waves," Handbook for Offshore Port Planing, Marine
                 Technology Society, September 1974.

                 K. L. Davidson and T. Houlihan, "Laser Propagation
                 in the Marine Boundary Layer," Proceedings of the
                 Ordnance Hydroballistics Activities Committee
                 Meeting, Newport, R. I., October, 1974.

                 K. L. Davidson and T. Houlihan, "Laser Transmission
                 in the Marine Environment." Accepted for publication
                 in Naval Engineers Journal.

                 K. L. Davidson and T. Houlihan, "Optically Relevant
                 Turbulence Parameters in the Marine Boundary Layer,"
                 Proceedings 13th Annual SES Meeting, Nov 1976, NASA-
                 Langley Research Center, Hampton, VA 15 pages (in
                 press).

K. L. Davidson and T. Houlihan, "Turbulence Effects upon Laser Propagation in the Marine Boundary Layer," Proceedings of SPIE, Imaging through the Atmosphere, Mar 22-23,1976, Reston, VA.

K. L. Davidson and R. J. Stricker, "Temporal Variations and Spectral Properties of Wind and Temperature near the Surface over the Tropical Ocean," Boundary-Layer Meteorology, 1976. Accepted for publication.

Title: Tropical Cyclone Studies

Investigator: R. L. Elsberry, Associate Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: This research is part of a continuing, cooperative effort to develop an operational, dynamic forecast model for typhoons in the western North Pacific region.

Summary: Based on a review of the status of nested grid and limited region numerical models, the development of an operational tropical cyclone prediction model was initiated in cooperation with other Navy research and operational units. An existing triply nested numerical model was used to demonstrate the feasibility of forecasting typhoon movement using hand-analyzed data. For this special case, the numerical model forecasts were considerably better than the official motion forecasts. An improved method of initializing such a nested grid model has been devised to avoid the requirement for very fine scale data throughout the region, and yet permit a smooth evolution of the flow near the interfaces between grid meshes. The model is being tested on a quasi-operational basis at Fleet Numerical Weather Central during the 1976 typhoon season. In addition, a research version is being tested at NEPRF on a large number of cases from the 1975 season.

Conference
Presentations: Elsberry, R. L., "Developmental Experiments for a Western Pacific Tropical Cyclone Forecast Model." Presentation at Joint Organizing Committee Study Conference on the Development of Numerical Models in the Tropics, Exeter, England, 4-10 April 1976.

Publications: Elsberry, R. L., and G. W. Ley, "On the Strategy of Initializing Nested Grid Meshes in Numerical Weather Prediction." Monthly Weather Review, 104, June 1976.

                    Elsberry, R. L., R. Perry and D. Hinsman, "Experiments With a Nested Grid Model for Tropical Cyclone Motion Forecasts." Pre-print Joint DMG/AMS International Conference on Simulation of Large-scale Atmospheric Processes, Hamburg, Germany, September 1976.

                    Elsberry, R. L., "Feasibility of an Operational Tropical Cyclone Prediction Model for the Western North Pacific Area." Technical Report NPS-51Es 75051, May 1975.

Thesis
Directed: Ley, G. W., "Some Design Experiments for a Nested Grid Forecast Model of Western Pacific Tropical Cyclones," Master's Thesis, September 1975.

Title: The Oceans and Severe Tropical Storms

Investigators: R. L. Elsberry, Associate Professor of Meteorology
                  D. F. Leipper, Professor of Oceanography

Sponsor: Office of Naval Research

Objective: The long-range scientific objective of this
                  project is to describe the effect of severe
                  tropical cyclones upon the surface layers of
                  the oceans through a coordinated numerical modeling
                  and data collection effort. We hypothesize that
                  significant large-scale changes in new-surface
                  oceanic parameters occur during periods of intense
                  forcing due to passage of tropical cyclones. Thus
                  the potential improvement in analysis and predictive
                  capability for near-surface oceanic parameters could
                  have an important impact on environmental support
                  for fleet operations in the tropical oceans.

Summary: The first phase of the modeling effort was to
                  develop an interacting hurricane-ocean model
                  capable of simulating the surface heat and momentum
                  fluxes (Elsberry, Pearson and Corgnati, 1974, J.
                  Geophys. Res.). Next an oceanic mixed-layer model
                  was developed to predict the thermal response in
                  the ocean (Elsberry, Fraim and Trapnell, 1976,
                  J. Geophys. Res.). Recently the oceanic model has
                  been improved through the use of the hydrodynamic
                  equations to predict the layer-mean currents, and
                  thus the upwelling of the thermocline. The
                  objective is to predict the different mode of
                  response over a range of tropical cyclone displace-
                  ments and intensities. One of the primary results
                  of the modeling effort has been to illustrate the
                  important role of thermally and mechanically
                  generated turbulence in cooling and deepening the
                  mixed layer. The production of an intermediate
                  warmer layer due to downward heat flux at the base
                  of the mixed layer is simulated in this model and
                  is found in the observations. Furthermore the
                  horizontal distribution of mixed-layer depth
                  simulated by this model is more realistic than in
                  previous models. Inclusion of the hydrodynamic
                  equations has produced a simulation of an oscilla-
                  tory response in mixed-layer depth in the wake of
                  fast-moving storms that is similar to observations
                  and linear theory. Some of these results have
                  been summarized in a review article (Elsberry, 1975).

                  Since the best ship data on hurricane-ocean inter-
                  action must cover a time period of several weeks

and cannot provide a true synoptic picture of shorter period changes, we set out to obtain observations by aircraft. Through a combination of careful planning, fleet cooperation and fortunate circumstances, CDR William Schramm was able in 1975 to obtain three sets of oceanic data associated with typhoon Phyllis. A pattern of bathythermograph observations was repeated three times; once immediately before the typhoon passage, once immediately after and once 48 hours later. Sixty-seven soundings were obtained providing the best synoptic coverage to date in such a situation. The analysis of these data is continuing.

Publications: Camp, N. T. and R. L. Elsberry, "Vertical Heat Fluxes Associated with the Deepening Mixed Layer During the Cooling Season." (Abstract) Bulletin American Meteorological Society, 57, 135, 1976.

Elsberry, R. L., et al., "Numerical Simulation of Ocean Thermal Response to Hurricane Passage." (Abstract) Bulletin American Meteorological Society, 56, 1975.

Elsberry, R. L., T. S. Fraim, and R. N. Trapnell, Jr., "A Mixed-layer Model of the Oceanic Thermal Response to Hurricanes." Journal Geophysical Research, 81, 1976.

Schramm, W., "Ocean Thermal Response to the Passage of Typhoon Phyllis." (Abstract) Bulletin American Meteorological Society, 57, 1976.

Title: Primitive Equation Model Initialization by a
                     Variational Method

Investigators: George J. Haltiner, Professor of Meteorology
                     Edward H. Barker, Naval Environmental Prediction
                     Research Facility (NEPRF)

Sponsor: Naval Environmental Prediction Research Facility

Objective: To produce global balanced wind and mass fields
                     for initializing a primitive equation numerical
                     weather prediction model.

Summary: A variational method is used to adjust objec-
                     tively-analyzed wind and geopotential fields
                     using the balance equation as a strong constraint.
                     The resulting Euler-Lagrange equations are simpler
                     on p-surfaces than on σ-surfaces; hence the
                     initial experiments have been carried out on
                     p-surfaces. After interpolating the data to
                     σ-surfaces, the data are rebalanced on the
                     σ-surfaces with the aim of suppressing the
                     inertial-gravity noise normally generated in the
                     early stages of a numerical forecast. The method
                     has been shown to be successful in suppressing
                     noise in an adiabatic two-level version of the
                     Arakawa-Mintz general circulation model without
                     mountains. Further experiments are now in progress
                     with a five-level model with mountains. The next
                     step will be to carry out the variational procedure
                     directly on σ-surfaces to avoid the need for
                     rebalancing. A comparison will be made of accuracy
                     and required computer time for the two methods.

Publications: Haltiner, G. J., E. H. Barker and Y. K. Sasaki,
                     "An Initialization Technique for Primitive
                     Equation Models Using a Balance Equation Technique".
                     Proceedings of the GARP Joint Organizing Committee
                     Study Group Conference on Four-Dimensional Data
                     Assimilation, Paris, France, November 17-21, 1976.

                     Haltiner, G. J. and E. H. Barker, "Initial Balancing
                     with a Variational Method", Annalen Der Meteorologie,
                     Neue Folge, Nr 11, 1976.

Title: The Numerical Simulation of the Coupled North
                   Pacific Ocean-Atmosphere System

Investigator: R. L. Haney, Associate Professor of Meteorology

Sponsor: Office of Naval Research

Objective: The objective of this project is to continually
                   develop and improve a numerical model of the
                   North Pacific Ocean and to use the model to
                   identify processes responsible for the formation
                   and evolution of large-scale thermal anomalies.

Summary: The ocean model (Haney, 1974) has been improved
                   to include time dependent seasonal forcing by the
                   atmosphere; a parameterization of surface generated
                   wind stirring and convective overturning (Haney
                   and Davies, 1976); and nonlinear lateral eddy
                   viscosity based on two-dimensional turbulence
                   theory (Haney and Wright, 1975). A "model
                   climatology" has been generated by integrating
                   the ocean model over a long period of time (240
                   years) starting from a stratified initial state
                   and using climatological seasonal forcing by the
                   atmosphere. This model climatology is being com-
                   bined with thermal anomalies to form the initial
                   conditions for a number of initial value prediction
                   experiments. These experiments examine and compare
                   the evolution of large scale thermal anomalies
                   having different vertical structures. The initial
                   conditions for the anomalies consist of idealized
                   thermal anomalies as well as actual anomalies
                   observed within the NORPAX program. Anomaly pre-
                   diction experiments using anomalous forcing by
                   the atmosphere are also planned.

Conference   Haney, R. L., and K. L. Hunt, "Preliminary Experi-
Presentations: ments in the Numerical Prediction of Large-scale
                   Sea Surface Temperature Anomalies." Presented at
                   the Fall Annual Meeting of the A.G.U., Dec. 8-12,
                   1975, San Francisco.

Publications: Haney, R. L., and J. M. Wright Jr., "The Relation-
                   ship Between the Grid Size and the Coefficient of
                   Nonlinear Lateral Eddy Viscosity in Numerical Ocean
                   Circulation Models." Journal of Computational
                   Physics, 19, 1975.

                   Haney, R. L., and R. W. Davies, 1976: "The Role
                   of Surface Mixing in the Seasonal Variation of
                   the Ocean Thermal Structure." Journal of Physical
                   Oceanography, 6 (in press).

Title: Climatology, Observation, Analysis and Prediction of Marine Fog

Investigator: R. J. Renard, Professor of Meteorology

Sponsor: Naval Air Systems Command

Objective: To improve the observation, climatology, diagnosis (analysis) and prognosis (forecasting) of marine fog over the open ocean and coastal areas.

Summary: The program has been divided into three phases: (a) climatology of marine fog frequencies, (b) observation and diagnosis (analysis) of marine fog, and (c) prognosis (forecasting) of marine fog. To date, mostly the first two phases have been researched; all stages are in various stages of completion.

Phase (a): The climatology of marine fog over the open ocean is considered to be poorly documented, and, with reference to a source widely used by the Navy, the climatology is incorrect. The Naval Postgraduate School (NPS) group has developed a unique approach to deriving marine fog frequencies by synthesizing the information content of the visibility-weather group elements of the marine synoptic report into a computerized specification of the percentage of the synoptic period experiencing fog.

Some 12 years of North Pacific ship-report data (over a half million reports, 30-60N) for the major fog season months of June, July, August and September have been processes to derive credible fog frequencies for each 1 x 1 degree lat/long square; the data are being further stratified to relate frequencies to wind direction and speed on 10 x 10 degree lat/long squares. As a prototype study, the results have universal application to all ocean areas. The National Climatic Center has already adopted, in part, the approach used here. The work continues.

Phase (b): Until such time that marine-fog areas can be initially specified accurately and completely, the forecasting of marine fog will remain primitive. Conventional ship data, at best sparse, are not adequate. Therefore, weather satellite observations (infra-red [IR] and visual) are being researched as a potential prime source of specifying areas of marine fog.

A statistical approach to identifying critical
brightness (visual mode) and temperature
(IR mode) count values associated with marine
fog appears to have promise. Initially,
digital NOAA-2 data for the North Pacific Ocean,
July 1973, were computer processed, diagnosed
and statistically compared to 3250 ship
observations (ground truth) in the quest for a
usuable empirical scheme. Current work involves
the 5-9 August 1976 period in the eastern North
Pacific, for which DMSP and SMS-2 digital data
and imagery are being processed in context with
conventional data, climatology and numerical
statistical parameters in pursuit of an opera-
tionally useful approach to initialize areas of
fog over the open ocean.

Phase (c): A successful means of forecasting
marine fog by computer methods is, in part,
dependent on (a) and (b) above, combined with
the identification of marine-fog indices
compatible with the model output parameters of
Fleet Numerical Weather Central, Monterey,
California.

This aspect of the program is in the state of
identifying suitable atmospheric/oceanographic
parameters for a MOS (model output statistics)
approach to marine-fog forecasting, utilizing
Fleet Numerical Weather Central as source for
data and fields.

Conference
Presentations: R. J. Renard, "Marine-Fog Diagnosis and
Climatology from Synoptic Weather Reports and
Weather Satellite Observations over the North
Pacific Ocean," presented at the NASC Fourth
Conference on Marine Fog at the Laboratory of
Atmospheric Physics, Naval Air Systems Command,
Desert Research Institute, 6-7 January 1976,
Reno, Nevada.

R. J. Renard, "A New Approach to the Determi-
nation of Climatological Marine Fog Frequencies
with Application to the Summer Fog Season of
the North Pacific Area," presented at the
American Meteorological Society Second Con-
ference on Ocean-Atmosphere Interactions
30 March - 01 April 1976, Seattle, Washington.
(Abstract: Bulletin of the American Meteoro-
logical Society, Vol. 57, #1, January 1976.)

Publication: R. J. Renard, "The Observation, Analysis,
Forecasting and Climatology of Marine Fog
on the High Seas and in Coastal Areas; in
World Meteorological Organizations,"
invited paper, published in Symposia Pro-
ceedings, WMO Technical Conference on the
Applications of Marine Meteorology to the
High Seas and Coastal Zone Development,
Geneva, Switzerland,22-26 November 1976,
Publication Number 454, 211-223 (1976).

Theses
Directed: LT C. B. Ihli, Jr, "Use of DMSP and SMS-2
Visual/IR Satellite Data for Diagnosing
Marine Fog over the North Pacific Ocean,"
Master's Thesis, 1976.

CAPT B. L. Van Orman, "A Statistical-Numerical
Approach to Forecasting Marine Fog over the
Open Ocean and Coastal Areas," Master's Thesis,
1976.

Title: Forecasting Motion of Tropical Cyclones in Eastern North Pacific Ocean by Statistical Means

Investigator: R. J. Renard, Professor of Meteorology
J. D. Jarrell, Assistant Professor of Meteorology

Sponsor: Navy Environmental Prediction Research Facility,

Objective: To develop a statistical analog scheme to forecast tropical cyclone motion in the eastern North Pacific Ocean area.

Summary: Fleet Weather Central, Honolulu, Hawaii, and the National Weather Service Forecast Office, at Honolulu, Hawaii, and Redwood City, California, are co-responsible for forecasting tropical cyclone activity in the North Pacific east of 180°. The area averages sixteen depressions, storms and hurricanes a year, occurring from mid May to mid November. To date, mostly subjective means have been used to forecast motion and intensity of these cyclones. A computerized, objective scheme was needed to improve the forecase accuracy as well as give a common starting point for the coordinated-agency forecast effort. The project resulted in the development of the Navy's Northeastern Pacific Analog Tropical Cyclone Tracker (EPANALOG) forecast program.

EPANALOG selects analog tropical cyclones from a 25-year Northeastern Pacific Ocean history. The selected anolog tracks, statistically adjusted for position, vector motion, and date differences between them and the recent history of the tropical cyclone being forecast, were composited into a single forecast track. Verifications of EPANALOG forecasts to 96 hours, as initiated from best-track positions, were determined for randomly selected historical cases with a Monte Carlo simulation of initial position inaccuracies, as well as for forecasts generated from 1973, 1974 and 1975 operational cyclone positions. The latter were intercompared with a homogeneous set of objective persistence and Modified Hurricane and Typhoon Tracking (MOHATT) forecasts as well as subjective OFFICIAL forecasts for the 24-, 48- and 72-hour intervals.

1973-1975 EPANALOG accuracy generally excelled that of the existent techniques for all forecast intervals tested. Work has generally terminated except for preparation of a final set of evaluation statistics.

Publication: J. D. Jarrell, C. J. Mauck and R. J. Renard, "Forecasting Tropical Cyclone Motion on the Northeastern Pacific Ocean by an Analog Scheme," Monthly Weather Review. Vol. 103, August 1975.

Title:	Forecasting Marine Fog Using Numerical-Model Output Parameters
Investigator:	R. J. Renard, Professor of Meteorology
Sponsor:	Fleet Numerical Weather Central
Objective:	To evaluate the Fleet Numerical Weather Central (FNWC) Hemispheric F-TER Fog Probability Forecasts.

Summary: Fleet Numerical Weather Central (FNWC) operationally produces computerized fields of fog probability twice daily, 00 and 21 Greenwich Mean Time (GMT). The program statistically combines fog-related model output parameters to generate the probabilities, which are most prominently used by the Optimum Ship Routing group at FNWC. The product does not contain a climatological factor and it has not been extensively evaluated for accuracy, to date. The project coevaluated the F-TER probabilities in the North Pacific Ocean area for July 1974 (using over 10,000 ship reports) with climatological marine fog frequencies (used as forecast possibilities) being developed at the Naval Postgraduate School (NPS) under Naval Air Systems Command (NASC) sponsorship. Application of the Panofsky-Brier P-Score verification scheme indicated little difference in skill between the two forecast approaches. The research also developed criteria for discriminating between fog/ no fog F-Ter forecasts as a function of the probability values in the current version of the program. Work is continuing under another project (NASC sponsorship) to generally improve statistical marine-fog forecasting.

Publications: R. J. Renard, "A Coevaluation of FNWC's Fog Probability Forecasts and the NPS Marine-Fog Climatology for the North Pacific Fog Regions in Summer." Technical Report NPS51Rd75081, August 1975.

Title: Forecaster's Digest for Eastern North Pacific
Ocean Tropical Cyclones

Investigator: R. J. Renard, Professor of Meteorology
W. N. Bowman, Naval Environmental Prediction
Research Facility

Sponsor: Naval Environmental Prediction Research Facility

Objective: To compile climatological statistics on eastern
North Pacific Tropical Cyclone behavior for
presentation in a form suitable for operational
Navy use.

Summary: Previous work has determined that only the
operational weather satellite era (i.e., since
1965) is suitable for deriving statistics on
movement and development of Eastern Tropical
Pacific (EASTROPAC) cyclones. The Naval Weather
Service Detachment at the National Climatic Center,
Asheville, North Carolina, provided to the investi-
gators best tracks and derived movement statistics
for the ten-year period 1965-74.

Ten-year statistics and the accompanying text
have been prepared on initiation and termination
areas, movement statistics, durations, frequencies
and forecasting of EASTROPAC cyclones by half- and
whole- month periods.

Publications: R. J. Renard and W. N. Bowman, "The Climatology and
Forecasting of Eastern North Pacific Ocean Tropical
Cyclones,"Technical Paper No. 7-76, Naval Environ-
mental Prediction Research Facility, Monterey,
California, June 1976 (79p).

Title: Global Modeling

Investigator: R. T. Williams, Professor of Meteorology

Sponsor: Navy Environmental Prediction Research Facility

Objective: To develop and test numerical techniques for
                    global weather prediction.

Summary: The stability properties of the Shuman pressure
                    gradient averaging technique were investigated
                    with the linearized shallow water equations. In
                    the simplest case an analytic expression was
                    obtained for the stability region, and the maximum
                    time step was shown to be twice the value for the
                    leapfrog scheme. When a mean flow was added to
                    the equations, it was shown that the maximum time
                    step must be reduced. The time averaging sug-
                    gested by Robert was examined, and again a
                    smaller time step was required. In each case
                    however, the use of the Shuman averaging allowed
                    a significantly longer time step than the con-
                    ventional leapfrog scheme.

The possibility of using the finite element
method for numerical weather prediction has been
investigated by applying the method to the shallow
water equations. LT Hinsman, in a M.S. thesis,
applied the method to global prediction. It was
found that the finite element predictions were
much more accurate than corresponding finite
difference forecasts, but that the finite element
model required more computational effort. LT
Kelley is now investigating the use of a variable
element size model for tropical storm prediction.
The preliminary results show that the finite
element model generates noise around points where
the element size changes. The forecasts also
require considerable computer time.

The First GARP Global Experiment (FGGE) is a
year-long global observation experiment which will
begin in late 1978. A review of the experiment
has been prepared and its potential usefulness to
the Navy has been analyzed.

Two aspects of the monsoon circulation during the
Northern Summer have been examined: the dynamics
of the synoptic-scale wave disturbances generated
by the instability of the zonal-mean and planetary-
scale flows in the upper troposphere, and the
simulation of the planetary- and synoptic-scale
motions of the monsoon in a numerical model. The
first part was studied with a linearized barotropic

vorticity equation, while the second used a simplified general circulation model with specified heating.

Monaco and Williams (1975) developed a global prediction model which is based on the special finite difference scheme which was designed by Dr. A. Arakawa. This model was tested by using an initial condition which gave flow directly over the pole. These initial conditions gave numerical solutions which become distorted near the pole and eventually unstable. A modified procedure near the pole was tested which gave reasonable, stable integrations. The model was also tested with topography. A high mountain (about 3 kilometers) was inserted gradually at a single grid point. This was done near the equator in an experiment and also in mid-latitudes in another. The numerical solutions were smooth even near the mountain and the integrations were stable. These results indicate that the model would be well behaved even with other surface topography.

Conference Presentations:	C. P. Chang, R. T. Williams and J. B. Tupaz, "Study of Planetary and Synoptic-Scale Waves of the Northern Summer Monsoon." Presented at the GARP Study Conference on Tropical Numerical Modeling, Exeter, England, April 1976.
Publications:	A. L. Schoenstadt and R. T. Williams, "The Computational Stability Properties of the Shuman Pressure Gradient Averaging Technique." Journal of Computational Physics, 21, 1976.
	A. L. Schoenstadt and R. T. Williams, "The Computational Stability Properties of the Shuman Pressure Gradient Averaging Technique," Technical Report NPS-53Zh51Wu75091, September 1975.
Theses Directed:	R. J. Hartinger, "Upper Level Barotropic Instability," Master's Thesis, 1975.
	D. E. Hinsman, "Application of a Finite Element Method to the Barotropic Primitive Equations," Master's Thesis, 1975

DEPARTMENT OF AERONAUTICS

The research effort of the Aeronautics Department is very broadly based.

In the area of flow measurements and visualization Professors Schmidt and Miller have been investigating the aerodynamic performance of a high lift circulation controlled airfoil. Both steady and oscillating jet blowing into an oscillating free stream are being investigated.

Professor Platzer has continued his investigations into the theoretical analysis of oscillatory flows in transonic turbo-machines and has obtained a complete analytical solution for slowly oscillating infinite cascades in supersonic flow. Professor Shreeve has begun making detailed measurements of the flow from a transonic rotor using pneumatic probes. He has completed further work in turbine blade row performance measurements and highly loaded rotors.

Professor Collins has continued his work in flow field visualization using holographic methods and will shortly begin velocity measurements in the transonic compressor using a laser Doppler velocimeter.

The department also has an extensive activity in damage control and aircraft fatigue measurement. Professor Lindsey is developing new instrumentation, which uses a microprocessor for data acquisition to more accurately monitor inflight fatigue damage of aircraft. Experimental work in fatigue measurements accompanies this study. Results of this research are currently being used by Naval Air Development Center, Warminster, PA, in the development of a Life Management Program for all new Navy aircraft. Professor Ball, in addition to organizing the second biennial aircraft survivability symposium, has done further analysis on aircraft fuel tank response to small arms fire and missile fragments. The object of this investigation is to develop fuel tank designs that can withstand the hydraulic ram loading. Professor Bank has continued his work on the effect on stress distributions of a hole or of a thermally degraded region.

Professor Gawain has carried out further calculations relating to the hydrodynamic stability of flow in pipes and channels. Also, working in collaboration with Professor Ball, he has devised finite difference methods of improved accuracy for the solution of linear differential equations of fourth order.

Further research activity in the Aeronautics Department have covered some important and developing fields. Professor Hess has applied modern control theoretic methods to the design of control systems and cockpit displays for V/STOL aircraft.

Professor Netzer has been active in assessing the emission levels and air quality effects from Naval Air Station aircraft operations and test cells. He has completed some further work in the area of solid fuel ramjet combustion and the burning rate characteristics of solid propellants.

Professor Layton has completed further development on basic measurements in the analysis of captured air bubble vehicles. The latter is an experimental program utilizing the department's XR-3 testcraft. Professor Biblarz has obtained an exact solution to the transonic flow equation. He has also continued his work in electrode loss mechanisms in magnetohydrodynamic generators and has done further work with high pressure discharges for electro-aerodynamic lasers.

Title: Aircraft Fuel Tank Response to Small Arms Fire and Missile Fragments (Hydraulic Ram)

Investigator: R. E. Ball, Associate Professor of Aeronautics

Sponsor: DOD Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) and Naval Weapons Center

Objectives: 1. To obtain fuel tank wall strain data and fuel pressure data caused by a ballistic penetrator; 2. To develop analytical models and computer programs that adequately describe the fuel tank response to the penetrator; and 3. To develop fuel tank designs that can withstand the hydraulic ram loading. Both metal and composite material fuel tanks are considered.

Summary: Metal aircraft fuel tanks that are subjected to ballistic impact and penetration by small arms fire and missile fragments can be severely damaged, with large petalling of the tank walls occurring at the entrance and exit points of the projectile. The damage mechanism, called hydraulic ram, is a very high pressure wave in the fuel caused by the passage of a ballistic penetrator through the fuel. An analytical and experimental hydraulic ram program has been in existence at the Naval Postgraduate School (NPS) for over three years. Fluid pressures and wall strains have been experimentally measured and analytically predicted at NPS for rectangular tanks with aluminum walls. A comprehensive summary of this work is given in Ref. 1. A method for predicting the extent of cracking in metal tank walls due to hydraulic ram is presented in Ref. 3. Very good correlation with experimental results was observed. A scanning electron microscope was used to identify the type of fracture.

Due to the fact that aircraft fuel tanks made of composite materials are now being seriously considered, the effect of hydraulic ram on composite material tank walls has been investigated. In Ref. 4, the various effects of hydraulic ram on a clamped 11 inch square, 0.067 inch thick, graphite/

epoxy wall due to penetration by a .222
caliber projectile are examined. Shots at
2600 fps caused only light damage to the
plate. At 2800 fps, the hydraulic ram
caused considerable damage, including total
severance of the plate from its clamped
support over much of the outer perimeter.
The objectives of the research in Ref. 5
were to show the relative importance of the
transverse shearing forces produced by
hydraulic ram loading on military aircraft
fuel tank joint designs for composite mater-
ials, and to propose fuel tank test section
designs based upon specific composite mater-
ial fuel tank design concepts for the F-16,
F-18, and a Navy V/STOL delta wing. With
the use of a finite element analysis, the
transverse shearing force at a metal fast-
ener was shown to be a major cause of
failure at attachment, primarily by an out-
of-plane push-out mode of failure. This
type of failure could have a significant
effect on the structural integrity of a
major load carrying member of the aircraft,
such as the wing box beam. In this situa-
tion, a large portion of the wing skin over
the fuel tank may become detached from the
spars, ribs and stringers, causing a serious
degradation in the strength and stiffness of
the wing. Future research will be devoted
to the study of the amount of resistance to
out-of-plane push-out shown by various com-
posite attachment designs and to the deter-
mination of the amount of area over which
push-out may occur.

Publications: R. E. Ball, "Structural Response of Fluid-
containing-tanks to Penetrating Projectiles
(Hydraulic Ram) - A Comparison of Experi-
mental and Analytical Results," Technical
Report NPS-57Bp76051, May 1976.

R. T. Remers and R. E. Ball, "Designing
Military Aircraft for Survival in Combat,"
Astronautics & Aeronautics, Vol. 14, No. 5,
May 1976.

Theses Directed:

S. L. Fahrenkrog, "A Study of the Crack Damage in Fuel-Filled Tank Walls Due to Ballistic Penetrators," Master's Thesis, March 1976.

A. N. Duva, Jr, "Hydraulic Ram Effect on Composite Fuel Cell Entry Walls," Master's Thesis, March 1976.

H. S. Ezzard, Jr, "A Study of the Failure of Joints in Composite Material Fuel Cells Due to Hydraulic Ram Loading," Master's Thesis, June 1976.

Title: Impact of Trident on the Naval Torpedo Station Ranges

Investigators: M. H. Bank, Assistant Professor of Aeronautics, W. P. Cunningham, Professor of Physics and Chemistry, D. A. Stenz, Professor of Electrical Engineering, and C. O. Wilde, Professor of Mathematics

Sponsor: Naval Torpedo Station

Objective: Study the TRIDENT program, and delineate its impact on the NTS ranges, especially in the areas of the WSAT and FORACS test and evaluation procedures.

Summary: An important feature of this study was to obtain authentic input from officer students at NPS, and involve them in the investigations. In preparation for these activities, a seminar course (EE 4900) was conducted by D. Stentz, assisted by C. Wilde, in the final quarter of FY 75 to acquaint the students with the Navy's underwater acoustic tracking range system and explore possible thesis topics. In this connection, an NB indoctrination visit for a large group of NPS students and faculty resulted from the seminar. Two theses on NTS range studies were completed by three of the students from the seminar; one of these theses was on TRIDENT, and it is cited below as a publication resulting from this project. Another seminar course was conducted during the final quarter of FY 76 for a new group of potential thesis students, and research for two more theses is currently underway.

As part of the investigation, relevant documentation concerning the TRIDENT program was collected. Since most of the TRIDENT systems are still under development, it was often difficult to obtain information; for example, almost no data are available concerning the towed array, its beam characteristics, the need for full deployment, and its trailing (hydrodynamic) and operational characteristics. Only comparable data specifying the electrical and operational cahracteristics of the passive sonar systems, linear arrays and the STASS array could be located.

Some WSAT and FORACS test and evaluation
programs that could be adapted for TRIDENT
have been studied. In addition, a study of
navigational characteristics of both sur-
faced and submerged submarines was conducted
to determine whether the TRIDENT could safely
perform the necessary navigational movements
within the confined waters of the NTS ranges.
Only limited information on the operational
characteristics of a submarine towing a
long thin array was found. The lack of
specific information on the TRIDENT weapon
towed array, fire control systems, and modes
of operation make it difficult to predict
the tests that will be required, and how
and where they should be conducted.

Publications: M. H. Bank, W. P. Cunningham, D. A. Stentz,
and C. O. Wilde, "Research Summary Report
of NPS Range Design Studies," NPS-71Wl76081,
Edited by O. B. Wilson, August 1976.

Thesis
Directed: H. A. Bunch and R. G. Lacher, "On the mea-
surement of Operational Performance of the
Trident Sonar System," (U), Master's Thesis,
March 1976.

Title: Aircraft Structures Research: Composite Stress Concentrations

Investigator: M. H. Bank, Assistant Professor of Aeronautics

Sponsor: Naval Air Systems Command and Foundation Research Program

Objectives: To determine the effect on the stress distribution in an advanced composite structure of a hole or thermally degraded region. Three immediate objectives are being pursued: (1) a one-parameter characterization of residual strength as a function of ballistic damage size is being attempted; (2) an investigation of the effects of low energy impact on composite plates is underway; and (3) a concurrent investigation of a liquid-crystal inspection technique for evaluation of the extent of damage supports both (1) and (2). This is a continuing program.

Summary: Improvements have been made in the composite made in the composite materials fabrication laboratory, permitting manufacture of flat plate specimens as large as 24" x 36". A precision cut-off machine with a diamond wheel has been added to facilitate specimen preparation. The ballistic-impact and ball-drop devices are operational and producing data.

A photoelastic investigation of stress concentrations around central holes in finite glass-epoxy composite plates under uniaxial tension demonstrated that the state of stress was not adequately described by theoretical solutions for homogeneous orthotropic plates. Stress concentration factors were shown to be dependent on hole size. Strain gage investigations of stress concentrations around off-center holes in similar plates under uniaxial load have shown that the effect of hole size on the stress concentration factor is increased when the hole is moved toward the unloaded edge.

Ball-drop testing of graphite-epoxy panels is producing interesting results. Damage to the specimens has been detected at low energy levels, well before any visible damage takes place at the surface. Growth

of the damaged area is monitored under successive impacts until fracture occurs. An effort is being made to correlate the impact at fracture with computer predictions utilizing a finite-element method solution.

Inspection of damaged areas using various techniques has been investigated. The most promising method seems to be the use of liquid crystals to detect anomalies in the heat-transmissions properties of the material. Deliberately introduced de-bonds between laminae have been detected seven laminae from the front surface of an eight-ply plate (i.e. one lamina from the back side). Heat transfer properties of the composite material are being studied, and devices are being designed to turn this technique from a qualitative to a quantitative inspection procedure.

Publications: None

Theses Directed: Sakol Vudhivai, "Stress Concentration in Glass-Epoxy Composite Plates," Master's Thesis, December 1975.

T. J. Davis, "Ballistic Range Development," Master's Thesis, June 1976.

R. T. Schaum, "Development of a Non-Destructive Inspection Technique for Advanced Composite Materials Using Cholestric Liquid Crystals," Master's Thesis, September 1976.

Title: Electrode Loss Mechanism in Magnetohydro-
        dynamic (MHD) Generators

Investigator: O. Biblarz, Associate Professor of Aero-
        nautics

Sponsor: Air Force Office of Scientific Research

Objectives: To define the nature and extent of voltage
        drops in MHD generators attributable to the
        electrodes. Principal loss mechanisms
        studied are collision-dominated sheath los-
        ses due to the conductivity decrease of a
        thermal boundary layer.

Summary: The two-dimensional, active-site model of a
        non-emitting anode has been successfully
        solved in a computer using a quasi-Jacobi
        technique. This formulation allows the
        insertion of magnetic field effects and of
        Joule heating. The system is considered
        thermally stable and ionization and recomb-
        ination are neglected. Future plans include
        the extension of our results to higher vol-
        tages and the inclusion of the ionization
        term in the equations.

Conference R. C. Dolson, "A Computer Analysis of the
Presentation: MHD-Sheath Voltage Drop," Presented at the
        Institute of Electrical and Electronics
        Engineers International Conference on Plasma
        Science, University of Texas at Austin, May
        1976.

Thesis   R. C. Dolson, "A Computer Analysis for the
Directed: Determination of Voltage Losses in Magnet-
        ohydrodynamic-Generator Plasmas," PhD
        Dissertation, December 1975.

Title: Applications of an Exact Non-Hodograph
Solution to the Transonic Equation

Investigator: O. Biblarz, Associate Professor of Aero-
nautics

Sponsor: Naval Air Systems Command

Objective: An exact solution to the transonic equation
has been found which is both novel and
relatively uncomplicated. The objective is
to study the features of this solution
which may have practical importance. Be-
cause of the generality of phase diagrams,
the present approach is used to study pro-
perties of the transonic equation which are
then compared with results for real airfoils.

Summary: The exact solution along with intrinsic
flows which represent that solution have
been established; the sonic flow result is
related to other sonic solutions. It has
been found that the transonic equation is
essentially sonic or parabolic in character
and that it is a simple matter to extend
sonic solutions to the full transonic range
(but with some loss of generality). A
phase plot has been constructed which re-
presents the perturbation velocities and
transonic normal shocks have been investi-
gated in the phase plane.

Conference
Presentation: O. Biblarz, "Phase Plane Analysis of
Transonic Flows," Presented at the American
Institute of Aeronautics and Astronautics
Fluid and Plasmaodynamics Conference,
San Diego, California, July 1976.

Publication: O. Biblarz, "An Exact Solution to the Tran-
sonic Equation," the Israel Journal of Tech-
nology, 1975.

Title: High Pressure Discharge for Electro-Aero-
                    dynamic Lasers

Investigator: O. Biblarz, Associate Professor of Aero-
                    nautics

Sponsor: None

Objective: Fluid dynamic stabilization of discharges
                    of interest for electric-laser applications
                    has been shown to be very effective. This
                    work extends previous efforts to subatmosp-
                    heric discharges with screen-generated
                    turbulence. In addition, a model for the
                    effects of convection and turbulence on the
                    discharge is being developed.

Summary: A test section in which air flows with
                    speeds up to 600ft/sec was built and opera-
                    ted. Various configurations were tested
                    both at atmospheric and subatmospheric
                    pressures. The effect of reducing pressure,
                    increasing velocity, and of introducing
                    turbulence was to increase the power to the
                    discharge in the order of 500 times. Future
                    plans include a closed loop facility in
                    which various gas combinations may be used
                    at reduced pressures. Ultimately, a dis-
                    charge geometry suitable for electric laser
                    operation is envisaged.

Theses   J. L. Barto, "Gasdynamic Effects on an Elec-
Directed: tric Discharge in Air," Master's Thesis,
                    September 1976.

                    H. A. Post, "Investigation of the Velocity,
                    Density, and Turbulence Dependance of a
                    Discharge in Air," Master's Thesis, September
                    1976.

Title:	Holographic & L.D.V. Studies of Low Speed Flow
Investigator:	Daniel J. Collins, Professor of Aeronautics
Sponsor:	Naval Air Systems Command
Objective:	Holographic interferometry and laser velocimetry will be applied to low speed flows.
Summary:	Holographic investigations have been completed on a free low speed jet simulating a thrust augmentor[1]. Work has begun on L.D.V. measurement of flow fields[1]. Flow around a cylinder in slow flow has been obtained by L.D.V.[2]. Preliminary measurement using L.D.V. were begun on the fluidic jet.
Theses Directed:	I. A. Maliv, "Flow Visualization of the Turbulent Jet at the Exit of a Single Element Nozzle by Holographic Technique, and Mean Velocity Profile Measurements with a Laser Doppler Anemometer," Aeronautical Engineer Thesis, March 1976. T. S. Wanner, "Laser Doppler Anemometer Measurement and Analytical Comparisons of Flow Around a Cylinder at Low Reynolds Number," Master's Thesis, March 1976.

Title: L.D.V. and Holographic Studies of VSTOL
                    and Transonic Compressors

Investigator: Daniel J. Collins, Professor of Aeronautics

Sponsor: Naval Air Systems Command

Objective: Flow measurement and visualization of flows
                    in VSTOL propulsion, transonic flows and
                    unsteady flows and aeroelasticity.

Summary: Further measurements have been made with
                    the Laser Doppler Velocimeter on a thrust
                    augmentor[1]. Work is continuing on in-
                    stantaneous velocity profiles. Unsteady
                    holographic using a television camera with
                    a heated enclosure has been further devel-
                    oped[2].

                    Work will shortly begin on the velocity
                    measurements in the transonic compressor. Two
                    thesis students are presently studying the
                    applications of the finite element method
                    to turbomachinery calculations and transonic
                    flow.

Theses   G. P. Braun, "Time-Dependent Holographic
Directed: Interferometry and Finite Element Analysis
                    of Convective Heat Transfer within a Rec-
                    tangular Enclose," Master's Thesis, September
                    1976.

                    M. K. Hollis, "Measurement of Instantaneous
                    Velocities from a Fluidically Controlled
                    Nozzle using a Laser Doppler Velocimeter,"
                    Master's Thesis, September 1976.

Title: Decision-Making & Optimization in the
                    Design of Advanced Aircraft Systems

Investigator: Ulrich Haupt, Associate Professor Emeritus,
                    Department of Aeronautics

Sponsor: Naval Air Systems Command

Objective: To evaluate recent experience gained in the
                    design of advanced aircraft systems with
                    respect to applying the methodology of
                    operations research to the decision-making
                    and optimization process in engineering.

                    To clarify existing problem areas;

                    To establish basic needs regarding feedback
                    from industry to universities in the border
                    regions between engineering and operations
                    research.

Summary: The investigator visited most of the major
                    aircraft companies in the United States,
                    some of them twice, and discussed various
                    aspects of this project with about one
                    hundred engineers - most of them in respon-
                    sible, design oriented positions in the air-
                    craft industry, others in government agen-
                    cies, engineering organizations, and at
                    universities. As a result of these visits
                    and discussions, the objectives of this
                    project have assumed a firmer shape and they
                    can be closely related to some fundamental
                    developments which are taking place through-
                    out the aircraft industry.

                    One of these trends can be seen in the in-
                    creasing demands on design optimization as
                    trade-offs between aerodynamic performance,
                    weight, production cost, life-cycle cost,
                    reliability, maintainability, and other
                    considerations have to be evaluated.
                    Another trend is the liberation of the de-
                    signer from much drudgery as a consequence
                    of computer-aided design. These two trends
                    create a new and challenging situation in
                    aircraft design. The primary responsibility
                    of the designer has to be directed toward
                    developing alternative proposals; coordi-
                    nating, integrating, and optimizing the
                    various elements; and finally finding the
                    optimal design. This requires a basic

understanding of the decision making process. The corresponding implications form the subject of this project.

Publications: None

Title:	Application of Manual/Automatic Control Theory to the Design of V/STOL Control/Display Systems
Investigator:	R. A. Hess, Assistant Professor of Aeronautics
Sponsor:	National Aeronautics and Space Administration, Ames Research Center
Objective:	To apply modern control theoretic methods to the design of control systems and cockpit displays for V/STOL aircraft.

Summary: An application of an analytic pilot model to a helicopter display improvement study was undertaken. A flight director design technique was developed and implemented in a helicopter hover task. A method for analytically predicting aircraft handling qualities was introduced and finally, a general pilot-model based display design technique was developed.

Conference Presentation: R. A. Hess, "An Application of Flight Director Design Technique to a Helicopter Hover Task," Paper presented at 12th Annual Conference on Manual Control, University of Illinois, May 1976.

Publications: R. A. Hess, "A Model-Based Analysis of a Display for Helicopter Landing Approach," Institute of Electrical and Electronics Engineers Transactions on Systems, Man, and Cybernetics, July 1976. Paper also presented at 11th Annual Conference on Manual Control, Ames Research Center, California, May 1975.

R. A. Hess, "A Method for Generating Numerical Pilot Opinion Ratings Using the Optimal Pilot Model," NASA TM X-73, 101, February 1976. Paper also presented at 12th Annual Conference on Manual Control, University of Illinois, May 1976.

R. H. Hess, "Analytical Display Design for Flight Tasks Conducted Under Instrument Meterological Conditions," NASA TM X-73, 146, July 1976.

Theses
Directed:

L. W. Wheat, "A Comparison of Optimal Control Theory Predictions with Actual Pilot Performance in a Helicopter Longitudinal Tracking Task," Master's Thesis, June 1975.

T. W. Duffy, "An Analysis of the Effect of a Flight Director on Pilot Performance in a Helicopter Hovering Task," Master's Thesis, March 1976.

Title: Surface Effect Ship Technology Program

Investigator: Donald M. Layton, Associate Professor of
                    Aeronautics

Sponsor: Naval Sea Systems Command

Objective: To investigate several facets of basic and
                    advanced Surface Effect Ship technology as
                    they apply to Captured Air Bubble vehicles.

Summary: Two (2) tasks were developed by the Sponsor's
                    Statement of Work and one (1) additional
                    task was developed by the Investigator
                    during Fiscal Year (FY) 1976. All three (3)
                    of these tasks were completed and reported
                    during FY 1976.

                    (A) Pressure Distriburion (SESPO Project).
                    The distribution of the pressure in the
                    plenum of the XR-3 Testcraft was determined
                    by the use of static pressure orifices lo-
                    cated on the wet deck of the plenum chamber.
                    It was found that the static pressure in-
                    creases from the forwarded portion of the
                    plenum toward the rear seal, and from the
                    sidewalls toward the center line of the
                    plenum. The pressure profile was a di-
                    rect function of the testcraft velocity,
                    and the distribution of pressure was affected
                    to a minor degree as the trim of the test-
                    craft was varied. The existence of a
                    "rooster tail" wave behind the trailing
                    edge of the bow seal after Secondary Hump
                    transistion was validated by an observable
                    change in the pressure profile at the
                    rooster tail crest.

                    (B) Rear Seal Air Loads (SESPO Project).
                    The air loads on the rear seal of the XR-3
                    Testcraft were measured in the post-Hump
                    velocity regieme by means of static pres-
                    sure orifices attached to the face of the
                    rear seal. The shape of the seal was de-
                    termined by means of photographs of a video
                    picture of the rear seal face against a
                    grid painted on the inside of shape infor-
                    mation, the air loads normal to the seal
                    face were resolved into lift and drag loads.
                    Evidence of a back flow at the trailing
                    edge of the seal was observed and this
                    reverse flow was adjudged to be due to the
                    venting under the rear seal.

(C) Early Transition (NPS Project). Previous attempts at obtaining an early transition of Secondary Hump by mechanically lifting the bow seal just prior to Secondary Hump had not been successful. Optimum shaping of the bow seal, based on experiments conducted during FY 1975, permitted the testcraft to transition at lower values of thrust and velocity than were normally required. It was shown that with an optimally shaped bow seal, transition could be accomplished at approximately fourteen percent (14%) reduction in thrust required and a five percent (5%) reduction in velocity.

Pulications: None

Theses
Directed:

R. M. Eddy, "A Survey of the Pressure Distribution withing the Plenum Chamber of the XR-3 Testcraft," Master 's Thesis,September 1975.

J. S. Payne, "Air Pressure Loads on the Rear Seal of the XR-3 Captured Air Bubble Testcraft," Master's Thesis,December 1975.

W. T. Moore, "The Effects of Rapid Raising of the Bow Seal on Early Transition of the XR-3 Captured Air Bubble Testcraft," Master's Thesis, March 1976.

Title: Aircraft Sensors

Investigator: Donald M. Layton, Associate Professor of
                  Aeronautics

Sponsor: Naval Air Systems Command

Objectives: To study current Navy aircraft sensor con-
                  figurations by aircraft types and extra-
                  ploate to last two decades of the 20th
                  Century utilizing available technology and
                  new concepts.

Summary: Baseline data was obtained on the sensors
                  currently being used on fighters (F-14),
                  and Anti-submarine (S-3) aircraft. Pre-
                  liminary examination of the state of the art
                  of aircraft sensors was commenced for use
                  during the Fiscal Year 1977 portion of the
                  project.

Publications: None

Title:	Aircraft Fatigue Monitoring
Investigator:	Gerald H. Lindsey, Associate Professor of Aeronautics
Sponsor:	Naval Air Systems Command
Objective:	To develop methods by which fatigue damage of aircraft may be more accurately calculated from in-flight monitoring data.

Summary:

A microcomputer data acquisition instrument has been developed at NPS for recording in-flight strains of airplane structures by means of strain gages located near fatigue critical points. The analog voltage signal from the strain gage is digitized and interrogated for maxima and minima, which are the significant points of the data for fatigue analysis purposes. These extrema are stored in solid state random access memory (RAM) in the sequence in which they occurred. At the end of each flight, the microprocessor transfers the data in RAM to magnetic tape for convenient handling and subsequent processing and use in fatigue damage calculations.

The research presently underway is directed toward obtaining a sufficient depth of understanding of material behavior to use the recorded strain data in making a reliable fatigue damage calculation. The primary effect being focused on is the influence of sequence of loading upon the damage when there is local plastic yielding at a point of stress concentration. Our experiments have shown that in the post yield state there is a significant relaxation of stress in the material, which changes dramatically the damage calculation. This reduction in stress for a given strain level reduces the damage incurred and increases the life expectancy over that calculated by ignoring the relaxation. Tests on aluminum sheets that duplicate wing panels, which are partially complete, are leading to a quantification of this effect.

Publications:	None

Theses
Directed:

LCDR D. M. Vidrine, "A Sequential Strain Monitor and Recorder for Use in Aircraft Fatigue Life Prediction," Master's Thesis.

LT W. C. Stanfield, "Microprogrammable Integrated Data Acquisition System--Fatigue Life Data Application," Master's Thesis.

LT C. L. Butler, "Software Design for a Fatigue Monitoring Data Acquisition System," Master's Thesis.

LT. G. M. Horne, "An Investigation of Stress Determination for Aircraft Fatigue Life Predictions from In-Flight Strain Data," Master's Thesis.

Title: Nonsteady Aerodynamic Performance of High Lift Circulation Controlled Airfoils

Investigator: J. A. Miller and L. V. Schmidt, Associate Professors of Aeronautics

Sponsor: Naval Ship Research and Development Center

Objective: To obtain aerodynamic performance data in an oscillating free stream for a typical example of high lift airfoil section whose circulation is controlled by Coanda Effect jet blowing. Both steady and oscillating jet blowing into an oscillating free stream is to be investigated.

Summary: The test section to be investigated was supplied to NPS by NSRDC and was found to be unsuitably instrumented and to have structural separations upon receipt. Subsequent to replacement of the surface pressure sampling taps and repair of the structural defects the model was installed in the NPS Oscillating Flow Wind Tunnel and instrumented for preliminary runs in a steady free stream to confirm previous data collected by NSRDC.

Static pressure data was obtained for two angles of attack 1.67 and 5.0 degrees, at a chordwise Reynolds Number $\simeq$ 500,000 for various blowing rates corresponding to momentum coefficients, $C\mu = 0.14$. From this data the lift, drag and moment coefficients C_L, C_D and C_M were calculated for comparison with the earlier NSRDC data. The probable source of the substantial differences noted between the NPS data and that obtained by NSRDC was identified as leakage occasioned by the structural defects noted above. The linearity in the lift and moment data obtained at NPS gives theoretical support to the validity of these data.

Concurrent with this initial experimental phase work was undertaken to develop a valve to produce controllable oscillations in the blowing rate as well as microprocessor hardware and software for recording and processing the very large mass of oscillating pressure data. Measurement of the nonsteady pressures is effected using

a technique well established at NPS which
involves measurement of system transfer
functions and digital inversion permitting
the recreation of actual surface pressure
histories from remotely measured values.
In addition to the two principal investi-
gators, five thesis students, including
one doctoral candidate, are involved in
this effort.

To date a suitable valve has been developed
and is currently being installed, the data
acquisition system has been designed and
is in the hardware procurement phase and
software is being developed. It is expected
that the data acquisition system will be-
come operational by the end of 1976.

Publications: None

Thesis   R. B. Johnson, "A Technique for Measuring
Directed: Unsteady Pressures," Master's Thesis, Sep-
                  tember 1968.

Title: Burning Rate Characterstics of Solid
                    Propellants

Investigator: D. W. Netzer, Associate Professor of
                    Aeronautics

Sponsor: Naval Sea Systems Command

Objective: To develop a laser schlieren system and to
                    apply it to the study of solid propellant
                    combustion.

Summary: An optically active laser schlieren system
                    was developed and used together with com-
                    bustion bombs capable of operation to 3500
                    psi in order to study the gas phase temper-
                    ature field above burning solid propellants.
                    Advantages and limitations of the system
                    were delineated. Ammonium perchlorate (AP)
                    deflagration behavior at pressures below
                    800 psi was found to be in agreement with
                    earlier results which used conventional
                    color schlieren. At 1000 psi AP was found
                    to deflagrate with a planar surface but in
                    a pulsating manner. Surface reaction sites,
                    if existing at all, were very small. At
                    2200 psi the surface was locally nonuniform
                    but the pulsating behavior was not evident.
                    Local reaction sites on the surface were
                    evidenced by density gradients in the gas
                    phase across the surface.

Publications: J. R. Andrews and D. W. Netzer, "Laser
                    Schlieren for Study of Solid-Propellant
                    Deflagration," American Institute of Aero-
                    nautics and Astronautics Journal, Vol. 13,
                    No. 4, March 1976.

                    J. R. Andrews and D. W. Netzer, "The devel-
                    opment of Optically Active Laser Schlieren
                    System with Application to High Pressure
                    Solid Propellant Combustion," Technical
                    Report, NPS-57Nt75082, September 1975.

Title: Solid Fuel Ramjet Combustion

Investigator: D. W. Netzer, Associate Professor of
                     Aeronautics

Sponsor: Naval Weapons Center

Objective: To develope an internal ballistics computer
                     model and to provide experimental data
                     which can be used for model verification.

Summary: For the past two years experimental and
                     theoretical studies have been conducted at
                     the Naval Postgraduate School with the
                     primary purpose of developing a combustion
                     model for solid fuel ramjets. Until re-
                     cently the model has had quite limited
                     capabilities. Recently, improvements have
                     been made in the turbulence modeling and
                     in the techniques for obtaining numerical
                     stability which have greatly improved the
                     predictive capability of the model. The
                     model predicts a fuel rich recirculation
                     zone, a flame pattern, and a distribution
                     of turbulence intensity which are in good
                     agreement with experiment. In addition,
                     fuel regression rates and patterns as a
                     function of air flow rate are predicted
                     which are also in reasonably good agreement
                     with experiment. Current work with the
                     model includes combustion efficiency pre-
                     dictions through the use of the unburned
                     mass fraction of fuel and the effects of
                     aft end mixing.

Conference   D. W. Netzer, "Experimental Study of the
Presentations: Flow Field in Solid Fuel Ramjets," presented
                     at the Joint Army, Navy, National Aero-
                     nautics Space Administration, and Air Force
                     Workshop on Airbreathing Combustors,
                     Naval War College, Newport, RI, 12-13 Aug-
                     ust 1975.

                     D. W. Netzer, "Experimental Investigation
                     of Solid Fuel Ramjet Combustors," presented
                     at the Joint Army, Navy, National Aeronau-
                     tics Space Administration, and Air Force
                     Workshop on Solid Fuel Ramjets, Naval
                     Postgraduate School, 8-10 June 1976.

D. W. Netzer, "Modeling Solid Fuel Ramjet Combustion," presented at the Joint Army, Navy, National Aeronautics Space Administration, and Air Force, Workshop on Solid Fuel Ramjets, Naval Postgraduate School, 8-10 June 1976.

Publications: D. W. Netzer, "Modeling Solid Fuel Ramjet Combustion," 12th Joint Army, Navy, National Aeronautics Space Administration, and Air Force Combustion Meeting, CPIA publication No. 273, Vol. II, December 1975.

Title: Emission Levels and Air Quality Effects
                    from Naval Air Station Aircraft Operations
                    and Test Cells

Investigator: D. W. Netzer, Associate Professor of
                    Aeronautics

Sponsor: Naval Air Propulsion Test Center

Objective: To adopt the Air Quality Assessment Model
                    (AQAM) to Naval air operations and to apply
                    the model to operations at NAS Miramar. To
                    develop a computer program which can be used
                    to predict the effects of engine operating
                    characteristics and test cell design on the
                    flow in jet engine test cells.

Summary: The AQAM model developed by Argonne Labora-
                    tory for the U.S.A.F. has been modified to
                    better simulate Naval air operations. In
                    particular, VFR approaches, touch-and-go's,
                    FCLP's, helicopter operations, hot refueling,
                    and aircraft delays were added. Data were
                    taken at NAS Miramar and used as input into
                    the Source Inventory (total pollution per
                    year by source type) and Short Term (1 hr.
                    average concentrations at various receptors)
                    models for aircraft, air base, and non-air
                    base pollution sources. A parametric study
                    was conducted to demonstrate the capabili-
                    ties and limitations of the model.

                    Two computer models have been developed to
                    predict the internal aerodynamics of jet
                    engine test cells. One model is for
                    studying engine exhaust gas recirculation
                    and augmenter pressure rise. It is limited
                    to low subsonic engine exhaust velocities.
                    Current work is concerned with developing
                    a model which can handle afterburning con-
                    ditions. The second model is for examining
                    the flow field in test cell exhaust stacks
                    as a function of augmenter/stack configur-
                    ation and engine flow rate.

Publications: K. I. Weal and D. W. Netzer, "Modification
                    of an Ambient Air Quality Model for Asses-
                    ment of US Naval Aviation Emmittants,"
                    Technical Report, NPS-57Nt75071, August 1975.

J. D. Hayes and D. W. Netzer, "An Investigation of the Flow in Turbojet Test Cells and Augmenters," Technical Report, NPS-57Nt75101, October 1975.

G. R. Thompson and D. W. Netzer, "An Ambient Air Quality Model for Assessment of US Naval Aviation Emittants," Technical Report, NPS-67Nt76091, September 1976.

Title: Unsteady Flows in Aircraft Propulsion
Systems

Investigator: M. F. Platzer, Professor of Aeronautics

Sponsor: Naval Air Systems Command

Objectives: The objective of this work unit is the investigation of unsteady flows in aircraft propulsion systems. The emphasis will be placed upon the development of theoretical models and experimental techniques which can contribute to our understanding of the complex unsteady flow phenomena in aircraft propulsion systems. Primary attention will be given to the analysis of unsteady flows in transonic turbomachines and to the experimental investigation of the effectiveness of unsteady flows for flow augmentation and control purposes.

Summary: The theoretical analysis of oscillatory flows in transonic turbomachines was continued during the past year. The major accomplishment was a complete analytical solution for slowly oscillating infinite cascades in supersonic flow which provides valuable insight into the convergence characteristics of numerical finite cascade solutions. Also, detailed measurements of flow characteristics and entrainment rates of oscillating jets were completed using hot-wire instrumentation.

Conference Presentations: M. F. Platzer, W. R. Chadwick, P. B. Schlien, "On the Analysis of the Aerodynamic and Flutter Characteristics of Transonic Compressor Blades,". Paper presented at the IUTAM Symposium on Aeroelasticity in Turbomachines, Paris, France, 18-23 October 1976, published in Revue Francaise de Mecanique, Numero Speciale 1976, pp. 65-72.

Publications: M. F. Platzer and R. J. Margason, "Prediction Methods for Jet V/STOL Propulsion Aerodynamics," American Institute of Aeronautics and Astronautics, Aircraft Systems and Technology Meeting, Dallas, Texas, 27-29 September 1976, AIAA - paper No. 76-932.

D. D. Liu and M. F. Platzer, "Approximate Methods for Transonic Flow Past Finite Wedge Profiles," Zeitschrift fuer angewandte Mathematik und Mechanik (ZAMM), Vol. 56, pp. 51-57, 1976.

M. F. Platzer, "Unsteady Phenomena in
Turbomachines," Technical Evaluation
Report, AGARD   Conference Proceedings
No. 177, Advisory Groups for Aerospace
Research and Development, April 1976.

**Theses
Directed:**

D. L. Weiss, "An Experimental Investi-
gation of the Whistler Nozzle and an
Analytical Investigation of a Ring Wing
in Supersonic Flow," Master's Thesis, March
1976.

R. J. Veltman, "An Experimental Investi-
gation of the Efficiency and Entrainment
Rates of a Fluidically Oscillated Jet,"
Master's Thesis, June 1976.

R. K. Crowe, "Pulsating Combustion Device
Miniaturization," Master's Thesis, December
1976.

Title: Test Data Control and Analysis

Investigator: R. P. Shreeve, Associate Professor of Aeronautics

Sponsor: Foundation Research Council (6.1)

Objective: To remotely control the acquisition of and
                  to obtain on-line reduction of data from
                  traversing probe systems.

Summary: A programmable data acquisition system was
                  constructed using an inexpensive microprocessor.
                  The system was programmed to drive a probe
                  survey mechanism, to rotate and set a probe
                  into the flow direction, and to scan, record
                  and punch onto the paper tape up to 48 channels
                  of data. A direct interface to a Hewlett-
                  Packard Model HP 9830 calculator system will
                  complete the system and allow immediate display
                  of reduced data using an X-Y plotter.

Publications: None.

Thesis
Directed:

                  D. D. Patton, "Microprogrammable Data Acquisition
                  and Probe Control System (MIDAS IV) with
                  Application to Compressor Testing," Master's
                  Thesis, March 1976.

Title: Flow in Highly Loaded Rotors

Investigator: R. P. Shreeve, Associate Professor of Aeronautics

Sponsor: Foundation Research Program (6.2)

Objective: To explore the application of stationary
                hot wire, hot film and semi-conductor probes
                to the determination of the flow relative
                to a highly loaded rotor.

Summary: The flow in the first rotor of an impulse
                fan should be periodic in a stationary frame
                (fixed probes), or steady with respect to
                the rotor itself. It is proposed to determine
                the flow at a point in the rotor frame by
                controlled digital sampling (using real-time
                instrumentation) at one sample per revolution.
                Trigger signals at 1 per revolution and 1
                per blade have been designed. Digital logic
                with phase-lock-loop circuitry enables samples
                to be taken at fixed peripheral locations
                in the rotor frame, at arbitrary speeds.
                A periodic flow generator was built to provide
                30,000 HZ signals typical of rotor exit flow
                conditions. Semi-conductor measurements
                of impact pressure were made using the generator.
                Experimentation with hot wire probes will
                begin when the trigger and delay circuits
                have been incorporated satisfactorily into
                the real-time digital data acquisition system.

Publications: None

Title: Turbine Blade Row Performance Measurements

Investigator: R. P. Shreeve, Associate Professor of
                Aeronautics

Sponsor: None

Objective: To determine by test rig measurements the
                losses occuring in the stator and rotor
                blade rows of a single stage axial turbine.

Summary: A test rig for single stage axial air tur-
                bines has been developed for subsonic and
                supersonic turbine stages producing less
                than 200 horsepower. The rig is instru-
                mented to allow stator and rotor blade row
                losses (in addition to stage performance)
                to be calculated from measurements of
                forces, torques and pressures. Following
                successive improvements in hardware and
                instrumentation and the development of data
                reduction programs, smooth data for blade
                row loss coefficients has been obtained. A
                determination of the effects of tip clearance
                and axial spacing can now be made.

Publications: None

Thesis   E. F. Robbins, "Determination of Rotor and
Directed: Stator Loss Coefficients for an Axial Tur-
                bine with Supersonic Stator Exit Condi-
                tions," Master's Thesis, June 1976.

Title:	Transonic Compressor Investigations
Investigator:	R. P. Shreeve, Associate Professor of Aeronautics
Sponsor:	Naval Air Systems Command
Objective:	To investigate in detail the behavior of the flow in Transonic axial compressor stages. The ultimate goal is the accurate prediction of the performance of advanced compressors through the use of a model which better approximates the real flow behavior. The long and expensive development cycle for new engines would then be reduced.

Summary: An 11 inch diameter, 450 Horsepower single stage transonic compressor is being used in this continuing experimental program. An air turbine drives the compressor which is designed for 31000 RPM. Tests speeds have been held to 20,000 RPM while new measurement techniques were developed. The stage performace was mapped and the flow from the rotor was measured using pneumatic probes. A new combination temperature-pnematic probe was designed, built, and calibrated to determine the velocity vector in the relatively small compressor annulus. Fast response measurements of case wall static pressures were made using a single Kulite transducer with digital computer data recording. An on-line calibration technique was adopted to partially overcome the temperature sensitivity of the transducer. Programs were written to plot the measurements as pressure distributions across a blade space. The location of the leading shock wave in the rotor passage was clearly determined. Instrumentation has been installed to obtain maps of the case wall pressures using 8 transducer channels. Triggering and delay techniques will be used to analyse one blade space at a time in tests in which the machine speed will be increased toward design. Further, measurements of the flow from the rotor will be made with real-time instrumentation.

Conference Presentation:	R. P. Shreeve, "Real-Time Measurements in a Transonic Compressor," Workshop on Transonic Flow Problems in Turbomachinery, Naval Postgraduate School, Monterey, CA, February 11-13, 1976.

Publication: R. P. Shreeve, D. J. Anderson, and J. A. Olson, "Calibration and Application of Multi-Sensor Pneumatic Probes for Velocity Determination with Corrections for Boundary Effects," American Institute of Aeronautics and Astronautics Paper No. 76-373, American Institute of Aeronautics and Astronautics 9th Fluid and Plasma Dynamics Conference, San Diego, California, July 14-16 1976.

Theses Directed: F. J. Dodge, "Development of a Temperature-Pneumatic Probe and Application at the Rotor Exit in a Transonic Compressor," Master's Thesis, June 1976.

G. C. Paige, "Measurement of Case Wall Pressure Signatures in a Transonic Compressor Using Real-Time Digital Instrumentation," Master's Thesis, June 1976.

DEPARTMENT OF OCEANOGRAPHY

The research program of the Department of Oceanography may be considered under four headings according to the facilities utilized and the sources of data. These headings are: (1) ship programs, (2) coastal field studies, (3) deep ocean data analyses, and (4) special studies.

SHIP PROGRAMS

There are 4 investigations in this category which make use of the Naval Postgraduate School research vessel ACANIA, a ship supported by the Oceanographer of the Navy. The first of these studies conducted by J. B. Wickham, concerns the mesoscale oceanographic characteristics of the boundary between the California Counter Current and the California Current itself. The emphasis is on seasonal variations.

The second ship study is by S. P. Tucker and involves the definition of the optical properties of the waters in a band 30 nautical miles wide and 200 miles long off the California coast between Point Reyes and Point Buchon. The objective is to understand temporal and spatial variations in the optical properties in terms of the ordinary oceanographic observables.

Also, from the ACANIA, E. C. Haderlie carries out a survey of the biology of stone and wood boring organisms in the deeper waters of the Monterey Bay. His purpose is to determine the identity and the vertical and horizontal distribution of these borers as well as their growth rates, settlement times, and destructive effects.

In chemical oceanography, the ACANIA is used by E. D. Traganza to collect samples to determine concentrations of zooplankton biomass and the correlations between the biological, chemical, and acoustical properties of the ocean.

Two other faculty members, namely, R. G. Paquette and R. H. Bourke make use of ice breakers furnished by the U.S. Coast Guard to observe and analyze ocean thermal microstructure near the ice margin in the Chukchi Sea.

COASTAL FIELD STUDIES

The first of these studies, conducted under the direction of E. B. Thornton, concerns the kinematics of breaking waves in the surf zone. It is based on measurements of water particle motion and will provide increased understanding of the energy distribution within the surf zone and associated phenomena. Measurements are being made in the surf in Hawaii.

Dr. Haderlie has been using concrete wharf pilings and other structures on the coast in identifying organisms responsible for deterioration of engineering materials placed in the sea and in determining the general biology and destructive effects of these organisms.

Another study involving coastal field work is a program in marine fog being conducted by D. F. Leipper and G. H. Jung. This project involves relationships between measurements from the R/V ACANIA and regularly obtained meteorological observations at shore stations. The project also undertakes analyses of data gathered at sea by other means such as through aircraft, satellites and commercial and weather ships. The research has been expanded to include segments in the Departments of Meteorology and also Physics and Chemistry. A coordinated survey is being conducted off Southern California in September 1976.

DEEP OCEAN DATA ANALYSIS

One program in this category is the study of oceans and mid latitude cyclones. It involves the analysis of observations before and after cyclones. The program was initiated in Oceanography but it now includes a model development and testing program by R. L. Elsberry in the Department of Meteorology. Under this program R. W. Garwood is conducting research with his mixed layer model with an eventual objective of operational forecast adaptation.

Deep ocean weather data from ocean station NOVEMBER are used by R. H. Bourke in examining the temperature and salinity fluctuations at the sea surface and in the mixed layer. He is attempting to isolate the nature of the atmospheric processes which may be responsible for creating the observed fluctuations and to determine the magnitude and effect of horizontal thermal advection on the heat content in the water column.

Ocean observations taken along latitude sections in the Atlantic Ocean during the IGY are being used by G. H. Jung as the basis for new geostrophic calculations of mass, salt and heat transported in that ocean. Values of heat carried by these large scale circulations will be compared to values transported by various smaller scale phenomena there.

SPECIAL STUDIES

J. J. von Schwind is preparing a detailed and systematic treatise covering the geophysical fluid dynamics of the ocean. This treatise will cover the fundamentals, ocean circulation theories and models, elementary and advanced wave theory, internal waves and tides, and advanced topics.

W. C. Thompson is preparing spectral wave generation graphs which will be more operationally useful than those now available. There are to be auxiliary graphs of wave steepness, wave age, and other parameters characteristic of waves undergoing generation.

Title: Subarctic Water Mass Intrusions at Ocean
                    Weather Station NOVEMBER

Investigator: Robert H. Bourke, Assistant Professor of
                    Oceanography

Sponsor: Fleet Numerical Weather Central

Objective: To examine the effect of horizontal thermal
                    advection on the heat content of the upper
                    layers of the ocean. Specifically, to
                    correlate thermal advection anomalies with
                    other physical properties to assess the
                    physical reality of this term.

Summary: This is a continuation of a project to in-
                    vestigate the various energy fluxes con-
                    trolling the heat content of the upper
                    layers of the ocean in the vicinity of
                    Ocean Weather Station (OWS) NOVEMBER. This
                    station is located on the southern boundary
                    of the transition zone separating the Sub-
                    arctic Water mass from the Subtropic Water
                    mass. A divergent heat budget equation was
                    used to compute horizontal thermal advec-
                    tion changes in the upper 250 m of the ocean
                    over the period 1962-1970. This term was
                    correlated with salinity fluctuations over
                    the period 1968-1970. Pulse-like periods
                    of cool advection were associated with
                    periods of reduced salinities suggesting
                    these were intrusions of Subarctic Water.
                    Over the 9 year period of analysis, these
                    intrusions had a periodicity of 7 to 8
                    months with a duration of 3 to 4.5 months.
                    It is probable these wave-like intrusions
                    along the subtropic front are the result
                    of the passage of nondispersive baroclinic
                    Rossby waves.

Publications: None

Thesis   John F. Pfeiffer, "Evidence of Subarctic
Directed: Water Mass Intrusions at Ocean Weather
                    Station NOVEMBER," Master's Thesis, September
                    1976, Published as Technical Report,
                    NPS-68BF76091, September 1976.

Title: Biodeterioration Studies in Monterey Bay

Investigator: E. C. Haderlie, Professor of Oceanography

Sponsor: Naval Facilities Engineering Command

Objective: To identify the various organisms in the
                  shallow water of Monterey Bay that are
                  responsible for the deterioration of engine-
                  ering materials placed in the sea, and to
                  determine the general biology and destruc-
                  tive effects of these organisms.

Summary: This is a long-term project that has been
                  underway for several years. During the
                  past year emphasis has been on the biodeter-
                  ioration of concrete wharf pilings and the
                  evaluation of tropical woods to wood borer
                  attack. Certain types of concrete have
                  been found to be totally resistant to marine
                  borers, while other types are subject to
                  severe deterioration in the Monterey Harbor.
                  Several types of tropical woods have been
                  found to resist wood borers, but other
                  types previously reported to be immune to
                  attack are bored both by shipworms and
                  gribbles.

Publications: E. C. Haderlie, "Fouling Communities in the
                  Intertidal Zone on Wooden and Concrete
                  Pilings at Monterey, California". Corrosion
                  and Fouling, Juan-les-Pins, France, 1976.

Title: Biology of Stone and Wood Boring Organisms in Monterey Bay and the Monterey Submarine Canyon

Investigator: E. C. Haderlie, Professor of Oceanography

Sponsor: Office of Naval Research

Objectives: To determine the identity, vertical and horizontal distribution, and the substrate preference of major stone and wood borers in the deeper waters of Monterey Bay, and to effect of these organisms by exposing experimental materials at various depths to be recovered at regular intervals for analysis.

Summary: This is a long-term study that will require several years to complete. During the past year extensive dredging operations have continued, with special emphasis on recovery of sedimentary rock from the walls of the Monterey Canyon and on the floor of the Bay. Experimental materials have been recovered and analyzed, and new arrays have been exposed. Numerous species of stone borers have been found in the recovered rock and their vertical and horizontal distribution is being mapped. Techniques for measuring directly the growth rates of stone borers have been developed, and in some cases these rates exceed by several orders of magnitude any recorded before.

Publications: E. C. Haderlie, "Destructive Marine Wood and Stone Borers in Monterey Bay," In: J. M. Sharpley and A. M. Kaplan (Eds.) Proceedings of the Third International Biodegradation Symposium Applied Science Publication, London, England, 1976.

Title: Mass, Salt and Heat Transports in the Atlantic
            Ocean During the IGY

Investigator: Glenn H. Jung, Professor of Oceanography

Sponsor: Foundation Research Program (6.1)

Objective: (1) Use computer program to calculate geostrophic
            currents and associated transport values through
            vertical crosssections across the Atlantic
            Ocean at 36, 32, 24, 16 and 8N latitude; eventually
            sections at 48N and at 8, 16, 24, and 32S
            will also be processed;
            (2) Develop computer plot and analysis program
            for results display;
            (3) Compare data when separated seasonally
            to describe seasonal variation.

Summary: Card decks punched for use on an earlier NPS
            computer were adapted to present computer
            program format; cards for observations between
            depths of 3000 meters and the ocean floor
            were punched and added, as well as title cards
            with basic information for each of the 267
            stations (comprising 5942 observations of
            temperature and salinity versus depth). Sections
            were processed with at least three runs each
            to obtain adjustment of the level of no motion
            (LNM) so net mass and salt transport values
            across each section are approximately zero.
            The initial run LNM was a first guess; the
            second run attempted to overcompensate the
            net results of the first trial; and the final
            run LNM was based on careful comparisons between
            the first and second trials by which selection
            of the optimum LNM was made.
            The total observations for sections at
            36, 32, 24, 16, and 8N have been processed
            in this manner. Also the earlier 40N results
            summarized by Greeson have been recalculated
            for use here. The net resulting heat transport
            values at 40 and 36N compare well with prior
            estimates interpolated from earlier data for
            nearby sections. From 32 through 16N the
            new calculations are significantly lower than
            prior estimates; this may be the result of

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1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
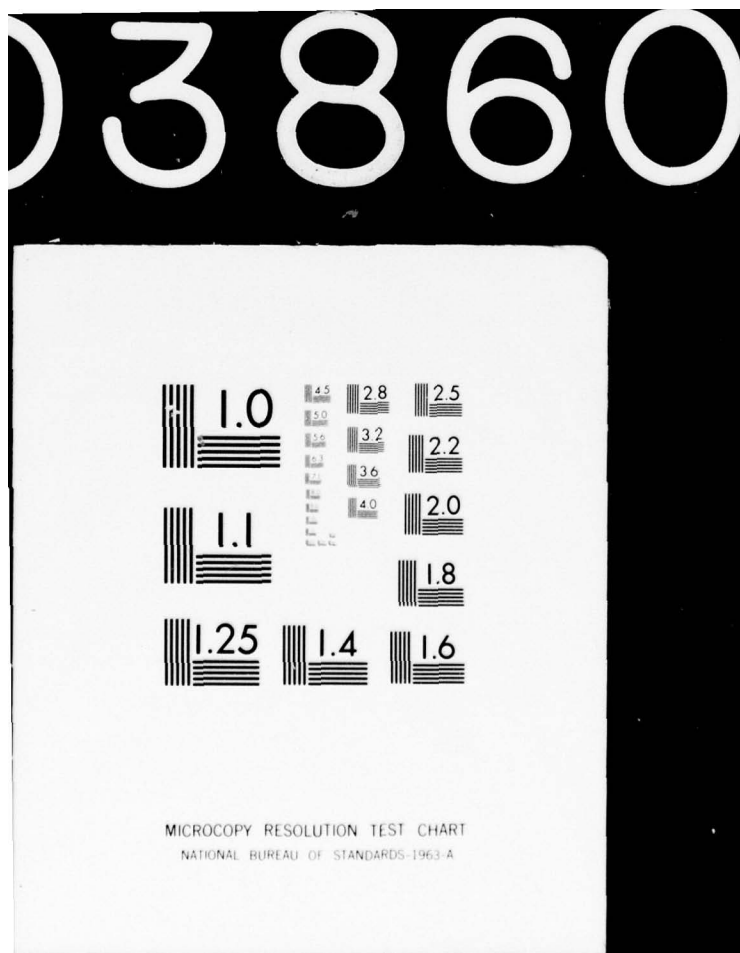
IGY sections combining sets of observations
taken during different years and seasons for
one latitude (as for 32N and 24-27N); at 16N
the heat transport value is very small and
poleward, taken during the same autumn season
as the bulk of the 24N observations; this
may be reflecting an actual anomalously low
heat transport during that particular season
and year. At 8N the net transport is equatorward
which has been checked as computationally
correct, but this change in direction remains
to be explained. Data at 8N are taken about
6 months prior to observations at 24 and 16N
and may be consistent with those low values
mentioned above. The level of no motion used
varies somewhat around the 1100-meter level
in the open ocean; it is clear through the
balancing process used for optimizing the
LNM that no significant departure from this
general value will permit the required balance
of mass and salt transport across each section.

A thesis student has begun work on summarizing
the mass transport calculations into an overall
three-dimensional circulation model of the
North Atlantic Ocean between 40 and 8N. Careful
comparison of these with earlier calculations
will be included, and comparison with available
actual mass transport and current observations.

Code 481 of ONR has approved a proposal
for continuation of this project during the
next academic year, when detailed summaries
of the salt and heat energy circulations of
the North Atlantic should be completed from
0 to 48N. Comparisons of these large-scale
transports with those effected by smaller-
scale eddies will be made; objectives (2)
and (3) will be done. Future proposed studies
beyond next year will continue this work into
the South Atlantic Ocean.

Publications: None

Title: Oceanographic Investigation Associated with the Marginal Sea-Ice Zone of the Chukchi Sea

Investigators: R. G. Paquette and R. H. Bourke, Professors of Oceanography

Sponsor: Arctic Submarine Laboratory, Naval Undersea Center

Objective: To continue with field experiments and data analysis to discover the mechanisms responsible for the formation of mesoscale temperature fluctuations found in the vicinity of the ice edge in the Chukchi Sea. This project is a continuation of studies made in Fiscal Years 1972 to 1975 under general title MIZPAC.

Summary: Experimental measurements were made from a Coast Guard icebreaker in August 1975 using a conductivity-temperature-depth recorder (CTD) and a hand-lowered, direct-reading current meter. Measurements began in the warm, ice-free waters off Nome and generally followed the previous year's track to the ice margin. Unlike previous cruises, mesostructure was mostly found in ice-free waters immediately south of the ice edge. Current meter measurements indicated this to be a region of complex flow. No correlation existed between direction of flow and ice margin orientation. Spatial correlation of mesostructure elements was poor most likely because the observational measurements across the ice margin or across a region of mesostructure were not aligned with the direction of flow. An unusual finding was the occurrence of an anomalously warm bottom water overlying much of the Chukchi Shelf. This water, often more than 1^0C warmer than the relict bottom water normally found in the Chukchi Sea in summer, is probably Atlantic water from the Arctic Ocean which has impusively surged up the canyons near the shelf edge and spilled over onto the shelf.

Conference Presentation: R. H. Bourke and R. G. Paquette, "Ocean Dynamics Leading to Temperature Mesostructure Near the Arctic Ice Margin," paper presented at the Fall Annual Meeting, American Geophysical Union, San Francisco, December 1975. Abstract in: Transactions, American Geophysical Union, Vol. 56 (12), 1975.

Publications: R. H. Bourke and R. G. Paquette, "Atlantic Water on the Chukchi Shelf," _Geophysical Research Letters_, 3 (10), 629-632, 1976. Also published as Technical Report NPS-68BF76121, December 1976.

Thesis Directed: W. J. Zuberbuhler and J. A. Roeder, "Oceanography, Mesostructure, and Currents in the Pacific Marginal Sea-Ice Zone - - MISPAC 75," Master's Thesis, September 1976. Also published as Technical Report, NPS-68PA76091, September 1976.

Title: Environmental Factors Affecting Sea-to-Beach Solid Cargo Transfer

Investigator: W. C. Thompson, Professor of Oceanography

Sponsor: Naval Coastal Systems Laboratory

Objectives: To evaluate the influence of a large number of environmental parameters on the logistics operation of solid cargo transfer from supply ships offshore to the beach or to shore facilities following the assault phase of an amphibious operation.

Summary: Analysis procedures developed at the Naval Coastal Systems Laboratory (NCSL) (ref: "Guide to the Analysis of Environmental Requirements for Naval Coastal Operations"; Dorman, Sterwart and Tolbert; NCSL, Feb. 1975) were used to assess the influence of 70 environmental parameters on the logistics of transferring solid cargo ashore from supply ships under secure beach conditions following an amphibious assault. The operational scenarios analysed include: cargo off-loading of ship to landing craft, landing craft transit to the beach, transit across the beach, supply ship transit to a shore facility, and cargo off-loading at the shore facility. The effect of each parameter on each scenario was quantitatively evaluated and critical points and go/no go situations identified. A large abstracted bibliography on the logistics of marine cargo transfer is included. This analysis constitutes an element of the Naval Inshore Warfare Program of NCSL designed to determine the status of environmental information collection and use in naval coastal operations.

Publications: None

Thesis
Directed: A. W. Winter, "Analysis of Environmental Factors Affecting Sea/Beach Solid Cargo Transfer," Master's Thesis, Technical Report, NPS-68WiTh76091, September 1976.

Title: Ocean Wave Climatology for the California
                     Coast

Investigator: W. C. Thompson, Professor of Oceanography

Sponsor: Department of Navigation and Ocean Devel-
                     opment, State of California

Objectives: a. To prepare specifications for the pro-
                     duction of ocean wave statistics for the
                     coast of California from non-spectral wave
                     analyses contained in the archives of the
                     Fleet Numerical Weather Central (FNWC),
                     Monterey, California.

                     b. To develop formats for presenting wave
                     statistics compiled from FNWC spectral ocean
                     wave analyses.

Summary: The state of California plans to produce
                     improved ocean wave statistics for the
                     California coast for coastal engineering
                     use. The technical specifications for pro-
                     ducing these statistics from non-spectral
                     (singular) wave hindcasts archived in FNWC
                     were developed under this contract (Ob-
                     jective (a)). Meteorology International,
                     Inc. is currently producing statistics under
                     a contract with the state in accordance with
                     these specifications. Looking to the fu-
                     ture, the possibility of compiling ocean
                     wave statistics from FNWC spectral wave
                     hindcasts was examined (Objective (b)). It
                     was determined that climatological wave
                     data that can be shoaled and refracted from
                     a deep-water station can be compiled in two
                     forms from spectral hindcasts: (1) sig-
                     nificant wave statistics, which are similar
                     to tables in current use except that the
                     simultaneous occurrence of multiple wave
                     trains is accounted for, and (2) spectral
                     element statistics, which give the occurrence
                     of energy densities contained in a matrix of
                     15 frequency bands and 12 directions bands.
                     The uses for spectral statistics are not now
                     developed but appear to be in the realm of
                     resonant reaction of structures to waves.

Conference Presentation:	W. C. Thompson and F. M. Reynolds. "Ocean Wave Statistics from FNWC Spectral Analyses," Presented at the 15th International Conference on Coastal Engineering, Honolulu, Hawaii, 11-17 July 1976.
Publications:	W. C. Thompson, "Specifications for the Production of Ocean Wave Statistics for the California Coast from FNWC Singular Wave Analyses," Technical Report, NPS-68Th76031, March 1976.
Thesis Directed:	F. M. Reynolds, "Climatological Wave Statistics Derived from FNWC Synoptic Spectral Wave Analyses," Master's Thesis and published as a Technical Report, NPS-58ReTh76061, June 1976.

Title: Small Scale Interactions and Energy Ex-
                  change in the Upper Ocean

Investigator: E. B. Thornton and N. E. J. Boston, Asso-
                  ciate Professors of Oceanography
                  K. L. Davidson, Associate Professor of
                  Meterology
                  T. M. Houlihan, Associate Professor of
                  Mechanical Engineering

Sponsor: Office of Naval Research

Objective: To determine the relationship of fluc-
                  tuating quantities of waves, temperature,
                  turbulent velocities, and conductivity to
                  each other, and to determine their effect
                  of acoustic transmission over short ($\sim$2m)
                  distance.

Summary: A stochastic model of surface wave-induced
                  temperature fluctuations was derived by
                  obtaining an exact solution to the dif-
                  fusion equation assuming the temperature
                  isotherms are horizontal and the mean temp-
                  erature gradient constant; linear wave
                  theory is used to describe the wave spec-
                  tral components. The model illustrates
                  that moderate narrow banded swell type
                  waves do little mixing and serve only to
                  pump the thermocline (and temperature field)
                  up and down. Using this model, a means for
                  separating turbulent and surface wave-in-
                  duced temperature fluctuations is demon-
                  strated. Spectral measurements of temp-
                  erature and waves made from the Naval Under-
                  sea Research and Development Center's
                  Oceanographic Research Platform off Mission
                  Beach, California are used to apply the
                  methods developed. Spectra of temperature
                  fluctuations and waves were computed for a
                  number of cases over a 3-year sequence of
                  experiments. The experimental results show
                  reasonable correlation with theory in the
                  upper ten meters of the ocean. Reduced
                  coherence between waves and temperature is
                  shown to be due to ambient turbulence and
                  nonlinear modulation of the surface wave-
                  induced temperature fluctuations by in-
                  ternal waves. The turbulent temperature
                  spectra are interpreted as reflecting the
                  behavior of the velocity field. Power law
                  slopes were found indicating buoyant (-3)
                  and inertial subranges (-2 and -5/3).

The equilibrium region in the frequency spectrum of wind generated waves was rederived. Laboratory and theoretical work show that wave breaking is the result of kinematic instability, suggesting that wave celerity is the governing parameter in the equilibrium region. Using similarity arguments, a genral formulation is rederived giving the wave spectrum, $S_n(\omega) \propto \omega^{-3}$. Wave and velocity measurements made in deep and shallow water are presented showing agreement with theory.

Publications: E. B. Thornton and N. E. J. Boston, "Small Scale Interactions and Energy Changes in the Upper Ocean," Technical Report, NPS 68Tm76061, May 1976.

E. B. Thornton, "Redirivation of the Equilibrium Spectrum of Wind Generated Waves," Journal of Physical Oceanography, January 1977.

Title: Kinematics of Breaking Waves in the Surf Zone

Investigator: E. B. Thornton, Associate Professor of Oceanography

Sponsor: Office of Naval Research

Objective: Basic studies are being made on the kinematics of water-particle motion within the surf zone and of breaking waves. These measurements will provide an increased understanding of the energy distribution within the surf zone, water-sediment interactions, breakdown of wave-induced motion to turbulence, and non-linearities involved in describing breaking waves.

Summary: Measurement of waves, and vertical and horizontal water particle velocities were made of spilling, plunging and surging breakers at sandy beaches in the vicinity of Monterey, California. The measured breaking waves, derived characteristically from swelltype waves, can be described as highly nonlinear. Spectra and cross spectra were calculated between waves and velocities. Secondary waves were noted visually and by the strong harmonics in the spectra. The strength of the harmonics is related to the beach steepness, wave height and period. The phase difference between waves and horizontal velocities indicates the unstable crest of the wave leads the velocities on the average by 5-20 degrees. Phase measurements between wave gauges in a line perpendicular to the shore show breaking waves to be frequency nondispersive indicating phase-coupling of the various wave components. The coherence squared values between the sea surface elevation and the horizontal water particle velocity were high in all runs, ranging above 0.8 at the peak of the spectra. The high coherence suggests that most of the motion in the body of breaking waves is wave-induced and not turbulent.

Publications: E. B. Thornton, J. J. Galvin, F. L. Bub, D. P. Richardson, "Kinematics of Breaking Waves," Proceedings 13th Int. Coastal Engineering Conf., ASCE, July 1976.

**Theses
Directed:**   J. J. Galvin, "Kinematics of Surf Zone
Breaking Waves; Measurement and Analysis,"
Master's Thesis, September 1975.

R. M. Smith, "Breaking Wave Criterion on
a Sloping Beach," Master's Thesis, September
1976.

Title: Investigation of Biochemical Relationships
                  for Determining Concentrations of Zooplankton
                  Biomass and its Correlation with Chemical and
                  Acoustical Properties of the Ocean.

Investigator: E. D. Traganza, Associate Professor of
                  Oceanography

Sponsor: Office of Naval Research

Objective: To study biochemical relationships associated
                  with biomass and trophic level in marine
                  zooplankton.

Summary: Sonar systems are limited by the reverberation
                  of marine organisms. One hypothesis is that
                  zooplankton estimates can be useful in
                  predicting this "volume reverberation" by
                  virtue of their importance in marine food chains.
                  In the past there have been no simple, reliable
                  methods which would give estimates of zooplankton
                  biomass. Now there is considerable promise
                  that biochemical relationships of cellular
                  constituents can be used to measure the concen-
                  tration of zooplankton and identify their trophic
                  level. We have completed our evaluation of car-
                  bon as a measure of total biomass and adenosine
                  triphosphate (ATP) as a measure of living biomass
                  in marine zooplankton. The method we developed
                  for carbon has proven to be highly successful
                  and has received a wide international response
                  from other investigators. The central problem
                  with the ATP method is the conversion factor,
                  C/ATP, which relates ATP content to biomass.
                  The C/ATP ratio was relatively uniform in a pure
                  species, but in ocean samples of mixed composi-
                  tion it showed the scatter one might expect of
                  a semi-random mixture of species having C/ATP
                  ratios varying manyfold to either side of the
                  mean. The ATP method, therefore, probably will
                  require calibration for a given area and
                  possibly season before it can be used as a measure
                  of living zooplankton biomass. A computer
                  simulation model of seasonal variations of the
                  Monterey ecosystem has indicated the possibility
                  of a close correspondence between the number of
                  major seasonal plankton variations and major
                  wind driven upwelling variations. Evaluation
                  of this suggestion must be weighed against sus-
                  pected effects of the seasonal ebb and flow of
                  the California undercurrent which is also
                  coupled to major atmospheric variation. An im-
                  portant effort for the study of biomass distri-
                  bution is the ongoing development of a size

sampling, in situ, net system (SSISNTE). An
initial wind tunnel study has been completed
in cooperation with the department of Mechan-
ical Engineering. Other new developments
include the acquisition of a high pressure
liquid chromatograph system for the analysis
of other cellular constituents. The first
application will be directed toward the amino
acid taurine, which, as a constituent found
primarily in animals, may be useful as a means
to discriminate phytoplankton biomass from
zooplankton biomass in samples of mixed
composition.

Publications: E. D. Traganza, J. C. Radney and K. J. Graham,
"A Convient Method for the Determination of
Carbon in Marine Net Zooplankton," Marine
Chemistry, 4, 1976.

E. D. Traganza and K. J. Graham, "Carbon/
Adenosine Triphosphate Ratios in Marine
Zooplankton," American Chemical Society, 31st
North Western Regional Meeting, University
of Nevada at Reno, 14-15 June 1976. (Abstract).
Also in EOS Transactions, American Geophysical
Union, 57(12), December 1976.

E. D. Traganza, K. J. Graham, R. T. Pearson,
J. C. Radney, and J. S. Anderson, "Carbon/
Adenosine Triphosphate Ratios in Marine
Zooplankton and the Annual Oceanography off
Monterey, California, 1974," Technical Report
NPS-58Tg76041, April 1976.

Theses
Directed: D. Hendrickson, "An Evaluation of a Computer
Simulation Model of Plankton Dynamics in Monterey
Bay," Master's Thesis, September 1976.

R. Mitchke, "Design and Wind Tunnel Test of a
Size Sampling, in situ, Net System (SSISNET),"
Master's Thesis, September 1976.

Title: Size and Number Distributions of Suspended
                Particulates in the 1.5 to 35 Micron Range
                in Central California Coastal Waters in Relation
                to the Spacial and Temporal Variations of
                Water Temperature and Density

Investigator: Stevens P. Tucker, Assistant Professor of
                Oceanography

Sponsor: Foundation Research Program (6.1)

Summary: The geographical and seasonal distribution
                with depth of 1 - 35 micron particles suspended
                in sea water is investigated by means of
                standard hydrographic techniques. The size
                analyses are made with a 15-channel Coulter
                counter and include data from four cruises
                to the north and south of Monterey Bay, Califor-
                nia. The size distributions are presented
                as isometric drawings showing particle number
                density vs. particle size as functions of
                depth from the surface in the case of single
                station data and of horizontal distance when
                data are for a given depth along lines of
                stations located at distances of 1, 2, 3,
                5, 7, 10, 15, 20, 25, and 30 n mi from shore,
                or in the case of Monterey Bay, separated
                by a distance of 1.5 n mi. A paper for submission
                to the Journal of the American Geophysical
                Union and a longer technical report containing
                all the oceanographic observations from the
                four cruises will be completed by early January
                1977.

Publications: None.

Title:	Dynamics of the Oceans
Investigator:	J. J. Von Schwind, Associate Professor of Oceanography
Sponsor:	Naval Sea Systems Command
Objective:	To prepare a detailed and systematic treatise covering the geophysical fluid dynamics of the oceans. When complete, the said treatise will include fundamental and advanced topics and be so structured and written as to be particularly useful to technical persons whose work involves the ocean environment but who may have little or no formal education in theorectical phisical oceanography.
Summary:	The treatise in its entirety will consist of four major parts: (1) Fundamentals of Geophysical Fluid Dynamics; (2) Ocean circulation Theories and Models; (3) Elementary and Advanced Wave Theories, Internal Waves, Tides; and (4) Advanced Topics in the Fluid Dynamics of the Ocean. At the present time, the subject matter to be covered is found only in a wide variety of sources, ranging from textbooks and technical journals to personal unpublished notes. To date most of the first section "Fundamentals of Geophysical Fluid Dynamics" has been completed.
Publications:	None

Title: Structure of the California Countercurrent

Investigator: J. B. Wickham, Associate Professor of Oceanography

Sponsor: Foundation Research Program (6.1)

Objective: To describe the structure and flow in the
                latitude of Monterey in the California Counter-
                current, including the delineation of mesoscale
                oceanographic features of the system in the
                vicinity of its boundary with the California
                Current.

Summary: The most interesting result, from preliminary
                analysis of new XBT data acquired from the National
                Marine Fisheries Service (NMFS), is that
                a cyclonic eddy delineated by direct current
                measurements in early August 1972 appears
                to have persisted to nearly the end of that
                month. Observations of intermediate times
                suggest variations in the eddy's form and
                weakening during that period. Information
                on such short time scales of features such
                as this are rare.
                    Additional analysis has been completed
                on the annual variation of the water masses
                in the countercurrent region. It indicates
                that the "southern water" characteristics,
                at least in the year 1972-1973, appear with
                greatest intensity in a narrow band within
                20 km of the coast in the period August through
                December with an abrupt onset and cessation.
                The August arrival is consistent with the
                pattern observed in 1971-72 in the same region.
                    A filamental structure of this same type
                with a maximum near the shelf edge also appears
                in the geostrophic analysis of "southern
                water" flow in the Coronado trough (off San
                Diego), the data for this analysis having
                been collected by this reporter in August
                1971. Current meter measurements off of
                Oregon and Washington also indicate a "shelf-
                edge" jet.

Data processing continues, particularly
digitizing of STD analogue records obtained
by NMFS. Their analysis is needed to confirm,
by geostrophy, the preliminary conclusions
about the persistence of the cyclonic eddy
described above.

Thesis
Directed:

C. S. Nelson, "Wind Stress and Wind Stress
Curl Over the California Current," Master's
Thesis, 1976.

DEPARTMENT OF MECHANICAL ENGINEERING RESEARCH PROGRAM FY76

The Department of Mechanical Engineering has a diversity of research interest and talent as is evidenced by the variety of projects. The various categories are as follows: (1) materials science, (2) mechanical and component design, (3) heat transfer, (4) structures, vibrations, and solids, (5) guns and missiles, (6) hydrodynamics and fluid mechanics, (7) environment and energy, (8) laser technology, and (9) shipboard automation.

MATERIALS SCIENCE

The Naval Postgraduate School has a strong commitment in Materials Science, with excellent laboratory facilities and active faculty. Professor Jeff Perkins directs projects in several areas, including (1) materials development for ship silencing applications, (2) failure analysis and performance optimization of lead-acid and silver-zinc submarine batteries, (3) corrosion of sacrificial anode materials used for cathodic protection of ships hulls, (4) velocity effects on corrosion of structural materials in seawater, (5) corrosion of explosively-bonded transition joints between aluminum (ships superstructure) and steel (deck) under salt-spray conditions. Other active projects involve development of subgrain-strengthened alloys through thermomechanical treatment, and ballistic materials testing. These projects are supported by extensive microscopic, microanalytical, electrochemical, and mechanical behavior research facilities.

MECHANICAL AND COMPONENT DESIGN

The Mechanical Engineering Department is developing a research activity in the area of advanced marine vehicle synthesis and design. To determine the current state-of-the-art, a series of lectures were organized. Speakers included engineers from NAVSEA, NAVSEC and industry. Based on the information accumulated during the year, future directions for M.E. activity is being evaluated.

A computer program for synthesis of destroyer-type ships has been obtained from Center for Naval Analysis. The program is being adapted to use with the NPS IBM 360 computer. An evaluation of the vulnerability of the hull of a remotely controlled minesweeper is underway. The work is being accomplished for Minesweeper Squadron 12.

Professors A. J. Perkins and T. McNelley, together with several thesis students, have investigated material problems related to design. The areas of activity include, corrosion of the interface between aluminum superstructure and steel decks, velocity effects of corrosion on structural materials in sea water, high damping capacity materials for ship silencing applications, and failure analysis of

lead acid submarine batteries.

Professor J. Brock investigated the problem of asymmetric loading of annular elastic shells. The work, containing formulas and results for four cases, has been published in the Journal of Applied Mechanics, Vol. 43, Series E, No. 2, June 1976, pp. 353-355. Two of these cases correct formulas and results for cases in the literature. The formulas and results for the remaining two cases are presented for the first time.

Under the supervision of Professor P. Marto, LT H. Search has considered the feasibility of compact main condensers aboard surface ships and submarines. The investigation examines possible weight, volume and life cycle cost payoffs, and the impact upon overall ship design and machinery layout.

HEAT TRANSFER

Heat Transfer is an extremely important facet of the Mechanical Engineering Department. Transfer of heat is a pervasive phenomenon which occurs to some degree in all engineering systems. Over the past year the Department has continued to pursue a vigorous program of heat transfer research.

In a joint Departments of Mechanical Engineering and Aeronautics project Professors Pucci and Miller have studied the Fouling of Marine Gas Turbine Waste-Heat Systems. The purpose of this program was to assist NAVSEC and NSRDC-Annapolis in the survey of the state-of-the-art in the definition of those parameters affecting the fouling of marine gas turbine waste-heat recovery systems.

Professor Kelleher has been continuing the investigation of the effects of gravity on the performance of gas loaded heat pipes. A third experimental heat pipe has been constructed and is currently undergoing tests employing liquid crystals to map the surface temperature on the heat pipe condenser. Professor Kelleher is also investigating the effects of secondary motion due to centrifugal forces on the heat transfer in curved ducts. The results would be very useful in analyzing the heat transfer on turbine blades or other flow fields with curved streamlines.

Professor Cooper has been investigating the heat transfer and pressure distribution on cylinders placed in close proximity to a wall when subjected to a flow normal to the cylinder axis. Using liquid crystal thermography Professor Cooper has determined the effect of the cylinder to wall distance on the drag coefficient and the heat transfer coefficient for the cylinder.

Professor Brock has been investigating the transient temperature distribution in an insulated metal pipe containing a fluid having a given thermal history. A method of solution has been developed for the thermal history in the wall of the pipe which is externally

insulated and through which a fluid is flowing with given temper-
ature, pressure and flow rate as functions of time. The appropriate
nonlinear partial differential equation accounting for variable
thermal properties has been solved on a digital computer using a
Crank-Nicolson scheme to assure stability. The results are useful
in analyzing piping and pressure vessels which may experience severe
thermal stress transients due to the rapid variation in the
temperature - pressure - flow conditions of their fluid contents.

Professor Marto has continued to investigate the heat transfer
performance of rotating, wickless heat pipes. A new experimental
heat pipe has been constructed and tests are underway to study ways
to augment performance. Professor Marto has used liquid crystals
to map the surface temperature of a heating foil during nucleate
boiling of thin liquid films of water, alcohol and freon. Professor
Marto has recently begun a heat transfer analysis of main steam
condensers aboard surface ships and submarines. A feasibility study
is underway to examine compact condenser designs and the possible
payoffs in weight, volume and life-cycle costs.

STRUCTURES, VIBRATIONS, AND SOLIDS

Professors G. Cantin, D. Salinas, and R. E. Newton have continued
work on applications of the finite element method. Professor Cantin
has studied both elastic and inelastic responses of explosively
loaded structures, comparing the efficacy of four widely used
standard programs: SAP IV, NONSAP, MARC CDC and NASTRAN. During
the spring quarter, while serving as visiting professor at the
Université de Technologie in Compiègne, France, he participated in the
development of a new algorithm for constructing continuous stress
fields from the displacement fields found by finite element method
(FEM). A previously initiated study on methods for the experimental
determination of elastic constant of anisotropic materials was
continued.

Professor Salinas has completed extensive revisions to his
previously developed elastic-plastic FEM program. The new version
features a compact storage scheme for coefficient matrices with a
resulting substantial reduction in storage requirements.

Professor Newton has completed a study on the response of sub-
marine hull structures to nuclear blast waves. The technique
developed allows resolution of the three-dimensional problem into
an equivalent set of two-dimensional problems. For a representative
structure FEM is used to determine critical combinations of blast
and submergence pressures sufficient to produce shell collapse.

Professor J. E. Brock has investigated methods for estimating
the gravest frequency of a vibrating system. Two major extensions
of the method of Dunkerley have resulted. First of these is a
technique for suppressing rigid body modes whose presence makes the
classical form of the method inapplicable. The second is an iterative
process which yields major accuracy gains for successive estimates.
He has shown the applicability of these developments to a wide
variety of discrete and continuous systems.

GUNS AND MISSILES

Several professors are involved in a gun-related research; these are Professors Nunn*, Houlihan, Perkins, Edwards, Salinas and Fuhs. Results from Professor Nunn's work on liquid gun propellants was published in ASME Journal of Engineering for Industry. The dynamics of liquid gun propellant injection continues as an active research area under the leadership of Professor Houlihan; the work is funded by Naval Ordnance Station, Indian Head, MD. Liquid gun propellants offer many advantages especially in logistics. Digital simulation of propellant injection process has been completed. External burning in the supersonic stream near the base of a projectile can eliminate base drag and even provide a net thrust on the base to partially overcome nose drag. Professor Fuhs has investigated external burning with the goal of introducing performance parameters into a trajectory computer code.

Professor Salinas has investigated the elastic-plastic behavior of an obturator using a finite element method with an optimal compact storage scheme. The scheme provides a substantial improvement in computer efficiency over existing methods.

HYDRODYNAMICS AND FLUID MECHANICS

Hydrodynamics and fluid mechanics are a vital technology for the Navy; the Mechanical Engineering Department has a strong research program in support of Navy needs.

Professor T. Sarpkaya has investigated the problem of cable strumming, periodic flow about bluff bodies, effects of polymers on the lift and drag characteristics of hydrofoils, the vortex breakdown phenomenon in connection with the flight of delta wing aircraft, and the stability of swirling flows. During the past year, Professor Sarpkaya designed and constructed a large U-shaped water tunnel facility and carried out extensive tests on smooth and rough cylinders to predict wave forces on ocean structures. This work attracted world-wide attention and several letters of commendation from the Navy sponsors. Professor Sarpkaya is currently building a new vertical water tunnel to simulate impulsive flow about cylinders and flow about slender bodies at high angles of incidence.

Professor Garrison has continued his research in numerical free-surface hydrodynamics, his most recent effort being devoted to the second-order theory of wave-body interactions. He has also carried out fundamental experimental research on the oscillatory flow past circular cylinders at critical Reynolds number.

Research has been initiated in FY76 by Professor Pucci on the subject of the Optimized Ship Exhaust Eductor. The purpose of this investigation is to assist NSRDC-Annapolis in the design of exhaust gas stack eductors for shipboard gas turbine propulsion plants. The program involves the design, construction and testing of scale models.

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*On leave at ONR Office, London

During the FY76 a major portion of the design of the experimental
facility was completed, and some of the equipment fabricated.

ENVIRONMENT AND ENERGY

During FY76 several faculty members have contributed to the
area of environmental problems and new energy sources. Professor
Houlihan has improved upon prototype operation of an automatic
oil monitoring system which utilizes a direct difference method
of total organic carbon determination. His efforts have concen-
trated on achieving rapid evaluation of samples injected into the
system. Professor Kelleher has been investigating the optimization
of the design of Ocean Thermal Energy Conversion (OTEC) power
generating plants. These are power plants in which the naturally
occurring temperature differences in the oceans are utilized to
generate electric power. The study has attempted to formulate an
engineering design which takes into account the cost of the
various system components and then to optimize the design based on
a minimum cost of the entire system. Professor Nguyen continues
his research activities in the field of nuclear reactor dynamics
with temperature dependent feedback. Solutions for the two
following problems have been obtained and published: the one-
velocity space-dependent dynamics behavior following asymmetric
disturbances, and the multi-group space-dependent transient for
uniform initial conditions.

LASER TECHNOLOGY

The DoD annual budget in high energy lasers is approaching
$200,000,000. High energy lasers will have a significant impact
on future military operations; the influence of HEL on military
operations will be as great as the advent of nuclear detonations.
The Mechanical Engineering Department has as active research
program oriented to the many new and challenging laser problems.

Professor Houlihan is a member of the research team measuring
propagation of laser beams in the marine atmosphere. His knowledge
concerning instrumentation and turbulence contributes to the overall
goals of the propagation research.

On 6-8 April 1976, NPS hosted a workshop on nuclear pumped
lasers. The workshop was sponsored by ONR and AFOSR and was
attended by about 40 engineers and scientists from the major laser
laboratories in the U.S.A. The aim of the workshop, which was
organized by Professors Nguyen and Fuhs, was to identify research
essential to development of nuclear pumped lasers.

LCDR Fenton Carey working under the guidance of Professor Fuhs
completed his Ph.D. dissertation on transonic thermal blooming.
As a result of the research the boundaries where serious transonic
thermal blooming occurs have been delineated. Compressible flow
over a laser turret causes phase distortion in the laser beam.
Optimum turret designs are being investigated by Professor Fuhs
and Adjunct Research Professor Vanderplaats.

SHIPBOARD AUTOMATION

The Navy is placing increased emphasis on shipboard auto-
mation. Among the reasons for this emphasis is the ability to
operate an automated ship with fewer men and the ability to
increase fuel economy. In the rework of Building 500, space was
set aside for a shipboard automation laboratory. Professor
Houlihan is initiating research oriented toward automated
propulsion control.

Title: Transient Temperature Distribution in an Insulated
                    Metal Pipe Containing a Fluid Having a Given
                    Thermal History

Investigator: John E. Brock, Professor of Mechanical Engineering

Sponsor: Unsponsored

Objective: To develop a method of solution for the thermal
                    history in the wall of a metal pipe which is
                    externally insulated and which is convectively
                    exposed to fluid contents having given temperature,
                    pressure, and flow as functions of time.

Summary: In electric power generating stations (particularly
                    nuclear power plants) and in test facilities
                    intended to expose elements intended for use in
                    such stations to realistic environments, severe
                    transients may result from "scrams" and other
                    postulated events. Piping and vessels may experience
                    severe thermal stress transients because of rapid
                    variation in the temperature-pressure-flow conditions
                    of their fluid contents. The wide range through
                    which temperatures vary during such events vitiate
                    the customary assumptions of constant physical
                    properties of the piping material. Indeed there are
                    significant variations of thermal conductivity (and
                    other properties) during a typical transient.
                    Furthermore, the classical solution for hollow
                    cylinder geometry is quite inconvenient for routine
                    calculation purposes even under the unrealistic
                    assumption of constant properties. Accordingly,
                    the appropriate nonlinear partial differential
                    equation (accounting for nonconstant properties)
                    has been derived for the case of axisymmetrical
                    geometry (one space dimension, plus time) and has
                    been expressed in the form of a set of difference
                    equations, using a Crank-Nicolson scheme to assure
                    stability. Results have been compared with
                    theoretical results in a few idealized cases
                    (constant properties). A digital computer program
                    is used for the solution. Subroutines compute
                    properties for superheated steam (the fluid con-
                    tents presently incorporated) and for low chrome-
                    moly pipe (P22) material. Applications include
                    marine power plants.

Publications: None

Title: Dunkerley-Mikhlin Approximations for the Gravest
              Frequency of a Vibrating System

Investigator: John E. Brock, Professor, Mechanical Engineering
              Department

Sponsor: Foundation Research Program (6.2)

Objective: To sharpen and extend the method, usually
              known as "Dunkerley's Method" employed for
              obtaining a lower bound for the gravest frequency
              of a simple vibrating sound.

Summary: A method has been developed for analyzing
              discrete and/or continuous vibrating systems
              so as to obtain approximations of various
              degrees of accuracy for the gravest (nonzero)
              frequency of vibration. The treatment of
              cases involving rigid body modes is new, powerful,
              and particularly interesting in that it involves
              the compliance (flexibility) of a related
              system in which the rigid body modes are arbitrarily
              suppressed in an non-unique manner. Also
              new is the ability to obtain higher order
              approximations by iterating a certain matrix
              (in the discrete case) or by iterating a Green's
              function in the continuous case. The method
              has been applied to a number of cases having
              engineering significance. In particular some
              remarkably accurate and simple formulas have
              been developed for some useful cases of beam
              vibration.

Publications: J. E. Brock, "Dunkerley-Mikhlin Estimates
              of Gravest Frequency of a Vibrating System,"
              Journal of Applied Mechanics, Vol. 43, Series
              E, No. 2, June 1976 (Volume 98 of the Transactions
              of the American Society of Mechanical Engineering),
              345-348.

              J. E. Brock, "Asymmetric Moment Loading of
              Annular Elastic Plates," Journal of Applied
              Mechanics, Vol. 43, Series E, No. 2, June
              1976 (Volume 98 of the Transactions of the
              American Society of Mechanical Engineers),
              353-355.

              J. E. Brock, "Dunkerley-Mikhlin Estimates
              of Gravest Frequency of a Vibrating System,"
              Technical Report NPS59Bc75101, October 1975.

J. E. Brock, "DM Approximations for the Gravest
Frequency of a Vibrating System," Technical
Report NPS59Bc75111, November 1975.

Conference
Presentations:

J. E. Brock, "Dunkerley-Mikhlin Estimates
of Gravest Frequency of a Vibrating System,"
presented at the National Conference of Applied
Mechanics, University of Utah, Salt Lake City,
Utah, June 1976.

Title: Finite Element Methods in Structural Mechanics

Investigator: G. Cantin, Professor of Mechanical Engineering

Sponsor: Université de Technologie, Compiegnè, France

Objective: Teach Finite Element techniques to the Graduate
                 students of the Université de Technologie In
                 Compiegnè and participate in the research en-
                 deavors of these students.

Summary: The Fall quarter of 1974 and the Spring quarter
                 of 1976 were spent in France to accomplish the
                 stated objectives. Several short projects were
                 completed and some results published by the
                 students. One significant method was discovered
                 to solve an iterto intractable difficulty of
                 the F. E. method for structural problems. The
                 method permits to satisfy stress boundary condi-
                 tions with a considerable improvement of solu-
                 tions in all the cases treated. The research is
                 ongoing.

Publication: None

Title: Structural Integrity of Gas Turbine Caramic
                Components

Investigator: G. Cantin, Professor of Mechanical Engineering

Sponsor: Naval Ship Engineering Center

Objective: Gas turbine Caramic components must be able to
                sustain very high stress levels at high temper-
                ature under dynamic loading. These problems are
                very complex and require a group effort, so
                Professor Pucci and I have joined to provide
                consulting services to NAVSEC for this ARPA
                project, as well as conducting an independent
                study here at the Naval Postgraduate School for
                the solution of such problems.

Summary: The computation techniques of Airesearch Manu-
                facturing Company of Arizona were critically
                reviewed and the results transmitted to NAVSEC,
                the first design review of the same contractor
                also took place last month and we participated
                actively in this process.

Publication: None

Title: Nonlinear Stress Strain Analysis

Investigator: G. Cantin, Professor of Mechanical Engineering

Sponsor: Naval Weapons Center

Objective: Determine whether available analytical technology
                (codes) could be used in the design of shells
                that could penetrate a substantial thickness of
                concrete and preserve some structural integrity.
                The load on the shell is explosive and the
                deformations and material behavior expected to be
                in the nonlinear range.

Summary: MARC CDC, NASTRAN, SAP IV and NONSAP all have
                advertised capabilities to do all or part of the
                preliminary studies. Our first task was to
                verify that the advertised capabilities really
                existed and that the codes could give reliable
                results for design usage. Two problems were
                defined and solutions obtained with all four
                systems. The comparison of results is ongoing
                and another system ADINA has been added to our
                study.

Publications: None

Title: Finite Element Formulation for Doubly Curved
                Shells

Investigator: G. Cantin, Professor, Mechanical Engineering
                Department

Sponsor: Foundation Research Program (6.2)

Objective: The objective of the project was to review
                results obtained by G. Fonder of the University
                of California at Berkeley, that contradicted
                similar results obtained here at the Naval
                Postgraduate School, by Dean Kiess, one of
                our graduate students.

Summary: The results of Kiess were reproduced and found
                to be seemingly correct. It was impossible
                to reproduce the results of Fonder and there
                are indications that his computations may
                be erroneous. The work is not finished and
                had to be abandoned for more urgent projects.
                The support received from the Foundation was
                returned to the Foundation.

Publications: None

Title: Synthesis of Advanced Marine Vehicles

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Sponsor: Foundation Research Program (6.2)

Objective: To develop a computer program which provides
                  for computer-aided synthesis of an advanced
                  marine vehicle.

Summary: A modern navy has a variety of marine vehicles
                  from which to choose including hydrofoil craft,
                  capture air bubble, surface effect ships,
                  submerged hull, conventional hull, multiple
                  hull, and wing-in-ground-effect. Each class
                  of vehicle has different trade offs which
                  can be demonstrated by a realistic computer-
                  aided synthesis program. One of the vehicle
                  classes will be chosen for emphasis.

                  To initiate the work on the subject of
                  advanced marine vehicle synthesis, a series
                  of lecturers were invited from NAVSEC, NAVSEA,
                  industry and universities. These lectures
                  established a benchmark on current state-of-
                  the-art. As a result, the thrust of NPS effort
                  becomes clear and duplication of work done
                  elsewhere is avoided.

                  One project initiated as a result of a
                  preliminary work is the evolution of a remotely
                  controlled minesweeper. Professor Fuhs visited
                  MINRON 12 in Charleston, SC to coordinate
                  the work. MINRON 12 has a direct interest
                  in the remotely controlled minesweeper. The
                  project extends into FY7T and FY77.

Publications: None

Title: Cylindrical Shockwave Diffuser for Gas Dynamic
                  and Chemical Lasers

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Sponsor: Naval Air Systems Command

Objective: To determine to what degree significant reductions
                  in laser weight and volume can be achieved by use
                  of cylindrical laser geometry. Prior to this
                  investigation, a multiple-nozzle, cylindrical
                  geometry had never been operated in supersonic
                  flow with a cylindrical shock wave.

Summary: Apparatus using 4, 5, or 6 nozzle discs was
                  designed. The discs were fed along the centerline
                  from both ends of the stack. The design Mach number
                  was 4.2. Boundary layer bleed was provided in both
                  end walls. The cylindrical nozzles were installed
                  in a plenum which had ejectors for control of the
                  exit pressure. A cylindrical shock wave was
                  established with a region of supersonic flow
                  between nozzle exit and the shock wave. The shock
                  wave was corrugated due to variations in stagnation
                  pressure arising from nozzle boundary layers and
                  wakes. In spite of extensive suction on boundary
                  layer at end walls, the end flow channels were not
                  started. The experiments were a success in that
                  a stable cylindrical shock wave formed by a
                  multiple disc nozzle array was demonstrated. More
                  work is required to establish supersonic flow in
                  the channels next to the end walls.

Publications: D. Donoghue and A. E. Fuhs, "Cold Flow Tests of a
                  Multiple-Disc Cylindrical Nozzle with Shock Wave
                  Diffuser," TRI-SERVICE CHEMICAL LASER SYMPOSIUM,
                  AFWL, Kirtland AFB, NM, 18-20 Feb 1976.

Thesis   D. Donoghue, "An Experimental Analysis of A
Directed: Cylindrical Shock Wave for Use in a Cylindrical Gas
                  Dynamic Laser," Master's Thesis, June 1975.

Title: Partial-Isentropic Laser Diffuser with Boundary
                Layer Bleed

Investigator: A. E. Fuhs, Professor of Mechanical Engineering,
                and LT Paul Habel, Graduate School

Sponsor: Naval Weapons Center

Objective: There are two objectives: To construct a diffuser
                with large pressure recovery by using isentropic
                diffusion from M = 3.5 to M = 2.3 and to determine
                the influence of boundary layer bleed at various
                locations in the diffuser.

Summary: Boundary layer bleed is common practice in air-
                craft inlets; bleed enhances pressure recovery.
                An experimental investigation has been conducted
                using a partial-isentropic diffuser with extensive
                boundary layer bleed. To determine the influence
                of location and amount of bleed, 35 different
                bleed circuits were incorporated. Any combination
                of end wall, side wall compression surface, throat
                etc. bleed was attained by selectively opening
                the appropriate valves.

                The Mach number in the cavity was 3.5. Without
                bleed, the diffuser would unstart at a pressure
                ratio of 11 to 1, i.e., ratio of plenum to atmos-
                pheric pressure. With boundary layer bleed the
                minimum pressure ratio to maintain supersonic
                flow was 8.5 to 1. Bleed gives a significant
                improvement in diffuser pressure recovery.

                An important result was found experimentally.
                Pressure at the diffuser throat is greater than
                in the cavity. It is possible to bleed the
                boundary layer in the critical throat region and
                inject the gas into the cavity. External bleed
                pumps are not required. Bleed in this manner has
                been termed self-activated bleed. Using self-
                activated bleed, the minimum pressure to maintain
                supersonic flow was reduced from 11 to 9. Use of
                self-activated bleed translates directly into a
                20% reduction in the requirement for ejector
                propellants.

                Contraction ratios greater than values reported
                in the literature (1.64 vs. 1.39) were achieved.
                To start the diffuser fast-acting, self-activated,
                mass bleed valves were used to remove mass from
                the cavity during start. Once supersonic flow is
                established, the valves close automatically.

Conference
Presentations:
Paul Habel and A. E. Fuhs, "Influence of Mass and
Boundary Layer Bleed on Starting and Pressure
Recovery in Laser Diffusers," presented at the
TRI-SERVICE CHEMICAL LASER SYMPOSIUM, AFWL,
Kirtland AFB, New Mexico, 18-20 February 1976.

Thesis
Directed:
Paul G. Habel, "A Study of Boundary Layer and Mass
Bleed in a Short Length Supersonic Diffuser for a
Gas Dynamic Laser," Master's Thesis, March 1976.

Title:	Assessment of High Energy Laser Role on Future Navy
Investigator:	A. E. Fuhs, Professor of Mechanical Engineering
Sponsor:	Naval Air Systems Command and Naval Weapons Center
Objective:	To introduce operational experience into an assessment of potential of high-power lasers on board future Navy aircraft.

Summary:

High-energy lasers (HEL) have not reached the level of technological maturity where selection of type of laser, optics, turrets, etc., is a straightforward process. Naval Air Systems Command (NAVAIRSYSCOM) wants to inject the operational experience of Naval Aviators into the selection process. For example, what about logistics of deuterium fluoride on an Attack Aircraft Carrier (CVA)? What does the carrier landing do to microradian optical alignment? Students involved in the project have a total of 50 man years of carrier experience with F-4, F-8, A-4, A-6, E-2, A-3, and A-5 aircraft. Initially a state-of-the art gas dynamic laser was designed and packaged for the S-3 A aircraft making it a S-3 L. A joint project was initiated with National Aeronautics Space Administration (NASA) Ames to design an aircraft for a laser platform. The aircraft is the largest aircraft that can be operated from the Navy's 12 carriers. The aim was to incorporate the laser giving the most intensity (kW/cm^2) at a specified range.

Other aspects of HEL on an aircraft have been investigated. The improvement in specific power achieved by use of regenerative heating of nitrogen in a Gas Dynamic Laser (GDL) has been assessed. Future pointing and tracking needs have been studied. An important classified mission for HEL has been investigated.

Publications:	None
Thesis Directed:	L. Rhine, "A Regeneration Carbon Dioxide Gas Dynamic Laser," Master's Thesis, June 1975.

Title: External Burning Assisted Projectile

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Sponsor: Naval Ordnance Station

Objective: To develop a fast subroutine to replace the un-
                   wieldy external burning assisted projectile
                   (EBAP) computer code.

Summary: In prior years a computer program was developed
                   which predicts base pressure for supersonic
                   conbustion in the region near the recirculation
                   zone of a projectile. Validity of the predictions
                   was established by a complementary experimental
                   program. The computer program uses the saddle
                   point singularity to uniquely select the base
                   pressure. For trajectory analysis of an EBAP,
                   base pressure is required as a function of Mach
                   and Reynolds numbers.

                   To decrease computer time, selected combinations
                   of values of input parameters have been used for
                   determining base pressure. A regression analysis
                   in several dimensions has yielded a subroutine
                   which gives base pressure prediction in less than
                   a second. Correctness of the predictions hinges
                   on the full EBAP program. The subroutine is well
                   suited for trajectory analysis.

                   A ramjet program has been developed for the
                   HP9830 desk calculator for use by the personnel
                   at the Naval Ordnance Station. The program models
                   the inlet, combustion chamber and nozzle with
                   base flow to obtain component efficiencies. Effi-
                   ciencies are used to calculate specific fuel con-
                   sumption, thrust coefficient and specific thrust.
                   The program can be used in the NOS trajectory
                   computer code. In FY 1975 the ramjet inlet and
                   combustion chamber were modeled.

                   Another study initiated involves a comparison
                   between guns and missiles. Under what conditions
                   are guns the better weapon and under what condi-
                   tions are missiles superior. Development of pro-
                   jectile propulsion alters the importance or range
                   in selection of guns or missiles. There are many
                   parameters to be evaluated including cost, time of
                   flight, ordnance storage, response time, rate of
                   fire, launch accuracy, etc.

Conference
Presentations: A. Roberts and A. E. Fuhs, "Analysis of Propulsion for Gun Launched Projectiles," presented at the 12th Joint Army Navy Nasa Air Force (JANNAF) Propulsion Meeting, October 1975.

Publication: W. Smithey and A. E. Fuhs, "External Burning Assisted Projectile." (AIAA) Progress Series, Aerodynamics of Base Combustion, Volume 40, 1975.

Thesis
Directed: W. Smithey, "Projectile Thrust-Drag Optimization with External Burning," PhD Dissertation, June 1974.

Title: Transonic Thermal Blooming of a Slewed High Energy Laser Beam

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Sponsor: Air Force Weapons Laboratory

Objective: To study the seriousness of thermal blooming near Mach one.

Summary:
Due to absorption of radiation from a laser beam the index of refraction changes, causing spreading of the beam; this process is known as thermal blooming. When the beam is slewed, as it will be when tracking, there is a relative wind. Depending on the Mach number of the relative wind, the severity of thermal blooming varies. At precisely Mach one, the waves arising from heat addition add. In the linear theory the perturbation grows without limit. Nonlinear effects terminate the growth.

Near a Mach number of unity the equations of gas dynamics are nonlinear. Because the equations are nonlinear, systematic solutions are nonexistent. Many special techniques have been developed for airfoils; however, these methods are not applicable to distributed heat sources, i.e., heat from laser beam. A new approach was developed. Using the equations of gas dynamics in natural coordinates, the nonlinearity can be removed if streamline shape is specified. A pair of simple, first order partial differential equations result; these can be easily solved numerically. A check exists for choice of streamline shape; the check is the comparison of heat absorbed from the beam and the heat required to change flow properties. These two heat inputs must, of course, be equal. Streamline shape is adjusted until equality is achieved.

The research has shown that transonic thermal blooming is not as serious as originally feared.

Publications:
A. E. Fuhs, "Propagation of Laser Beams Which are Rapidly Slewed," The Proceedings of the Electro-Optical Systems Design/International Laser 1975 Conference, Laser Institute of America, 1975.

E. Fenton Carey and A. E. Fuhs, "Transonic Thermal Blooming Due to an Intense Laser Beam," Journal of Aircraft, 13, pp 974-980, December, 1976.

Title: Second-Order Theory of Wave Interaction with
                  Fixed Bodies

Investigator: C. J. Garrison, Associate Professor of Mechanical
                  Engineering

Sponsor: National Science Foundation

Objective: The objective of this research is to develop a
                  mathematically consistent, second-order perturba-
                  tion theory for the determination of gravity wave
                  interaction with large bodies of arbitrary shape.
                  The final phase of the work will involve the
                  experimental verification of the theory.

Summary: The development of the second-order theory of
                  wave/body interaction has been completed. Both
                  the first-order and second-order boundary value
                  problems have been formulated and a numerical
                  solution based on the use of a Green's function
                  has been developed. A computer code has also been
                  developed to carry out the numerical solution for
                  the velocity, pressure distribution and overall
                  forces acting on a semi-immersed body of arbitrary
                  shape. The results of the work are directly
                  applicable to the solution of practical problems
                  involving the determination of the loading of
                  offshore structures and are also of theoretical
                  interest with respect to the general theory of
                  free-surface hydrodynamics. This is a continuing
                  project.

Conference   C. J. Garrison, "The Consistent Second Order
Presentation: Diffraction Theory," presented at the 15th Coastal
                  Engineering Conference, July 11-17, 1976, Honolulu,
                  Hawaii.

Title: Dynamic Response of Moored OTEC Plants to Ocean
                        Waves

Investigator: C. J. Garrison, Associate Professor of Mechanical
                        Engineering

Sponsor: Energy Research and Development Administration

Objective: This research has as objectives the analysis of
                        the dynamic response of large flexible floating
                        objects to ocean waves. A computer code will be
                        generated as part of this project which will be
                        used to study the dynamic response of floating
                        OTEC plants. This analysis will include the
                        high-frequency response to an ocean spectrum as
                        well as the slow-drift response associated with
                        the so-called steady-state drift force.

Summary: The development of Ocean Thermal Energy Conversion
                        plants which will be moored in the ocean requires
                        a knowledge of the dynamic response incuded by
                        storm waves. Traditionally, naval architects
                        have been concerned with the motion of the two-
                        dimensional shiplike configuration; the floating
                        OTEC plant poses new problems. Additionally, the
                        mooring of large objects in the sea presents many
                        new problems. Slow-drift oscillations occur and
                        this low-frequency surging motion is very often
                        the most critical factor in design because it may
                        approach the natural frequency of the mooring
                        system. This is a continuing project.

Conference   C. J. Garrison, "Dynamic Response of Floating
Presentations: Bodies," Paper No. OTC 2067 presented at the
                        Offshore Technology Conference, Houston, Texas,
                        May 1974.

Publications: C. J. Garrison, "Hydrodynamics of Large Objects
                        in the Sea - Part I: Hydrodynamic Analysis,"
                        Journal of Hydronautics, Vol. 8, No. 1, Jan. 1974.

                        C. J. Garrison, "Hydrodynamics of Large Objects
                        in the Sea - Part II: Motion of Free-Floating
                        Bodies," Journal of Hydrodynamics, Vol. 9, No. 2,
                        April 1975.

Title: Drag and Inertia Coefficients in Oscillatory
                         Flow About Cylinders

Investigator: C. J. Garrison, Associate Professor of Mechanical
                         Engineering

Sponsor: Unsponsored

Objective: The objective of this work is the experimental
                         determination of the coefficients of drag and
                         inertia in oscillatory flow about both smooth and
                         rough circular cylinders. Emphasis was placed
                         on the correlation of these two coefficients with
                         Reynolds number and the relative amplitude of the
                         motion and extending this correlation into the
                         large Reynolds number range of interest in practice.

Summary: Experiments were conducted using a water channel
                         16 feet long, 4 feet deep and 2 feet wide. A
                         circular cylinder which spanned the distance
                         between the two walls of the channel was oscillated
                         in harmonic motion by use of a carriage connected
                         to an eccentric drive wheel. Several tests have
                         been carried out for both a smooth and rough
                         cylinder and the resulting values of the drag and
                         inertia coefficients correlated with the Reynolds
                         number and relative amplitude of the motion
                         (amplitude to diameter ratio). In the case of the
                         smooth cylinder, the Morison equation was found
                         to represent the measured force/time relationship;
                         satisfactorily and highly useful correlations of
                         the drag and inertial coefficients were produced.
                         These results extend into the large Reynolds
                         number range and, accordingly, are of great
                         importance in application. The results obtained
                         using a rough cylinder were not well-represented
                         by use of the Morison equation within the range of
                         the experiments. This area will be studied further
                         in the future; this is a continuing project.

Conference   C. J. Garrison, "Drag and Inertia Coefficients in
Presentations: Oscillatory Flow About Cylinders," Paper No. 2693,
                         presented at the American Society of Chemical
                         Engineers' National Water Resources and Ocean
                         Engineering Convention, San Diego, California,
                         April 5 - 8, 1976.

Title: LPG Feed System Dynamics

Investigator: T. M. Houlihan, Associate Professor of Mechanical
                Engineering

Sponsor: Naval Ordnance Station, Indian Head

Objective: A computer model was to be developed to simulate
                a projectile ram-propellant feed system for a
                Liquid Propellant Gun.

Summary: Using a lumped parameter approach, a set of
                simultaneous differential equations was derived
                for the interaction of propellant fluid, driving
                injector and projectile. The computer model was
                verified against a 20mm experimental apparatus.
                System parameters affecting projectile ram time
                and chamber pressure oscillations were investigated.

Publication: Dampier, C. R. and Houlihan, T. M., "Computer
                Simulation of an LPG Propellant Feed System,"
                Technical Report, NPS 69Hm76091, September 1976.

Title: A Study of the Secondary Flow in a Curved Rectangular Channel

Investigator: M. D. Kelleher, Associate Professor, Mechanical Engineering Department

Sponsor: Foundation Research Program (6.2)

Objective: The objective of this work has been to study the structure of the secondary motion induced by centrifugal forces in a curved channel of large aspect ratio. The study was carried out using a hot wire anemometer system which was capable of traversing in two directions over the channel cross section.

Summary: The apparatus for the present study consists of a plexiglas channel with a contraction inlet followed by a straight section 122 cm. long. This is then followed by the curved test section. The flow is maintained by suction from a centrifugal blower. A rotometer is installed between the outlet of the test section and the blower. The flow cross section is 0.635 cm by 25.4 cm for an aspect ratio of 40. The straight section immediately down stream of the inlet nozzle is of sufficient length for the flow to be fully developed before entering the curved section. With the high aspect ratio of the flow cross section the flow is essentially two dimensional Poiseuille flow before entering the curved section. The curved section of the channel turns through 180 degrees with the radius of curvature of the outer (concave) wall being 30.48 cm and the radius of the inner (convex) wall being 29.84 cm. The hot wire anemometer traverse is mounted through the convex wall at a location 135 degrees downstream of the start of the curved section.

This traverse mechanism is free to move in both the spanwise direction and the radial direction across the channel gap. The movement in the spanwise direction is controlled by a DC Stepper motor and sweep drive unit. With this system the speed of traverse could

be controlled over a very wide range. For
these experiments the spanwise traverse was
run at a speed of 0.85 mm/sec. The output
from the sweep drive unit also served as
a linear displacement transducer which indicated
the spanwise position of the hot wire probe.
The movement in the radial direction is controlled
by a hand operated micrometer unit. Although
the traverse mechanism was capable of sweeping
15.24 cm in the spanwise direction, during
the actual measurements it was found that
a 5.0 cm traverse gave good results. With
the relatively slow traverse speed of 0.85
mm/sec. a single traverse required approximately
one minute.

The velocity surveys were made as follows:
the blower for the channel was set to provide
the desired flow rate. With the traverse
set at the initial spanwise position the
hot wire probe was set at the desired radial
position by means of the micrometer. After
the initial position of the hot wire probe
has been established the sweep drive mechanism
was turned on to begin the automatic traverse
of the hot wire across the channel. When
the 5 cm traverse was completed the traverse
was reversed to return the probe to its original
position. The radial position was then changed
by 0.635 mm by adjusting the micrometer setting
and a new traverse was begun. The procedure
was continued until the probe was at a position
0.635 mm from the concave wall. This was
the closest position for traversing the hot
wire probe. The data was recorded directly
on an x-y plotter. The output from the sweep
drive unit representing spanwise displacement
was recorded on the x axis and the linearized
signal from the hot wire probe representing
velocity was recorded on the y axis. The
velocity surveys were conducted for three
different flow rates corresponding to Dean
numbers of 79.2, 94.9, and 113.5. In each
of these cases spanwise velocity traverses
were made at six different radial positions.
The periodic nature of the secondary flow
is clearly illustrated. As would be expected
the amplitude of the periodic motion is greatest
in the region close to the concave wall.
It is interesting to note that the velocity

profile on the convex side of the mid-plane
is 180 out of phase with the velocity profile
on the concave side of the mid-plane. This
is similar to the phenomenon observed by
Shubaur and Skramstad in their measurement
of the Tollmien-Schlichting waves in the
boundary layer on a flat plate. In the sense
that the mid-plane is the location across
which the phase reversal takes place, it
is similar to the critical layer for Tollmien-
Schlichting waves. The phase shift is present
at all three Dean Numbers. Average values
of the wave number were calculated from the
velocity profiles for the three Dean Numbers.

Publications: None

Title: Effects of Gravity on Gas-loaded Variable
                Conductance Heat Pipes

Investigator: M. D. Kelleher, Associate Professor of Mechanical
                Engineering

Support: National Science Foundation

Objective: To investigate the effects of gravity on the
                performance of gas-loaded, variable conductance
                heat pipes in which noncondensible gas and the
                working fluid are of significantly different
                molecular weights. The investigation is concerned
                with the nature of the vapor-gas interface region,
                particularly the phenomena associated with the
                vertical and horizontal operating positions.

Summary: The design procedures and analytical tools, which
                have so far been developed to predict the
                performance of gas-loaded heat pipes, do not
                consider many of the circumstances in which the
                gravitational field could have a profound effect
                on their operation. The situation in which the
                molecular weights of the working fluid and the
                non-condensible gas are very different is one in
                which the effects of gravity must be given careful
                consideration.

                Three heat pipes have been built and tested,
                1.6 cm diameter, 2.5 cm diameter and 5.0 cm
                diameter.   Each heat pipe is equipped with two
                pressure transducers, one at the evaporator
                end and one at the condenser end. In addition,
                each heat pipe has two stainless steel sheathed
                thermocouples which penetrate 1.25 cm into the
                evaporator and condenser of each pipe. Each heat
                pipe has 24 surface thermocouples spaced at 5 cm
                intervals along the adiabatic and condenser-reservoir
                sections. Each heat pipe has also been coated
                with temperature-sensitive encapsulated liquid
                crystals so that any deviations from one-dimensional
                behavior of the temperature distribution could be
                observed.

                Each pipe has been operated using methanol as the
                working fluid and in the variable conductance mode
                using both krypton and helium as the non-condensible
                gases. Each heat pipe has been operated in both the
                horizontal and the vertical (condenser up) mode.

                It has been demonstrated that orientation in the
                gravitational field can have a serious effect on the
                operation of gas-loaded heat pipes in which the
                working fluid and noncondensible gas are of signi-
                ficantly different molecular weights. For the smallest

diameter pipe (1.6 cm) the effect of gravity is to distort and displace the vapor-gas interface region while not seriously effecting the basically one-dimensional nature of the transport processes within the pipe.

For the larger diameter pipes (2.5 cm and 5 cm) of gravity are more profound. In the horizontal operating position stratification of the working fluid vapor and noncondensible gas occurs. The vapor and gas separate into horizontal layers. In this case the transport processes inside the pipe are highly three dimensional. In the vertical position with the larger diameter pipes gravity induces a distortion of the vapor-gas interface region which is more severe than for the smaller pipe.

No attempt has been made to determine what role other factors such as capillary pumping or wall conduction might play in the observed phenomena. It has been assumed that the large molecular weight differences were the dominant factor.

Publications: M. D. Kelleher and W. H. Batts, "Effects of Gravity on Gas-loaded Variable Conductance Heat Pipes," Proceedings of the Second International Heat Pipe Conference, Bologna, Italy, April 1976.

Title: Heat Transfer Enhancement in Naval Condensers

Investigator: P. J. Marto, Associate Professor of Mechanical
                Engineering

Sponsor: Naval Sea Systems Command

Objective: To examine current design procedures for Naval
                condensers, and perform a feasibility study of
                enhanced heat transfer designs, comparing weight,
                volume, life-cycle cost, etc. Evaluate current
                state-of-the-art of heat transfer augmentation
                techniques in condensers, including the promotion
                of dropwise condensation on the vapor side.
                Conduct heat transfer research and exploratory
                development in an effort to increase the overall
                condenser heat transfer coefficient U in a reliable
                manner.

Summary: An extensive literature review has been completed,
                with a wide variety of references, including patents,
                on dropwise condensation. Correspondence with
                active researchers in condensation heat transfer
                has been initiated including researchers at UC -
                Seawater Conversion Lab, Oklahoma State University,
                NSRDC (Annapolis) and Queen Mary College (London).

                Visits with personnel at NAVSEA, NAVSEC, NSRDC,
                as well as De Laval (Florence, N. J.) and Westing-
                house (Sunnyvale, CA), have attempted to examine
                present condenser designs and the need for compact
                condensers aboard surface ships and submarines.

                A feasibility design study of marine compact
                condensers is near completion. The study uses a
                computer program titled ORCON, developed by the
                Oak Ridge National Laboratory, which permits design
                modifications to be made including enhanced heat
                transfer on the steam and seawater side of the
                condenser. Possible weight, volume and life-cycle
                cost payoffs are being tabulated.

                The design and construction of an experimental
                test facility is now underway. The test section
                will facilitate operation over a range of input
                variables such as cooling water velocity, steam
                velocity and direction, and non-condensible gas
                concentration. Condensation heat transfer data
                will be obtained for different tube materials,
                tube geometries and condenser modes. The effect
                of ship roll/pitch on overall performance can also
                be studied.

Publications: None

Title: Performance Characteristics of Rotating Wickless
                        Heat Pipes

Investigator: P. J. Marto, Associate Professor of Mechanical
                        Engineering

Sponsor: Naval Sea Systems Command

Objective: To understand the operating characteristics and
                        to predict the heat transfer performance capa-
                        bilities of rotating wickless heat pipes as used
                        to cool rotating machinery components.

Summary: A theoretical model was derived for laminar film
                        condensation on the inside of a rotating, truncated
                        cone. Nusselt's classical analysis was modified
                        to include effects of vapor shear and vapor
                        pressure drop. Performance characteristics have
                        been studied for a variety of operating conditions.

                        An improved experimental apparatus has been
                        designed and constructed. A variety of copper
                        condenser sections will be tested using water,
                        ethyl alcohol, and Freon 113 in order to study
                        heat transfer augmentation techniques in the
                        presence of high gravity fields.

Conference   P. J. Marto, "Performance Characteristics of
Presentations: Rotating, Wickless Heat Pipes," Presented at 2nd
                        International Heat Pipe Conference, Bologna, Italy,
                        1976.

Title: Nucleate Boiling in Thin Liquid Films

Investigator: P. J. Marto, Associate Professor of Mechanical
                Engineering

Sponsor: None

Objective: To provide additional experimental data on this
                mode of heat transfer in order to further under-
                stand the complex processes which occur when
                bubbles form, grow and depart from a heated
                surface.

Summary: Experimental results have been obtained for
                distilled water, ethyl alcohol and Freon 113 at
                atmospheric pressure with liquid levels ranging
                from normal pool depths down to thin films near
                0.5 mm. Temperature measurements with thermo-
                couples and liquid crystals show that liquid
                level has little effect on the heat transfer
                coefficient above a level of 5 mm. Below this
                level, however, there is an increase of up to
                50 percent in the heat transfer coefficient as
                level is reduced, until dryout occurs. Additional
                tests are being run to study the effect of heater
                material and roughness on this phenomena.

Publications: P. J. Marto, LT D. K. Mackenzie, USN, and LT A. D.
                Rivers, USN, "Nucleate Boiling in Thin Liquid
                Films," AICHE Paper No. 16,   16th National
                Heat Transfer Conference, St. Louis, August 1976.

Title: Transient Response of Submerged Structures Subjected to Blast Loading

Investigator: R. E. Newton, Professor, Mechanical Engineering Department

Sponsor: Foundation Research Program (6.2)

Objective: To demonstrate the capabilities and limitations of the finite element method (FEM) in studying the transient response of submerged structures subjected to blast loading. This is a continuing project.

Summary: The first phase of this investigation was reported by D. L. Atchison in his thesis. He showed that the problem could be separated into a study of the propagation of a blast wave past a fixed rigid obstacle and a study of the motion of a submerged structure under loadings found in the propagation study. He also demonstrated that FEM gives satisfactory results for the two-dimensional problem of the propagation of a plane-fronted acoustic blast wave past a circular cylinder with axis parallel to the wave front.

The current phase of the investigation has dealt with the corresponding response motion of an infinitely long, ring-stiffened elastic cylinder having uniformly spaced elastic bulkheads. This problem is resolved into two-dimensional sub-problems by using Fourier series representation of the circumferential variation of fluid pressure and structural displacement. FEM solutions of the sub-problems are superposed to find resulting deflections and stresses. The critical combinations of blast pressure and submergence pressure, just sufficient to produce shell collapse, have been determined.

Publications: R. E. Newton and D. L. Atchison, "Response of a Ring-Stiffened Cylinder to an Acoustic Blast Wave," Proceedings of the Second International Symposium on Finite Element Methods in Flow Problems, Santa Margherita, Italy, June 1976.

Thesis
Directed:

D. L. Atchison, "Finite Element Solution of
the Interaction of a Plane Acoustic Blast
Wave and a Cylindric Structure," Master's
Thesis, June 1974.

Title: Nuclear Reactor Dynamics With Temperature
Dependent Feedbacks

Investigator: D. H. Nguyen, Associate Professor, Mechanical
Engineering Department

Sponsor: Foundation Research Program (6.1)

Objective: To obtain solutions of Nonlinear Space-Time
Reactor Dynamics Problems

Summary: The explicit inclusion of temperature dependent
feedbacks results in nonlinear neutron transport
problems. The one-velocity, space-time dependent
diffusion equation has been solved, using
the finite element method, for the multiregion
reactor system under highly discontinuous
initial disturbances. The space dependence
of fast reactor dynamics under such conditions
has been examined.

The multi-group space-time dynamics problem
has also been solved under uniform initial
disturbances. The method used is the Newton-
Raphson-Kantorovich iterative technique applicable
to operator equations. The space discretization
is achieved by finite element method, and
the resulting set of stiff ODE is integrated
by a modified Gear's method. The results
show a very fast rate of convergence. The
cost in terms of computer time and storage
is well within reasonable limits, so that
the method is attractive for the analysis
of real systems.

Publications: Dong H. Nguyen, "Finite Element Solutions
of Space-Time Nonlinear Reactor Dynamics,"
Nuclear Science and Engineering, 60, pp. 120-
130, (1976).

Dong H. Nguyen, "Space-Time Solutions of Multigroup
Nonlinear Reactor Dynamics Equations," Transactions
of the American Nuclear Society, 23, p. 590,
(1976).

**Conference
Presentation:**

Dong H. Nguyen, paper presented at the 1976
Joint Meeting of the American and Canadian
Nuclear Societies, Toronto, Canada. (June, 1976).

Title: Corrosion Studies on Zinc Anode Materials

Investigator: J. Perkins, Associate Professor of Mechanical
Engineering

Sponsor: Foundation Research Program (6.2)

Objective: To determine the environmental and materials-
related electro-chemical factors which determine
corrosion film structure and morphology and
corrosion kinetics for zinc anodes in sea
water. The study is intended to shed light
on the common problem of passivation of sacrificial
zinc anodes, which renders them useless in
their role as protection for structures such
as ships' hulls and ocean platforms.

Summary: Scanning electron microscopy has been used
extensively in the study of the morphology
of anodic corrosion products formed under
controlled electrochemical conditions in sea
water electrolyte. Interest in this area
is stimulated by the common naval use of zinc
alloys as sacrificial galvanic anodes for
cathodic protection of ship hulls. A common
problem associated with this usage has been
the development of apparent anode passivity,
and therefore loss of protection due to current
blockage. The Naval Postgraduate School (NPS)
program was initiated with the aim of delineating
the electrochemical and metallurgical features
that are critical in this regard. Direct
observation techniques have proved to be fruitful
in following the mechanism of film formation.
The general film structure consists of an
array of zinc oxide (ZnO) crystallites nucleated
with a population density on the order of
10^6 plates/cm^2. This represents a macroscopically
porous and nonpassive film condition for the
zinc anode. The crystallography growth mechanism,
and kinetics of development of such films
is being studied in detail utilizing microscopy,
x-ray diffraction, and energy-dispersive x-
ray analysis. Laboratory experiments are
being conducted to delineate critical ranges
of various electrochemical variables, including
current density and velocity effects.

Publications: R. A. Bornholdt and Jeff Perkins, "SEM Examination of Corrosion Product Morphology for Anodically Polarized Zinc," _Metallography_, 8 (1975) 401-409.

J. Perkins and R. A. Bornholdt, "Corrosion Product Morphology in Anodic Electrocrystallization of Zinc Oxide on Zinc in Sea Water," _Corrosion Science_ (in press).

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J. M. Todd and J. Perkins, "Nucleation and Growth of Anodic Electrocrystallization Products on Zinc in Sea Water," _Corrosion_, (in press).

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J. Perkins, W. H. Luebke, and J. M. Todd, "Anodic Corrosion of Zinc Alloys in Saltwater," TMS-AIME Fall Meeting 1976, Niagara Falls, NY, Sept. 20-23, 1976.

Theses Directed:

J. M. Todd, "Nucleation and Growth of Anodic Electrocrystallizied Products on Ship Hull Zinc in Saltwater Solutions," Mechanical Engineer Thesis, December 1975.

J. M. Price, "A Potentiokinetic Determination of Corrosion Rules in Artificial Seawater-Hypochloride Solutions," Master's Thesis, June 1976.

W. H. Luebke, "A Scanning Electron Microscope Study of the Effects of Anode Velocity and Current Density on the Corrosion of Ship Hull Zinc in Synthetic Seawater," Master's Thesis, June 1976.

Title: Materials Approaches to Ship Silencing

Investigator: J. Perkins, Associate Professor of Mechanical
                    Engineering

Sponsor: Naval Sea Systems Command

Objective: To investigate experimentally and analytically
                    materials and design factors affecting sound and
                    vibration in shipboard structures and machinery,
                    and to evaluate candidate alloy materials with
                    regard to damping properties as a function of
                    metallurgical processing, applied stress,
                    temperature, and vibration frequency.

Summary: Mn-Cu alloys have been evaluated in detail; these
                    alloys develop very high damping capacity after
                    proper heat treatment; the attainment of this
                    quality is found to be quite sensitive to heat-
                    conditions and to stress during heat treatment.
                    Various methods of evaluating the damping of
                    high-damping materials have been evaluated, and the
                    fatigue performance of these alloys has been
                    determined.

                    Resistivity measurements and internal friction
                    have been utilized to study mecrostructural
                    changes associated with the acoustic damping.
                    Results have shown that properly treated Incramute
                    I (a commercial Cu-Mn alloy) can develop a specific
                    damping capacity (SDC) as much as four times that
                    of grey cast iron, a material commonly used in
                    heavy industry because of its relatively good
                    damping characteristics. It has been found that
                    SDC is sensitive to stress applied during heat
                    treatment or in service. Results indicate a
                    correlation between resistivity and low-stress
                    SDC, and show that uniaxial tensile stress,
                    applied during either the age or the quench, inter-
                    feres with the development of high SDC.

Publications: None

Thesis   F. L. Youngblood, "Characterizing and Controlling
Directed: the Metallurgical Properties of a Cu-Mn Alloy for
                    Ship Silencing Applications," Master's Thesis,
                    June 1975.

Title: Fouling of Heat Exchangers

Investigators: Paul F. Pucci, Professor of Mechanical Engineering
                  James A. Miller, Associate Professor of Aeronautics

Sponsor: Naval Ship Research and Development Center

Objective: Survey of information (both literature and industry)
                  on fouling caused by gas turbine exhausts.

Summary: This program was done by Professor Miller. He sur-
                  veyed the literature and visited or telephoned
                  manufacturers, users and laboratories concerned
                  with this problem. He wrote a final summary report
                  and forwarded it to the sponsor on 8 April 1976.

Publications: None

Title: Fouling of Marine Gas Turbine Waste-Heat Systems

Investigator: Paul F. Pucci, Professor of Mechanical Engineering

Sponsor: Naval Ship Research and Development Center

Objective: Assist NAVSEC and NSRDC in the definition of those
                parameters affecting the fouling of marine gas
                turbine wast-heat systems.

Summary: Initial conferences with sponsors and with some
                industrial manufacturers led to the initiation of
                another project. (See Fouling of Heat Exchangers -
                Pucci and Miller)

Publications: None

Title: Optimized Ship Exhaust Eductor

Investigator: Paul F. Pucci, Professor of Mechanical Engineering

Sponsor: Naval Ship Research and Development Center

Objective: To assist in the design of shipboard gas turbine
                    exhaust eductors by constructing and testing scale
                    models.

Summary: The test facility for testing exhaust eductor
                    systems was designed and construction begun. A
                    scale model of an existing shipboard exhaust
                    system was designed. Project continued into
                    FY77.

Publications: None

Title: Fluidic Concepts Evaluation

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Sponsor: Naval Air Systems Command

Objective: To investigate low-frequency noise in fluidic
                  elements and to relate the results of this
                  investigation to NAVAIR development objectives.

Summary: Experience has shown that a wide range of fre-
                  quencies may be generated in fluidic devices. The
                  high frequencies do not generally present diffi-
                  culties but low frequencies (i.e., those below
                  1000 Hz and particularly below 100 Hz) pose
                  problems in the fluidic sensors and circuits
                  being developed for fluidic guidance and control
                  systems. This noise which is associated with
                  various fluid dynamic phenomena, is a limiting
                  factor in optimizing the low-level signal perfor-
                  mance of many fluidic components and circuits,
                  particularly analog-type devices. The present
                  investigation dealt with a survey of the previous
                  noise studies, definition of the noise and its
                  related properties, and the design and construc-
                  tion of variable geometry amplifiers and the use
                  of hot-wire anemometer techniques to obtain velocity
                  and noise profile measurements.

                  The second part of the concept evaluation concerns
                  the design of circulation control rotors (CCR)
                  and the use of fluidic elements in achieving
                  circulation control in helicopters with rigid
                  blades. The section lift, drag, and moment coef-
                  ficients at any angle of attack has been expressed
                  in terms of five independent flow variables and
                  six main geometric parameters. The flow variables
                  are the momentum coefficient, mass flow coefficient,
                  jet Mach number, free-stream Mach number, and the
                  Reynolds number. The primary geometric parameters
                  are profile family, thickness ratio, slot height
                  to trailing-edge radius ratio, camber, trailing-
                  edge radius to chord ratio, and the slot chordal
                  position. The optimization of the hover and flight
                  performance of the vehicle in terms of these para-
                  meters requires a detailed analysis of the blade
                  dynamics and the design of a novel CCR control
                  valving which will minimize vibrations, ballistic
                  damage, and the number of movable parts. A com-
                  prehensive analysis has been carried out to achieve
                  these objectives and a non-moving part CCR control
                  valving has been designed.

Publications: T. Sarpkaya, "On the Art of Advancing the
Science of Fluidics," Journal of Dynamic
Systems, Measurements, and Control, 95 (1975).

T. Sarpkaya, "Investigation of the Characteristics
of Semi-Confined Laminar Jets," Technical Report,
NPS-59SL76052, 1976.

Title: Cable Strumming in Cross Current - Analysis and Experiments

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Sponsor: Civil Engineering Laboratory

Objective: To extend Sarpkaya's two-dimensional potential flow model to circular cylinders oscillating longitudinally and/or transversely to the flow, for the purpose of determining added mass, lift, and drag coefficients for oscillating cylinders. Also, to initiate laboratory experiments to check and validate the analytical model.

Summary: Elastic structures of one or more degrees of freedom can extract energy from the flow about them and can develop catastrophic flow-induced oscillations. The understanding of this energy-transfer process is of paramount importance if one is either to eliminate or minimize it or to design the elastic structure in such a manner that it can withstand the oscillations under the contemplated environmental conditions.

The discrete-vortex model has been applied to the determination of the flow characteristics about cylinders undergoing in-line and transverse oscillations. The results have been expressed in terms of a mean drag coefficient, and Fourier-averaged drag and inertia coefficients. The variations of these coefficients with Reynolds number, period parameter, and the relative amplitude of oscillations have been determined. Experiments have been carried out in a water tunnel with circular cylinders, and the coefficients cited above have been evaluated and compared with those obtained analytically. The results have shown that the mean flow has significant effects on the various coefficients, and that the results of experiments with harmonic oscillations in a fluid otherwise at rest are not applicable to oscillations of a cylinder in a uniform flow.

Publications: T. Sarpkaya, "An Analytical and Experimental Study of the In-line and Transverse Oscillations of a Circular Cylinder in Uniform Flow," Technical Report NPS59Sl75051, May 1975.

Theses   J. T. Fry, "Harmonic Motion of Cylinders in
Directed: Uniform Flow," Master's Thesis, June 1975.

Paulo Arruda Raposo, "Transverse Oscillations of a Cylinder in Uniform Flow," Master's Thesis, June 1976.

Donald Fortik, "Forced Oscillations of a Cylinder in Uniform Flow," Master's Thesis, June 1976.

David W. Meyers, "Transverse Oscillations of a Circular Cylinder in Uniform Flow," Master's Thesis, December 1975.

Title: Unsteady Flow About Bluff Bodies

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Sponsor: National Science Foundation

Objectives: To determine the forces acting on bluff bodies
                  immersed in time-dependent flows.

Summary: Experiments were conducted in a recirculating
                  water tunnel, in a small U-shaped water tunnel,
                  and a large U-shaped water tunnel with smooth
                  and rough circular cylinders and spheres in the
                  range of Reynolds numbers from 5,000 to 1,000,000.
                  The velocity in the water tunnel consisted of a
                  harmonically oscillating component superposed on
                  a mean velocity. The drag and lift coefficients
                  have been determined in terms of the Reynolds
                  number and the appropriate flow parameters. The
                  velocity in the U-shaped tunnels consisted of a
                  purely harmonic oscillation. The lift, drag, and
                  inertia coefficients have been determined in terms
                  of the Reynolds number, period parameter, and the
                  relative roughness.

                  A potential flow model of two-dimentional vortex
                  shedding behind bluff bodies was developed. The
                  free shear layers which emanate from the sides of
                  the body were represented by discrete vortices
                  through the use of the appropriate complex-velocity
                  potential and the Joukowsky transformation between
                  a circle and the body cross-section. The analysis
                  was then applied to predict the Kinematic and
                  dynamic characteristics of the flow for various
                  flow parameters.

Publications: T. Sarpkaya, "An Inviscid Model of Two-Dimensional
                  Vortex Shedding for Transient and Asymptotically
                  Steady Separated Flow Over an Inclined Plate,"
                  Journal of Fluid Mechanics, 68, Pt. 1 (1975).

                  T. Sarpkaya, "Forces on Cylinders Near a Plane
                  Boundary in a Sinusoidally Oscillating Fluid,"
                  Fluid Mechanics in Petroleum Engineering, American
                  Society of Mechanical Engineers, 1975, pp. 45-52.

                  T. Sarpkaya, "In-Line and transverse Forces on
                  Cylinders in Oscillatory Flow at High Reynolds
                  Numbers," Proceedings of the Offshore Technology
                  Conference, OTC-2533, May 1976.

                  T. Sarpkaya, "Vortex Shedding and Resistance in
                  Harmonic Flow About Smooth and Rough Circular
                  Cylinders at High Renolds Numbers," Technical
                  Report No. NPS-59SL76021, 2 February 1976.

Thesis
Directed: Neil Jon Collins, "Transverse Forces on Smooth
            and Rough Cylinders in Harmonic Flow at High
            Reynolds Numbers," Master's and Engineer's
            Degree Thesis, June 1976.

Title: Prediction of Forces and Moments Acting on Bodies
                    of Revolution at Large Angles of Attack

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Sponsor: Naval Air Systems Command

Objective: To develop a reliable numerical computation method
                    to determine the asymmetric flow field of a body
                    of revolution moving at high angles of attack,
                    including the prediction of the forces and moments.

Summary: The vortex sheets emanating from the sides of the
                    body have been represented by discrete vortices.
                    This procedure has been combined with the cross-
                    flow analogy or the impulsive flow analogy and
                    applied to the analysis of asymmetric vortex
                    shedding behind cylinders of increasing radius.
                    Normal force, pitching moment and yawing force
                    coefficients have been caculated for slender bodies
                    with various nose fineness ratios at Mach numbers
                    less than about 0.9. The analytical results will
                    be combined with those obtained experimentally.

                    Experiments will be carried out in a vertical water
                    tunnel capable of generating impulsively started
                    uniform flows at various Reynolds numbers. The
                    in-line as well as the side forces will be
                    measured and correlated with the instantaneous
                    position of the shed vortices.

Publications: T. Sarpkaya, "Comments on the
                    Theoretical Study of Lift Generated Vortex Wakes
                    Designed to Avoid Rollup," American Institute of
                    Aeronautics and Astronautics Journal, Vol. 13,
                    No. 12, December 1975.

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