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NAVAL POSTGRADUATE SCHOOL

Monterey, California

A SUMMARY OF THE

FOUNDATION RESEARCH PROGRAM

November 1976

Report for the Period

1 July 1975 to 30 June 1976

Approved for public release; distribution unlimited

Prepared for:
Chief of Naval Research
Arlington, Virginia 22217 and
Director of Laboratory Programs
Washington, D. C. 20360

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral I. W. Linder, USN

Jack R. Borsting
Provost

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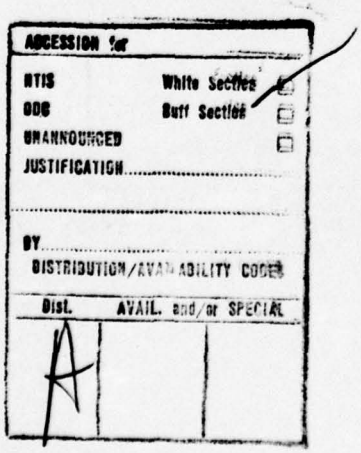

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number): Forty-three summaries of Independent Research/Independent Exploratory Development work carried out under funding to the Naval Postgraduate School Foundation Research Program. This research was carried out in the areas of Computer Science, Mathematics, Administrative Science, Operations Research, Physics and Chemistry, Electrical Engineering, Meteorology, Aeronautics, Oceanography, and Mechanical Engineering. A tabulation in the index identifies area of research and the principal investigator. The category of independent research or independent exploratory research is also identified for each research task.

Research areas included

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U. S. NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

OFFICE OF THE SUPERINTENDENT

Rear Admiral Robert K. Geiger, USN
Chief of Naval Research
Washington, D.C.

Dear Admiral Geiger:

The thirtieth anniversary of the Office of Naval Research has been celebrated this year with ceremony and praise - and, more importantly, with thoughtful realization within the scientific community of the immense value of the basic research fostered and supported by ONR in universities and laboratories across the nation. The Office of Naval Research has led the way in the creation of policies for the support of scientific research and has earned and holds the respect of scholars throughout the United States.

From its beginning the Office of Naval Research has maintained a close and special relationship with the Naval Postgraduate School. The substantial scientific research program which supports the academic progress of the Postgraduate School today was inaugurated by ONR support of scholarly investigations by faculty and officer students. Postgraduate School Technical Report #1, issued in 1949, presents the results of mathematical and physical analyses performed in fulfillment of an ONR project. The Naval Postgraduate School Foundation Research Program through which ONR today provides support for new and imaginative areas of investigation, is the logical evolution of that initial project.

This close relationship between the Navy's graduate education university and the Navy's scientific research organization extends also to our mutual efforts to maintain close ties with the scientific community in the universities of our nation. The Office of Naval Research sponsorship of distinguished scholars as visiting faculty members at the Postgraduate School broadens and strengthens these ties.

With so many positive and productive developments in the 30 years of support of science by the Office of Naval Research the Postgraduate School looks forward with anticipation and enthusiasm to the future products of our close association.

Sincerely,

ISHAM LINDER
Rear Admiral, U. S. Navy

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FY 1976 FOUNDATION RESEARCH

I. Introduction

The principal thrust of research and exploratory development program 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 foster and encourage a program of research in order to sustain academic excellence.

In fulfillment of the research and development program objectives and within the above constraints, the Naval Postgraduate School

> 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.

In addition, NPS performs scientific research and exploratory development, where uniquely qualified, for other agencies of the Department of Defense and, in defense related efforts, for other Federal Government agencies. NPS also furnishes consulting services for the Navy and, where specifically qualified, for other agencies of the Department of Defense and in defense related efforts for other Government agencies.

II. Background on the NPS Research Program

The Navy has developed the Naval Postgraduate School as an academic institution which uses university educational methods to address the special graduate education requirements of the Navy. The Superintendent of the Naval Postgraduate School is a Rear Admiral of the line of the Navy. He is supported by a dual management structure, part military and part civilian. The faculty, mostly civilian, is responsible for the academic programs and, in support of these, conducts an active research effort. The military staff specifies the educational needs of the Navy, in terms of curricula, and provides administrative logistic support.

At the Naval Postgraduate School, as in other academic institutions, the faculty is organized into departments. The department represents a resource center of faculty members with allied disciplinary specialization. Currently, the departments at the Naval Postgraduate School include Computer Science, Mathematics, Administrative Science, Operations Research, Physics and Chemistry, Electrical Engineering, Meteorology, Aeronautics, Oceanography, Mechanical Engineering, and National Security Affairs. Inter-disciplinary groups which have effective departmental status include Engineering Acoustics and Anti-Submarine Warfare.

Research and development projects are largely conducted by the individual faculty members on a project basis. Projects typically originate from proposals prepared either by individual faculty members, or by groups of faculty members from the same or different departments.

The research program is divided administratively into two parts. First is the Sponsored Research Program. This program includes projects awarded by sponsoring agencies to an individual principal investigator. The principal source of funds is the various commands and laboratories of the Naval Material Command. The sponsored program constitutes about 80% of the total NPS research program. The Foundation Research Program is based on a grant from the Chief of Naval Research and the Director of Navy Laboratories. This program is administered internally by a Research Council, made up of faculty members appointed by the Provost. The Dean of Research is the Chairman of the Council. The Council meets periodically to review faculty proposals, allocate funding, and review results of completed projects.

Appendix I identifies each project by title and category or type funding (Research - 6.1 and Exploratory Development - 6.2). The 6.1 category was funded by the Chief of Naval Research, Arlington, Virginia 22217 and the 6.2 category was funded by Director of Laboratory Programs, Washington, D. C. 20360.

This report summarizes the FY 1976 Foundation Research Program.

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.

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: On the Stability of Multidimensional Digital Filters

Investigator: Associate Professor Daniel L. Davis, Mathematics Department

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: The Use of Time Series in Improving Meterological Forecasting

Investigators: Dean R. R. Fossum, Professors C. Comstock and F. D. Faulkner, 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 ϕ 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

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

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: 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.

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

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: 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: 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 timating procedure.

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

Title: Discrete Transforms and Convolutions

Investigator: Carroll O. Wilde, Professor, Department 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

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

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

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: 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: 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.

Theses Directed:

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

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

Investigator: William J. Haga, Associate Professor, Administrative 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 activities 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 considerable "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: 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.

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

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

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

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: 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 predicting 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: 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 oscillation (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, "[illegible] Structure and Resonant Structure in [illegible]," 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: 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 environment 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: 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: 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: 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," Acoustical Holography, Vol. 7, Lawrence Kessler, Ed., Plenum Press, 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 of Science, June 1976.

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 = $BW \geq \frac{1}{2\tau}$

Sampling frequency requirement = $fs \geq 2BW = \frac{1}{\tau}$

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 Applications 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 of Science, December 1975.

S. V. Holmes, "Theory of Operation and Applications of Sampled Analog Devices in Recursive Comb Filters," Ph.D. Thesis, June 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 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 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, Charlottesville, VA, July 1976. Abstract published in Bulletin of American Meteorological Society, 57, 1976.

Title: Aircraft Structures Research: Composite Stress Concentrations

Investigator: M. H. Bank, Assistant Professor of Aeronautics

Sponsor: Foundation Research Program (6.2)

Objective: 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 characterication 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 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. The kinetic energy of the impacter required to fail the plate seems to be essentially constant. An attempt to correlate the impact at fracture with computer predictions utilizing a linear finite-element method solution was unsuccessful; deflections are large and a non-linear solution is required.

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-transmission properties of the material. Deliberately introducted 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: 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: 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

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 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, California. 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: 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 Countercurrent, 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.

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 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: 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 79.3, 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: 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.

Theses 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 Presentations:

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).

J. M. Todd and J. Perkins, "Corrosion of Zinc Anodes in Sea Water," Naval Engineers Journal (in press).

J. M. Todd and J. Perkins, "Nucleation and Growth of Anodic Electrocrystallization Products on Zinc in Sea Water," Corrosion, (in press).

J. Perkins, "Growth of ZnO Crystals During Anodic Electrocrystallization," Journal of Crystal Growth (in press).

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 of Science Thesis, June 1976.

APPENDIX I

Summary Title	Investigator	Type Funding
COMPUTER SCIENCE		
Large Scale Network Optimization	G. Brown	6.1
Analysis of Binary Trees Arising from Applications in Sorting and Information Retrieval	G. Brown	6.1
MATHEMATICS		
On the Stability of Multi-dimensional Digital Filters	D. L. Davis	6.1
The Use of Time Series in Improving Meterological Forecasting	R. R. Fossum C. Comstock F. D. Faulkner	6.1
Analysis and Evaluation of Procedures for Computing Lower Bounds for System Reliability	T. Jayachandran	6.1
Numerical Solution of Very Large Sparse Systems of Stiff Ordinary Differential Equations	R. Ranke	6.1
Necessary Conditions for General Problems Involving Higher Derivative Bounded State Variables	I. B. Russak	6.1
Analysis of Reliability Estimating Methods	A. L. Schoenstadt	6.1
Discrete Transforms and Convolutions	C. O. Wilde	6.1
ADMINISTRATIVE SCIENCE		
Development of a Theoretical Framework and a Methodology for Analyzing Stages in a Naval Officer's Career	C. B. Derr	6.1

Summary Title	Investigator	Type Funding
ADMINISTRATIVE SCIENCE, cont.		
Development of a Methodology for Analyzing Data Describing Officer Billets	R. S. Elster	6.1
A Taxonomy of Systems Acquisition	C. K. Eoyang	6.1
A Multiattribute Utility Approach to Measure Quality of Health Care	W. C. Giauque	6.1
Evaluation of RDT&E Manpower Utilization Through Structural Variables: Phase I	W. J. Haga	6.2
Modeling a Defense Contractor	C. R. Jones	6.1
Determination of Maximal Flows in Nonplanar Networks by Using Dual Graphs	A. W. McMasters	6.1
Pattern Analysis Applied to Retention Data: Comparison of PAIN and STRAIN	R. A. Weitzman	6.1
OPERATIONS RESEARCH		
Global Optimization of Non-linear Programming Problems	J. K. Hartman	6.1
Ridge Regression	H. J. Larson	6.1
Analysis of Discrete Time Resource Allocation Policies with Applications to Budgeting	K. T. Marshall F. R. Richards	6.1
Study of Variable-Coefficient Lanchester-Type Equations of Warfare	J. G. Taylor	6.1
PHYSICS AND CHEMISTRY		
Measurement of Nuclear Giant Resonances by High Energy Electron Scattering	F. R. Buskirk E. B. Dally J. N. Dyer R. Pitthan	6.1

Summary Title	Investigator	Type Funding
PHYSICS AND CHEMISTRY, cont.		
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Computer Simulation of Sputtering III	D. E. Harrison, Jr.	6.1
Homogeneous Catalysis by Palladium Complexes	R. A. Reinhardt	6.1
Characteristics of Resistance Wires Used for Atmospheric Turbulence Measurements in the Marine Environment	G. Schacher C. W. Fairall	6.1
ELECTRICAL ENGINEERING		
Computer-Aided Acoustic Imaging	J. P. Powers	6.2
Magnetic Background Noise Studies	G. L. Sackman	6.2
Application of Recursive Comb Filter to MTI Radar Signal Processing	T. F. Tao	6.2
METEOROLOGY		
Tropical Wave Dynamics	C. P. Chang R. T. Williams	6.1
AERONAUTICS		
Aircraft Structures Research: Composite Stress Concentrations	M. H. Bank	6.2
Test Data Control & Analysis	R. P. Shreeve	6.1
Flow in Highly Loaded Rotors	R. P. Shreeve	6.2
OCEANOGRAPHY		
Mass, Salt and Heat Transports in the Atlantic Ocean During the IGY	G. H. Jung	6.1

Summary Title	Investigator	Type Funding
OCEANOGRAPHY, cont.		
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 & Density	S. P. Tucker	6.1
Structure of California Countercurrent	J. B. Wickham	6.1
MECHANICAL ENGINEERING		
Dunkerley-Mikhlin Approximations for the Gravest Frequency of a Vibrating System	J. E. Brock	6.2
Finite Element Formulation for Doubly Curved Shells	G. Cantin	6.2
Synthesis of Advanced Marine Vehicles	A. E. Fuhs	6.2
A Study of the Secondary Flow in a Curved Rectangular Channel	M. D. Kelleher	6.2
Transient Response of Submerged Structures Subjected to Blast Loading	R. E. Newton	6.2
Nuclear Reactor Dynamics With Temperature Dependent Feedbacks	D. H. Nguyen	6.1
Corrosion Studies on Zinc Anode Materials	J. Perkins	6.2

PROGRAM REVIEW

The Foundation Research Program is monitored by the Pasadena Branch Office of the Office of Naval Research.

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