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A SUMMARY OF THE NAVAL POSTGRADUATE SCHOOL RESEARCH PROGRAM.(U)
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February 1976

Report for the Period
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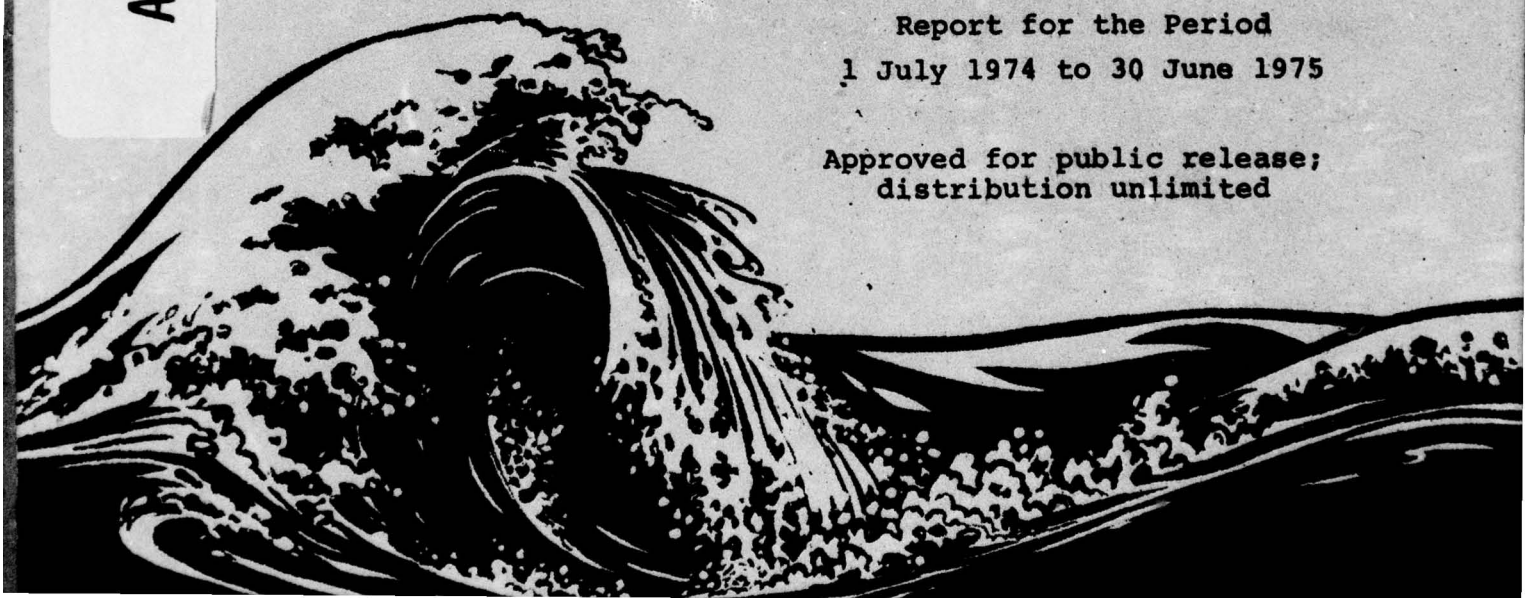

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral I. W. Linder, USN
Superintendent

Jack R. Borsting
Provost

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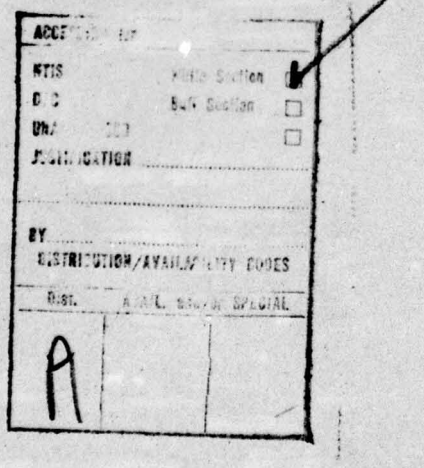
This report was edited by:

Loftur Bjarnason
Professor Emeritus

Released by:

Robert R. Fossum
Dean of Research

Jack R. Borsting
Provost



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

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

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A SUMMARY OF RESEARCH ACTIVITIES

1. INTRODUCTION AND BACKGROUND

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

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

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

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

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

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

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

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

The following sections briefly describe the program and summarize the areas of interest and competence of the academic departments and review the research output for the academic year 1974-75 (FY 1975):

2. PROGRAM DESCRIPTION

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

In fulfillment of the research program objectives, NPS:

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

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

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

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

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

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

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

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

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

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

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

Many sponsors have found it advantageous to place research tasks in NPS. First, the pervasive defense orientation of faculty research interests make NPS unique among graduate educational institutions in the United States. There is no question that the emphasis is in military-related areas. A second unique advantage is the concentration of young and experienced student officers in one facility. On the average, the student has six years operational experience in his warfare speciality before coming to NPS. Further, the student body is made up of officers from all warfare specialities - aviation, surface, subsurface, and Marines; as well as officers from the staff, sister services, and allied countries. These participants in the NPS research program insure a pragmatic and realistic orientation to most projects. A third advantage

is the ability to handle classified research projects including special classifications controlled by the Chief of Naval Intelligence.

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

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

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

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

The research program contributes to the emphasis and focus of the educational process. As mentioned above, problem-solving is the basis of the technical and management profession. While the basic structure and logic of professional

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

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

Many of the research projects also involve state-of-the-art laboratory equipment. This equipment is provided in many instances by the research program. Consequently, the laboratory facilities tend to be up-to-date even in those areas where technology is moving the fastest.

The program also contributes to the academic reputation of the School. As a graduate quality institution, NPS maintains close contact not only with the Navy community, but also with the academic community. The research program is a primary means for maintaining this contact and interaction. The result of such interaction is a continuing interest by faculty members in other academic institutions in the Naval Postgraduate School. Specifically, a number of faculty members from other institutions have served as visiting faculty or as Postdoctoral Fellows.

c. Program Management

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

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

DEPARTMENT OF METEOROLOGY

The research program in the Department of Meteorology has continued along several main lines as follows: (1) Numerical weather prediction, (2) Analysis and dynamics of tropical weather systems, (3) Marine boundary-layer turbulence, (4) Tropical cyclone prediction, (5) Marine fog observation and prediction. Under each of these headings, a number of related investigations are being pursued by various faculty members, as described briefly below.

NUMERICAL WEATHER PREDICTION

Under this heading are included: modeling of the large-scale weather systems by G. J. Haltiner and R. T. Williams; numerical prediction of ocean-hurricane interaction by R. L. Elsberry; ocean circulation and coupled atmosphere-ocean modeling and prediction by R. L. Haney; solar and terrestrial transfer simulation by F. L. Martin; boundary-layer parameterization by K. L. Davidson; and the dynamics of the formation of discontinuities by R. T. Williams.

ANALYSIS AND DYNAMICS OF TROPICAL WEATHER SYSTEMS

C. P. Chang, R. L. Elsberry and R. T. Williams are investigating various aspects of the dynamics of tropical weather systems, including development of hurricanes and typhoons by Elsberry, the dynamics and energetics of tropical wave disturbances and circulations by Chang and Williams, and the diagnostic analysis of tropical systems by Chang.

MARINE BOUNDARY-LAYER TURBULENCE

This research area includes observational studies of the air motion induced by ocean waves and its relation to the theory of wave growth by K. L. Davidson, an accompanying theoretical study by R. T. Williams, and boundary-layer simulation for numerical weather prediction models by K. L. Davidson. Turbulence plays an important role in the vertical transport of momentum, heat and water vapor which are essential processes in weather prediction. K. L. Davidson, in collaboration with other Naval Postgraduate School faculty, is involved in an interdisciplinary study of atmospheric effects in optical propagation in the marine boundary layer. This study includes observational experiments to obtain descriptions of the vertical distribution of small scale turbulence properties

which affect optical propagation and aerosol distributions.

TROPICAL CYCLONE PREDICTION

The prediction of the movement and intensification of tropical cyclones (typhoons, hurricanes, etc.) by statistical-dynamical techniques is a continuing project by R. J. Renard, R. L. Elsberry and J. D. Jarrell.

MARINE FOG OBSERVATION AND PREDICTION

An interdisciplinary project, involving both the Meteorology Department and the Oceanography Department faculty members, D. F. Leipper, G. H. Jung and R. J. Renard, is concerned with the observation, analysis, and prediction of fog at sea, both on a regional and hemispheric scale.

APPLICATION OF SATELLITE DATA TO TROPICAL ANALYSIS

Investigator: C. P. Chang, Assistant Professor of Meteorology

Support: National Environmental Satellite Service, National Oceanic and Atmospheric Administration

Objective:

To design objective methods that use the digitized satellite cloud brightness data as an aid to large-scale tropical analysis.

Summary:

A diagnostic model is proposed to use digitized satellite cloud brightness data to estimate objectively the large-scale flow patterns over data-void tropical regions. The model utilizes a linear barotropic vorticity equation with two primary assumptions: (1) that the area-averaged cloud brightness is positively correlated with large-scale divergence in the tropical upper troposphere; and (2) that the large-scale tropical flow is quasi-barotropic and quasi-non-divergent. It is designed to be used at any upper tropospheric level where divergence is important in determining the vorticity field. Three types of information are required: (1) boundary conditions determined from surrounding wind reports, (2) a mean zonal flow determined from climatology, and (3) an equivalent divergence forcing function constructed empirically from the brightness data.

The model was tested daily over a western North Pacific region for July-August 1971. Results for an 8-day representative period are presented and discussed. In general for 25% of the days tested, the model produced a flow field which accurately resembled the major features of the stream-function field analyzed by the National Meteorological Center (NMC). In another 30% of the days it provided some valuable information about the flow patterns which would be difficult to obtain from boundary information alone. Experiments were also performed for two days in which the brightness data were enhanced by time-interpolated satellite infrared data. The resultant flow fields bear better resemblance to the NMC analysis. It is thus suggested that improved results may be expected when infrared and other types of advanced satellite data are available.

Publications and Conference Presentations:

C. P. Chang and F. T. Jacobs, "A Diagnostic Model for Estimating Large-Scale Tropical Flow Patterns from Satellite Cloud Brightness."

Paper presented before the Fall Annual Meeting of American Geophysical Union, San Francisco, December 1974. Abstract printed in Transactions, 56 (November 1974).

C. P. Chang, F. T. Jacobs and B. B. Edwards, "A Diagnostic Model for Estimating Large-Scale Flow Patterns in the Tropical Upper Troposphere from Satellite Cloud Brightness Data," Monthly Weather Review, 103 (June 1975).

C. P. Chang, "A Correlation Study of Brightness and 200-mb Divergence," Technical Report NPS51Cj74081, August 1974.

EQUATORIAL WAVES FORCED BY HEATING

Investigator: C. P. Chang, Assistant Professor of Meteorology

Support: Foundation Research Program

Objective:

To study the structure and dynamics of large-scale wave disturbances in the tropical troposphere and stratosphere, generated from condensation heating of cumulus convection.

Summary:

Analytical solutions of equatorial waves forced by heating in the troposphere were studied. For special heating the maximum response of the atmosphere has a vertical wavelength of twice the vertical forcing scale which is equivalent to the depth of clouds. For waves forced by internal wave convergence, the only unstable mode assumes a vertical wavelength close to twice the forcing scale under marginally unstable conditions.

Consideration of energy fluxes at the tropopause led to an explanation for the preferred planetary wave modes observed in the lower stratosphere. Implications for the wave-Conditional Instability of the Second Kind (CISK) theory were also examined.

Publication: C. P. Chang, "Vertical Structure of Equatorial Wave Forced by Heating." Paper presented before the Ninth Technical Conference on Hurricane and Tropical Meteorology, Miami, May 1975. Abstract, Bulletin of the American Meteorological Society, Vol 56, No. 2, (February 1975).

METEOROLOGICAL EFFECTS ON OPTICAL PROPAGATION IN THE MARINE BOUNDARY LAYER

Investigator: K. L. Davidson, Associate Professor of Meteorology

Support: Naval Sea Systems Command

Objective:

The long range objective of this research is to develop methods for predicting optical propagation properties in the marine boundary layer on the basis of its bulk properties, e.g., wind speeds and air-water temperature differences. The short range objective is to obtain observational descriptions of coincident turbulent and mean properties, wind and temperature, from the sea surface to 10 meters above and also aerosol distributions. This is a continuing project.

Summary:

A specific goal of this study is to relate small scale turbulent properties to the mean hydrostatic stability. Such stability is definable from measures of the surface wind speed and the near surface air-water temperature difference. Small scale turbulent properties are expected to vary differently with height under different conditions of stability. Results from multi-level measurements under several conditions of stability reveal distinct difference in height variations of the small-scale parameters under different conditions of stability. The observed height dependencies approximate those predicted on the basis of overland investigations. The variations from the predictions will be examined for possible wave influence when more data become available. Aerosol distributions are to be added to the present measurements.

Publications: K. L. Davidson, "Descriptions for Wind Profiles and Wind Fluctuation (gust) Statistics Over Ocean Waves," Handbook for Offshore Port Planing, Marine Technology Society, September 1974.

K. L. Davidson and T. Houlihan, "Laser Propagation in the Marine Boundary Layer," Proceedings of the Ordnance Hydroballistics Activities Committee Meeting," Newport, R. I., October, 1974.

K. L. Davidson and T. Houlihan, "Signal Lamps of the Future." Accepted for publication in Office of Naval Research Review.

K. L. Davidson and T. Houlihan, "Laser Transmission in the Marine Environment." Accepted for publication in Naval Engineers Journal.

DESIGN EXPERIMENT FOR AN OCEAN-BASIN MIXED-LAYER MODEL

Investigator: R. L. Elsberry, Associate Professor of Meteorology

Support: Naval Oceanographic Office

Objective:

To examine the suitability of the Fleet Numerical Weather Central at Monterey, (FNWC), ocean thermal structure analyses as the initial data and the heat flux calculations as the forcing for a mixed-layer model.

Summary:

The oceanic heat budget above 250 m was examined on monthly time scales. Two variations (Q_n and Total Heat Flux (THF) of the surface heat flux as computed by FNWC were compared to observed heat storage changes calculated from the monthly mean thermal structure analyses. The area selected for study was the eastern North Pacific Ocean, because of the availability of detailed heat content calculations by National Marine Fisheries Service (NMFS) personnel using data collected between Hawaii and San Francisco. Whereas the NMFS data indicated that the heat content in the upper 250 m was nearly stationary for periods of months, the FNWC thermal structure analyses displayed unrealistically large monthly heat content changes. Changes in temperature profiles throughout the thermocline region of this magnitude could not be attributed to heat exchange or advective processes. Therefore, it was concluded that the existing FNWC thermal structure analysis would not be suitable for initializing or verifying a mixed-layer model. It was also concluded that the THF fields of heat flux were superior to the Q_n fields. Evidently, this was due to the explicit calculations of cloud cover in the primitive equation model heating package (THF field).

Publication: R. T. Schnoor and R. L. Elsberry, "Monthly Heat Budget Calculations for the Eastern North Pacific Ocean Using Synoptic-Scale Data." Technical Report NPS51Es75061, June 1974.

METEOROLOGICAL STUDIES: INITIALIZATION OF A NUMERICAL WEATHER PREDICTION MODEL

Investigator: G. J. Haltiner, Professor of Meteorology

Support: Environmental Prediction Research Facility

Objective:

To suppress the spurious inertial-gravity noise generated at the beginning of a numerical weather forecast.

Summary:

A global, multi-level, baroclinic primitive equation model was used as a vehicle to test various initialization procedures for suppressing inertial-gravity waves generated due to errors in the initial data. It was concluded that static balancing followed by dynamic balancing using a time averaging technique equivalent to a 12-hour forecast and the use of a time filter will suppress the noise sufficiently for forecast purposes and may also permit the assimilation of non-synoptic data about every 4-6 hours without serious trauma. Some new static balancing techniques are undergoing further testing.

Publications: G. J. Haltiner and J. M. McCollough, "Experiments in the Initialization of a Global Primitive Equation Model," Journal of Applied Meteorology, September 1975.

THE NUMERICAL SIMULATION OF THE COUPLED NORTH PACIFIC OCEAN ATMOSPHERE SYSTEM

Investigator: R. L. Haney, Associate Professor of Meteorology

Support: Office of Naval Research

Objective:

To identify oceanic processes responsible for the formation and evolution of large-scale sea surface temperature anomalies. This is being done by dynamically predicting such anomalies, starting from observed initial states in the ocean and using an improved version of the oceanic general circulation model of the principal investigator (Haney, 1974).

Summary:

The specific goal of the project is continually to improve the numerical model of the North Pacific Ocean Basin and to use the model to make dynamical predictions of the ocean's future state. The initial state consists of observed anomalies together with climatological data generated by the model through a long term numerical integration. The ocean model has been improved in two respects. Firstly, it was shown by Haney and Wright (1975) that the use of a nonlinear eddy viscosity coefficient based on two-dimensional turbulence theory permits the use of an eddy viscosity which, for large scale motion in the ocean's interior, is an order to magnitude smaller than is possible when a constant eddy viscosity coefficient is used. Secondly, a parameterization of wind and convective mixing has been introduced in the model which explains many features of the observed seasonal variation of ocean thermal structure at Ocean Station November (30N, 140W). Preliminary results from the prediction experiments are presently being examined.

Publications: R. L. Haney and J. M. Wright, Jr., "The Relationahip Between the Grid Size and the Coefficient of Nonlinear Lateral Eddy Viscosity in Numerical Ocean Circulation Models," Journal of Computational Physics, 19 (November 1975).

THE TEST AND EVALUATION OF A VERTICAL TEMPERATURE PROFILE RADIOMETER (VTPR) RETRIEVAL SYSTEM FROM CLEAR-COLUMN NATIONAL OCEANIC ATMOSPHERIC ADMINISTRATION-2 (NOAA-2) RADIANCES

Investigator: F. L. Martin, Professor of Meteorology

Support: Environmental Prediction Research Facility

Objective:

To test a retrieval scheme for deducing T(P)-profiles by remote sensing, utilizing the seven-channel (CO_2 and window channel) radiometer carried aboard the NOAA-2 satellite. The National Environmental Satellite Service (NESS) issues listings of the clear-column scan spots from which the effects of cloud-contamination on the Planckian radiances have been removed. The retrieval scheme was tested on data of the type just specified and the results were verified on observed T(p) profile located near the scan spot.

Summary:

A sample-set of 227 clear-column radiances in channels 1,...,7 of the NOAA-2 VTPR and the corresponding first guess T(p) profiles predicted to the time of each VTPR observation was available. In addition there was a real-time radiosonde observation available at or close to the time of the VTPR clear-column scan observation. It was found possible to use an iterative procedures to retrieve the temperature profile T(p) at each clear column scan spot with a high degree of accuracy relative to the verifying radiosonde.

Publications: None

Thesis Directed:

H. M. Dyck, "Test and Evaluation of a VTPR Retrieval System from Clear-Column NOAA-2 Radiances," Master's Thesis, March 1975.

THE HEAT BUDGET PARAMETERIZATION FOR THE FLEET NUMERICAL WEATHER CENTRAL (FNWC) PRIMITIVE EQUATION MODEL USING MIDSEASONAL FNWC INITIAL DATA

Investigator: F. L. Martin, Professor of Meteorology

Support: Fleet Numerical Weather Central

Objective:

To generate a radiation transfer model for input of solar insolation and (outgo of) terrestrial net flux to the applicable parts of the earth-atmosphere system, particularly over the ocean, where the physical principles of the transfer theory may best be tested for realistic applicability, due to the quasi-constancy of the temperature profiles at the midseasonal dates, and specifically to parameterize the absorptivity of atmospheric water vapor both in the clear and cloudy portions of the area surrounding each gridpoint.

Summary:

An empirical design for the cloud amounts in several layers was generated, using temperature and humidity parameters which are readily available in terms of the FNWC analysis and the stepwise prognosis of these parameters. The net radiational input into the ocean surface is a primary result which was examined at each of the four mid-seasonal dates 15 January, 15 April, 15 July, 15 October 1974 for which there is considerable climatological net radiational evidence on a geographical basis to support or deny the results of the project. In general, existing cloud-parameterization techniques in use (after Smagorinsky, 1960) have had to be reduced to account empirically for (1) the greater insolation absorbed at the surface than hitherto accounted for in the model, and (2) the reduced reflectivity to space as dictated by the evidence from the NIMBUS III satellite results.

Publications: None

Theses Directed:

W. T. Spaeth, "Heat Budget Parameterization for the FNWC Primitive Equation Model Using Data for 15 January 1974," Master's Thesis, March 1975.

W. T. Myers, "Heat Budget Parameterization for the FNWC Primitive Equation Model Using Data for 15 April 1974," Master's Thesis, September 1975.

T. W. Beahan, "Heat Budget Parameterization for the FNWC Primitive Equation Model, Using Data for 15 July 1974," Master's Thesis, September 1975.

FORECASTING MOTION OF TROPICAL CYCLONES IN EASTERN NORTH PACIFIC OCEAN BY STATISTICAL MEANS

Investigator: R. J. Renard, Professor of Meteorology and
J. D. Jarrell, Assistant Professor of Meteorology

Support: Environmental Prediction Research Facility

Objective:

To develop a statistical analog scheme to forecast tropical cyclone motion in the eastern North Pacific Ocean area.

Summary:

Fleet Weather Central, Honolulu, Hawaii, and the National Weather Service Forecast Offices, at Honolulu, Hawaii, and Redwood City, California, are co-responsible for forecasting tropical cyclone activity in the North Pacific east of 180°. The area averages sixteen depressions, storms and hurricanes a year, occurring from mid May to mid November. To date, mostly subjective means have been used to forecast motion and intensity of these cyclones. A computerized, objective scheme was needed to improve the forecast accuracy as well as give a common starting point for the coordinated-agency forecast effort. The project resulted in the development of the Navy's Northeastern Pacific Analog Tropical Cyclone Tracker (EPANALOG) forecast program.

EPANALOG selects analog tropical cyclones from a 25-year Northeastern Pacific Ocean history. The selected analog tracks, statistically adjusted for position, vector motion, and date differences between them and the recent history of the tropical cyclone being forecast, were composited into a single forecast track. Verifications of EPANALOG forecasts to 96 hours, as initiated from best-track positions, were determined for randomly selected historical cases with a Monte Carlo simulation of initial position inaccuracies, as well as for forecasts generated from 1973 and 1974 operational cyclone positions. The latter were intercompared with a homogeneous set of objective persistence and Modified Hurricane and Typhoon Tracking (MOHATT) forecasts as well as subjective official forecasts for the 24-, 48- and 72-hour intervals. 1973 and 1974 EPANALOG accuracy generally excelled that of the existent techniques for all forecast intervals tested. Work is continuing to monitor and further improve forecast results.

Publications: J. J. Jarrell, C. J. Mauck and R. J. Renard, "Forecasting Tropical Cyclone Motion Over the Northeastern Pacific Ocean by an Analog Scheme." Monthly Weather Review, Vol, 101 (August 1975).

J. J. Jarrell, C. J. Mauck, III, and R. J. Renard, "The Navy's Analog Scheme for Forecasting Tropical Cyclone Motion Over the Northeastern Pacific Ocean," EPRF Technical Paper, No. 6-75, April 1975.

Thesis Directed:

C. J. Mauck, III, "Forecasting Northeastern Pacific Tropical Cyclone Tracks Using an Analog Scheme," Master's Thesis, (Advisors: R. J. Renard and J. J. Jarrell), September 1974.

MARINE FOG: ANALYSIS AND FORECASTING

Investigator: R. J. Renard, Professor of Meteorology

Support: Naval Air Systems Command

Objective:

To improve the diagnosis (analysis) and prognosis (forecasting) of marine fog over the open ocean and coastal areas.

Summary:

The program has been divided into three phases: (a) climatology of marine fog frequencies, (b) diagnosis (analysis) of marine fog, and (c) prognosis (forecasting) of marine fog. To date the first two phases have been researched and are in various stages of completion. (a) The climatology of marine fog over the open ocean is considered to be poorly documented, and, with reference to a source widely used by the Navy, the climatology is incorrect. The Naval Postgraduate School (NPS) group has developed a unique approach to deriving marine fog frequencies by synthesizing the information content of the visibility-weather group elements of the marine synoptic report into a computerized specification of the percentage of the synoptic period experiencing fog. Some 12 years of North Pacific ship-report data (over a half million reports, 30-60N) for the major fog season months of June, July, August, and September have been processed to derive credible fog frequencies. As a prototype study the results have universal application to all ocean areas. The work continues. (b) Until such time that marine-fog areas can be initially specified accurately and completely, the forecasting of marine fog will remain primitive. Conventional ship data, at best sparse, are not adequate. Therefore, weather satellite observations (infra-red (IR) and VISUAL) are being utilized as the source to specify areas of marine fog. A statistical approach to identifying critical brightness (visual mode) and temperature (IR mode) values associated with marine fog appears to have promise. The work continues. (c) A successful means of forecasting marine fog by computer methods is, in part, dependent on (a) and (b) above, combined with the identification of marine-fog indices compatible with the model output parameters of Fleet Numerical Weather Central. This aspect of the program is in the early stages.

Publications: R. J. Renard, R. E. Englebretson and J. S. Daughenbaugh, "Climatological Marine-Fog Frequencies Derived from a Synthesis of the Visibility-Weather Group Elements of the Transient-Ship Synoptic Reports," Technical Report NPS51Rd75041 (prepared for NASC 370C), April 1975.

Theses Directed:

R. E. Englebretson, "A Synthesis of the Elements of Random-Ship Synoptic Report to Derive Climatological Marine-Fog Frequencies," Master's Thesis, September 1974.

J. S. Daughenbaugh, "Further Development and Applications of the Naval Postgraduate School's Program for Deriving Marine-Fog Frequencies," Master's Thesis, March 1975.

R. T. Wallace and R. J. Renard, "The Use of Meteorological Satellites for Discerning Marine Fog," Master's Thesis and Technical Report NPS51Wa75031, March 1975.

FORECASTING MARINE FOG USING NUMERICAL-MODEL OUTPUT PARAMETERS

Investigator: R. J. Renard, Professor of Meteorology

Support: Fleet Numerical Weather Central

Objective:

To evaluate and improve the Fleet Numerical Weather Central (FNWC) Hemispheric F-TER Fog Probability Forecasts.

Summary:

Fleet Numerical Weather Central (FNWC) operationally produces computerized fields of fog probability twice daily, 00 and 12 Greenwich Mean Time (GMT). The program statistically combines fog-related model output parameters to generate the probabilities, which are most prominently used by the Optimum Ship Routing group at FNWC. The product does not contain a climatological factor and it has not been extensively evaluated for accuracy, to date. The project coevaluated the F-TER probabilities in the North Pacific Ocean area for July 1974 (using over 10,000 ship reports) with climatological marine fog frequencies being developed at the Naval Postgraduate School (NPS) under Naval Air Systems Command (NASC) sponsorship. Application of the Panofsky-Brier P-Score verification scheme indicated little difference in skill between the two forecast approaches. The research also developed criteria for discriminating between fog/no fog F-TER forecasts as a function of the probability values in the current version of the program. Work is continuing under another project (NASC sponsorship) to generally improve statistical marine-fog forecasting.

Publications: R. J. Renard, "A Coevaluation of FNWC's Fog Probability Forecasts and the NPS Marine-Fog Climatology for the North Pacific Fog Regions in Summer." Technical Report NPS51Rd75081, August 1975.

DEVELOPMENT OF GLOBAL FORECAST MODEL

Investigator: R. T. Williams, Professor of Meteorology

Support: Fleet Numerical Weather Central

Objective:

To investigate various finite difference procedures which could improve the accuracy and efficiency of the global model which is now under development at FNWC.

Summary:

Fourth order space differencing was tested in the model with analytic initial data, and the phase speeds obtained were much better than with second order differencing. A special flow field was also tested which contained strong flow over the pole. The difficulties caused by the pole were investigated and some alternate procedures were proposed.

Publications: None

Thesis Directed:

D. E. Maher, "Experiments with a 5-Level Primitive Equation Atmospheric Model Using Analytically Determined Fields," Master's Thesis, 1974.

AN ATMOSPHERIC GLOBAL PREDICTION MODEL USING A MODIFIED ARAKAWA DIFFERENCING SCHEME

Investigator: R. T. Williams, Professor of Meteorology

Support: Environmental Prediction Research Facility & Fleet Numerical Weather Central

Objective:

To program and test a global prediction model based on the special finite difference scheme developed by A. Arakawa.

Summary:

A modified version of the new Arakawa differencing scheme for the atmospheric general circulation was programmed for a two-level, adiabatic and frictionless model. In all cases analytic initial data were used to simplify evaluation. Experiments were designed to test various terms in the primitive equations as well as over-all performance. The 48-hour forecasts were well-behaved and showed good phase propagation.

Publications: A. V. Monaco and R. T. Williams, "An Atmospheric Global Prediction Model Using a Modified Arakawa Differencing Scheme," Technical Report NPS51Wu75041, 1975.

THE INCLUSION OF MOISTURE IN A NUMERICAL MODEL OF STEADY-STATE FRONTS

Investigator: R. T. Williams, Professor of Meteorology

Support: None

Objective:

To determine the influence of moisture on steady-state atmospheric fronts.

Summary:

The numerical frontogenesis model of Williams (1973) was modified to include moisture with its subsequent condensation and release of latent heating. The turbulent diffusions of momentum, heat, and moisture were represented with various coefficients. The numerical solutions showed realistic quasi-steady fronts forming within one to two days. These solutions were examined and compared over a range of the various coefficients, and various ranges of temperature. Inclusion of moisture in the model caused intensification of baroclinicity at mid and upper levels. Also noted was a sensitivity of the moist model to reference potential temperature due to the exponential relationship between saturation vapor pressure and temperature.

Publications: C. J. Cornelius, Jr., D. F. Glevy and R. T. Williams, "The Inclusion of Moisture in a Numerical Model of Steady-State Fronts," Technical Report NPS51Wu75051, 1975.

NONLINEAR FLUCTUATIONS IN A SIMPLE MODEL OF THE ATMOSPHERIC GENERAL CIRCULATION

Investigator: R. T. Williams, Professor of Meteorology

Support: Foundation Research Program

Objective:

To determine the response of a simplified model of the atmosphere to the following types of heating: (1) specified function of latitude, (2) proportional to the difference between the temperature and a specified equilibrium temperature. These types of heating are analogous to atmospheric heating over land and over water, respectively.

Summary:

The quasi-geostrophic two-level equations are solved numerically over a range of the relevant parameters. The initial conditions include a simple Hadley solution for the mean flow which is determined by the heating. This flow is tested to obtain the most unstable disturbance. After inserting the most unstable disturbance into the initial conditions, the equations are then integrated until the fields become statistically steady. With type (1) heating two regimes are found when the heating is above a critical value: (I) steady propagating waves are obtained when the distance between the northern and southern boundaries is 4000 kilometers; (II) aperiodic waves are obtained when the distance between the walls is 8000 kilometers. When type (2) heating is used and when the distance between the walls is 4000 kilometers, the following regimes are obtained as the imposed temperature gradient is increased: steady waves; waves with a periodic variation in amplitude; aperiodic waves. When the distance between the boundaries is increased to 8000 kilometers, all of the solutions become aperiodic. The aperiodic behavior in this study arises from barotropic instability.

Publications: None

FORMATION OF DISCONTINUITIES IN A STRATIFIED, ROTATING ATMOSPHERE

Investigator: R. T. Williams, Professor of Meteorology

Support: Foundation Research Program

Objective:

To determine the conditions under which discontinuities will form in the atmosphere.

Summary:

The formation of discontinuities within internal gravity waves in a rotating Boussinesq atmosphere is investigated with a numerical model. The motion is bounded between two rigid horizontal boundaries, and heating and friction are neglected. Special sinusoidal initial conditions are used. The equations are integrated for a range of values of the initial Rossby (Ro) and Froude (F) numbers. Discontinuities are found when the following conditions are satisfied: $F \geq 0.2$, $Ro \geq 0.2$. These results are substantially different from those obtained with a one-layer fluid with a free upper surface.

Publications:

R. T. Williams and R. P. Kurth, "Formation of Discontinuities in a Stratified, Rotating Atmosphere." Accepted by the Journal of Geophysical Research, 1975.

R. T. Williams and R. P. Kurth, "Formation of Discontinuities in a Stratified, Rotating Atmosphere," Technical Report NPS51Wu75031, 1975.

DEPARTMENT OF ELECTRICAL ENGINEERING

The Department of Electrical Engineering is involved in a variety of research areas. The main efforts have been in the general areas of: (1) Communication and Information Systems, (2) Electronic Systems, (3) Microwave Devices and Systems, (4) Computer Engineering, (5) Solid State, (6) Antennas and Propagation, and (7) Control Systems.

In each of these, there are a number of projects being investigated by individual faculty members. In many cases these projects form the bases for student theses. A brief description is given below:

COMMUNICATION AND INFORMATION SYSTEMS

J. Ohlson is engaged in satellite communication in the military environment. He will be assisted in the work in part by R. Adler. (Professor Ohlson is preparing the Navy Satellite Communication Handbook). G. Myers and S. Jauregui are working in electrical engineering problems encountered in the gathering of technical intelligence. D. Hoisington is concerned with new modulation-demodulation systems as well as work with radar and electronic warfare systems.

ELECTRONIC SYSTEMS

G. Sackman, D. Stentz, J. Knorr, and D. Hoisington are concerned with basic problems associated with Anti Submarine Warfare (ASW) systems. G. Myers is working with new designs of radio receivers, modulators, detectors, correlators and signal analyzers.

MICROWAVE DEVICES AND SYSTEMS

J. Knorr is investigating the slot line in various forms.

COMPUTER ENGINEERING

G. Rahe and V. M. Powers are active in the measurement of the operational performance of large systems and in the development of models appropriate for use in the design of computer systems. G. Marmont is working in the area of neurophysiological monitoring and the analysis of the complex wave forms.

SOLID STATE

T. Tao is investigating various thin-film semi-conductors for infrared detection. His is also active in work with applications of charge-coupled devices as filter elements in moving Target Identification (MTI) radar systems.

ANTENNAS AND PROPAGATION

R. Adler is continuing his work in antenna design and measurements.

CONTROL SYSTEMS

D. Kirk is continuing his activity in various aspects of optimum control. H. Titus is concerned with Navy problems in aircraft weapon systems development. Work is in progress by G. Thaler and A. Gerba on the modeling of ships with the purpose of applying the results to ship control systems.

CURRENT AND IMPEDANCE MEASUREMENTS FOR MONOPOLE ANTENNA ON A RECTANGULAR BOX

Investigator: R. W. Adler, Associate Professor of Electrical Engineering

Support: Naval Ship Engineering Center

Objective:

To construct a 10M square image plane to support measurements on shipboard antenna shapes; and to develop current and charge probe and carriage systems to enable accurate measurements; and to collect experimental data for simple monopoles on a ground plane for verification of instrumentation and techniques; and to measure charge, current and feed point impedance for monopoles on shipboard-like rectangular prisms.

Summary:

These results will support the Navy's long-range program of shipboard Electromagnetic Compatability (EMC) and antenna design and analysis. By providing valuable "calibration" data to be used in evaluating the worth of the several computer models now under development. The technology and expertise required to do this exists only at a few selected university labs and will provide the Navy with low-cost measurements of real-world shapes, applicable to the shipboard EMC problem.

Publications: None

D J WAVEFORM ANALYSIS (NARROW BAND)

Investigator: O. M. Baycura, Associate Professor of Electrical Engineering

Support: Naval Electronics Laboratory Center

Objective:

To determine mathematically, the possibility of obtaining an auto correlation without using a pure time delay, as in conventional correlation.

Summary:

The mathematical analysis showed that auto correlation without a pure time dalay was possible by using the concept of orthogonal filters, which are mathematically, Laquerre function-type filters. In particular, the non-symmetric Laquerre filter was analyzed to realize a practical auto correlator for low frequency signals, near 155 Hz.

Publications: None

EXPERIMENTAL AND THEORETICAL INVESTIGATION OF ELECTROMAGNETIC PULSE (EMP) EFFECTS ON AIRCRAFT COMMUNICATION SYSTEMS

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

Support: Air Force Weapons Laboratory

Objective:

To determine the boundary conditions of charge density and current density in the vicinity of the junction in order to open the problem to analytic solution and later to computer analysis or more realistic model geometries.

Summary:

The work during this reporting period culminated a three-year joint study by the investigator and Professors R. W. P. King and T. T. Wu of the Gordon McKay Laboratory of Applied Physics, Harvard University. Complete experimental and theoretical investigations of relatively thin (ka = .2) receiving monopole antennas were accomplished to determine appropriate locations to examine junction effects on crossed dipoles. Junction conditions of maximum charge/minimum current, minimum charge/maximum current, and minimum charge/minimum current were examined experimentally and led to a full understanding of the boundary conditions physically existing at the junction. A complete analytic solution of the thin crossed-dipole receiving antenna soon followed.

Publications and Presentations:

R. W. Burton, "The Crossed-Dipole Structure of Aircraft in an Electromagnetic-Pulse Environment." Paper read before the International Conference on Electromagnetic Noise, Interference and Compatibility, Advisory Group for Aerospace Research and Development (AGARD/NATO), Paris, France, October 1974. Published in Proceedings, 1974.

R. W. Burton and R. W. P. King, "Induced Currents in Single and Crossed Wires." Paper read before the International Union of Radio Science Annual Meeting, Boulder, Colorado, October 1974.

R. W. Burton and R. W. P. King, "Induced Currents and Charges on Thin Cylinders in a Time-Varying Electromagnetic Field," IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-17 (August 1975).

R. W. Burton and R. W. P. King, "Measured Currents and Charges on Thin Crossed Antennas in a Plane-Wave Field," IEEE Transactions on Antennas and Propagation, Vol. AP-23 (September 1975).

FLIGHT DECK INTEGRATED LANDING AND CATAPULT LAUNCH TELEVISION SURVEILLANCE SYSTEM

Investigator: P. C. Cooper, Professor of Electrical Engineering

Support: Naval Air Systems Command

Objective:

To investigate the feasibility of extending and updating the existing pilot landing assistance television (PLAT) system, which is becoming obsolete, into an integrated low-light-level system which includes catapult launches. In particular, limits on resolution of cameras, stop-action video tape recorders, launch camera trackers, and system operating parameters were to be identified.

Summary:

A proposed system has been finalized. It has been shown that commercial TV standards (525 line) are sufficient and do not limit system resolution. The real limit lies in tracking action and target motion. A proposed tracking system and camera synched shuttering procedure has been developed, using an image isocon camera tube. Camera placement on the carriers has been recommended, and a specific Video Tape Recorder (VTR) configuration. The most significant result is the decision to use commercial standards, which saves development costs.

Publications: None

CREATION OF A SPECIALIZED EMISSION ANALYSIS SOFTWARE PACKAGE (AEOLUS) FOR THE WANG 2200B MINICOMPUTER

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

Support: Naval Air Rework Facility

Objective:

To create a software package for the real-time gathering of data on jet engine test cell operation and the subsequent analysis and reporting of this data.

Summary:

Since this work was to be done during the writer's intersessional period (approximately 9 weeks), the timing of the arrival of a new computer--the Wang 2200B--was critical. Unfortunately, it did not arrive until half way through the intersessional time. However, a similar computer was "loaned" to NARF and it was used for general familiarization and preliminary program writing.

The main software for the gathering and formatting of jet engine test cell data was written and initial test made. The analog/digital converter, made by Hewlett-Packard, did not properly interface with the Wang computer. These interface problems were not solved by the time the writer had to leave San Diego.

The data gathering part of the software package was written but only partially tested. The analysis and reporting part of the package was not written although the algorithms involved were detailed. Some work continued on this project at Monterey but the main effort of finishing AEOLUS was done by San Diego personnel.

Publications: None.

AN AIR POLLUTION MODEL TO PREDICT THE AIR POLLUTION CONTRIBUTION OF A NAVAL AIR FACILITY

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

Support: Foundation Research Program

Objective:

To improve the performance of an existing model for predicting the movement of air pollutants in the vicinity of Naval Air Facilities. The writer deems this to be a continuing program.

Summary:

The above-mentioned model improvement was to be done by incorporating better long-term meteorological data and by changing airplane landing take-off patterns to be more realistic. Also use of improved emission output of various jet engines was to be input to the model.

In the time available to the investigator it was possible to put into the model only the improved meteorological data and to generate data repollutant distribution. These data can only be checked in a gross sense at this time as on-site measurement because the data are very sparse. There appears to have been an improvement in model performance in the sense of slightly better agreement with what data are available.

Publications: None

IMPROVED BANDWIDTH UTILIZATION MODEM

Investigator: D. B. Hoisington, Professor of Electrical Engineering

Support: Naval Air Systems Command

Objective:

To develop modulators-demodulators (MODEMS) for multiplexing voice or date information on existing wire circuits. Addition of the new circuits should in no way impair the performance of existing circuits, nor should the existing circuits interfere with the new ones.

Summary:

The sound-powered telephone circuits on an aircraft carrier were selected as the circuits to be used for the initial development and tests since these circuits are widely distributed throughout aircraft carriers, and offer both long and short runs. The carrier system was designed to operate on four frequencies in the range from 50 to 200 kilohertz. Frequency modulation was selected since FM has the advantage of a wide tolerance to changes in signal level, and no synchronization is required when multiple channels operate on a wire pair. Integrated circuit phase-locked loops were used as modulators and demodulators for the voice signals and for the tones used in signaling. As designed, four stations may operate on each of the four channels in party-line fashion. Signaling activates the indicator on only the particular party called. It is also possible to transfer a station to any of the other channels, and to call selectively any station on that channel. More than one station may be called, and a party-line conversation can be carried out.

Initial tests of the system have been completed, but minor problems remain to be solved. There is some cross talk from the carrier circuit into the sound-powered circuit that need to be eliminated. Minor mechanical and electrical redesign is required to reduce the number of power supply voltages required from three to two, and to improve the switching convenience for calling other stations. Work on these problems continues.

Publications: None

Thesis Directed:

D. E. Bienlien, "A Frequency-Division Multiplex System for Use in Shipboard Internal Voice Communications," Master's Thesis, June 1975.

PLANAR TRANSMISSION LINE STUDIES

Investigator: J. B. Knorr, Associate Professor of Electrical Engineering

Support: Foundation Research Program

Objective:

To determine the theoretical and experimental analysis of planar transmission line structures which are useful for constructing microwave integrated circuits. Structures of interest include microstrip, slotline, and coplanar strips on dielectric and magnetic substrates. Wave propagation, coupling, transitions, terminations, resonators, discontinuities, and radiation are among the topics that have been or will be addressed in this continuing project.

Summary:

Frequency dependent analyses of coplanar strips, and single and coupled slots and microstrips have been carried out. Numerically efficient computer programs have been developed using a Fourier transform technique and the method of moments to compute wavelength and characteristic impedance vs. frequency. Similar programs have been written for resonant slots, slotline end effect, end coupled slots, and shielded slotline. Work has also been completed on slot-coax and slot-microstrip transitions. Investigations of microstrip and slotline on ferrite and slot antennas are currently being conducted.

Publications:

J. B. Knorr, "Hybrid Mode Analysis of Planar Lines," Proceedings of the Eighth Asilomar Conference on Circuits, Systems, and Computers, December 3-5, 1974.

J. B. Knorr, "Coupler Design Using Dispersive Transmission Lines," Proceedings of the Eighth Asilomar Conference on Circuits, Systems, and Computers, December 3-5, 1974.

J. B. Knorr, "Analysis of Coplanar Strips and Coupled Slots," IEEE Transactions Microwave Theory Techniques, July 1975.

J. B. Knorr, "Spectral Domain Calculation of Microstrip Characteristic Impedance." Submitted to IEEE Transactions on Microwave Theory and Techniques, September 1975.

NEUROPHYSIOLOGICAL RESEARCH PROGRAM

Investigator: G. H. Marmont, Professor of Electrical Engineering

Support: Naval Electronic Systems Command

Objective:

To develop advanced, real time, digital signal processing methods, and to use these methods to discover signals from the brain that are clearly indicative of mental processing, and finally to develop effective biofeedback, from the results of the real time signal processing techniques, to reinforce a subject engaged in a demanding mental task.

Summary:

The "tegule," defined as a waxing and then waning sinusoid (repeated in frequent bursts), was identified as a meaningful signature of mental processing. Electroencephalographic (EEG) techniques, followed by computer analysis with digital filtering, were used in identifying the tegule.

When demanding mental tasking was under way by a subject, tegules having certain preferred frequencies for their sinusoidal oscillations were prevalent.

Furthermore, such tegular activity was markedly correlated when the EEG signals were picked up from several specific regions of the scalp overlying the cerebral cortex of the brain.

Real time detection of the correlated signals afforded a suitable signal for biofeedback use.

Subjects doing such mental tasks as problem solving could enhance the degree of correlation when feedback was afforded.

A new very sensitive technique, called "tegulometric analysis," was developed for identifying frequency signatures from multisource and noise perturbed signals. It is proposed to apply this technique to analysis of Anti-Submarine Warfare (ASW) phonograms and other complex signals.

Publications: None

Theses Directed:

E. J. Ohlert, "A Study of Display Devices for Feedback of Meaningful Information to Electro-Encephalogram Subjects," Master's Thesis, March 1975.

R. E. McWey, "Signal Processing and Characterization of the Audio Evoked Cortical Response," Master's Thesis, June 1974.

W. E. Stockslager, "Computer Modeling of the Electroencephalogram," Master's Thesis, June 1974.

E. R. Wicklander, "An Analysis of Electroencephalograms," Master's Thesis, March 1975.

POSITION LOCATION REPORTING SYSTEM (PLRS) ENGINEERING DEVELOPMENT MODEL (EDM) TEST PROGRAM

Investigator: G. A. Myers, Associate Professor of Electrical Engineering

Support: U. S. Marine Corps

Objective:

To provide recommendations and assistance in the design of the PLRS electronic warfare test program.

Summary:

Analyses related to the jamming of the two different PLRS systems under contract were conducted and reported to USMC. A recommended jamming strategy for each system was developed. An investigation of the immunity to detectability of each PLRS system continues. This investigation is primarily experimental and will result in field tests.

Publications: None

STUDIES IN FIELDS OF SIGNAL ANALYSIS

Investigator: G. A. Myers, Associate Professor of Electrical Engineering

Support: Naval Electronic Systems Command

Objective:

To determine the properties of a carrier single-sideband modulated by a random binary (two-level) voltage.

Summary:

Single sideband (SSB) modulation is being considered for the transmission of binary data. The properties of the envelope of a carrier modulated in this manner have been determined. The form of this envelope as additional hormonics are retained has been calculated and plotted. The probability density function of the envelope of noise plus such a carrier has been plotted as signal-to-noise ratio varies. Processing gain versus hormonics retained has been plotted.

Publications: None

OPTIMUM PHASE AND AMPLITUDE ESTIMATION

Investigator: J. Ohlson, Associate Professor of Electrical Engineering

Support: Foundation Research Program

Objective:

To consider and evaluate the implementation of the optimum estimator of phase and amplitude as a special phase-locked loop.

Summary:

In some applications of acquiring a sinusoid in noise, the frequency can be assumed to be known, at least during the acquisition phase. The causal maximum a posteriori (MAP) estimates of phase and amplitude are well-known but are inconvenient to use for oscillator synchronization in real systems since they involve calculation and open-loop direction of oscillator phase. Hence a phase-locked loop (PLL) is generally used, but the loop bandwidth is usually chosen in some ad hoc fashion so the PLL acquisition performance is inferior to use of the MAP estimate. We have shown that the causal MAP estimator can be implemented exactly as a first-order PLL whose loop gain is a function of the synchronously detected envelope of the signal--using the phase estimate as the reference for detection. Furthermore, it has been demonstrated that if an automatic gain control capability precedes the PLL and synchronous detector, the loop gain is automatically varied in the optimum fashion. Finally, the estimator is easy to implement in practice.

Publications: None

IV-VI METAL-INSULATOR SEMICONDUCTOR (MIS) STUDY AND NOISE CANCELLATION STUDY

Investigator: T. F. Tao, Professor of Electrical Engineering

Support: Naval Electronic Systems Command

Objective:

To develop MIS of 4-6 semiconductors for infrared charge coupled imaging applications, and to study the background noise cancellation using recirculation of charge-coupled devices (CCD) signal.

Summary:

Charge transport devices (CTD) are being successfully developed for visible imaging. In comparison, serious developments of using CTD for infrared imaging are just being started. We are pursuing the monolithic approach which requires the development of new MIS devices of narrow gap semiconductors. In this project, we are using 4-6 semiconductor pbTe.

One of the basic difficulties of infrared imaging is the proper recirculation of the signal. Because a CTD imager is inherently a memory device, it could be conceivably used either to cancel out stationary background noise or to enhance the signal to noise ratio by integration. In either case, recirculation, recursive operation, is used. What was originally a study for imaging application is now extended as a general study of a new class of sampled analog recursive filters.

Publications and Conference Presentations:

T. F. Tao, V. Iamsaad, S. Holmes, B. B. Freund, L. Saetre and T. Zimmerman, "Sampled Analog CCD Recursive Comb Filters and Their Applications." Paper presented before the 1975 International CCD Applications Conference and published in the Conference Proceedings, October 1975.

Theses Directed:

R. Renzelman, "Study of Infrared Solid-State Imagors Using Charge Transport Devices," Master's Thesis, December 1974.

N. Boudreaux, "Design Optimization of MIS Devices for Infrared Solid-State Imaging," Master's Thesis, December 1974.

V. Iamsaad, "Charge Coupled Devices for Analog Signal Processing," Master's Thesis, December 1974.

B. Freund, "Implementation of Comb Filters by Sampled Analog Techniques," Master's Thesis, June 1975.

LARGE SCALE INTEGRATION (LSI) DEVICES FOR LOW PROBABILITY INTERCEPT/ANTI-JAMMING (LPI/AJ) APPLICATIONS

Investigator: T. F. Tao, Professor of Electrical Engineering

Support: Naval Electronics Systems Command

Objective:

To survey the matched filter and correlator developments, and standardize test procedure, and finally to carry out comparative evaluations.

Summary:

Matched filters (MF) and correlators are playing increasingly more important roles in modern communication systems, especially in low probability intercept/anti-jamming systems. Four types of devices based on different principles are being used to develop both digital and analog MF and correlators. They are the analog surface acoustic wave devices, digital LSI devices and charge transport devices (CTD), which can be either digital or sampled analog, and analog optical devices. A survey has been carried out of these devices and a standardized evaluation procedure has been selected.

At this stage, comparative evaluations are being carried out on digital LSI emitter follower logic (EFL) and complimentary metal-oxide-semiconductor on shappire (CMOS) correlators. Evaluations of analog MF will be carried out in the future.

Publications: None

Thesis Directed:

J. Poliakon, "A Survey of Matched Filter and Correlation Devices with an Evaluation of Two Digital Correlators," Master's Thesis, September 1975.

ELECTRICAL OPERATION OF CCD AND APPLICATION OF RECURSIVE CCD FILTERS TO MTI RADAR

Investigator: T. F. Tao, Professor of Electrical Engineering

Support: Foundation Research Program

Objective:

(1) To investigate the electrical operation of CCD for good linearity and wide dynamic range performance. (2) To investigate the feasibility of using recursive CCD filters for radar applications.

Summary:

Applications of charge-coupled devices (CCD) for sampled analog signal processing have been mainly concentrated in the nonrecursive filter and discrete Fourier transform areas. We are pursing the sampled analog recursive CCD filter approach. Since the implementation of a recursive filter requires the feedback of the output signal of a CCD back through its input, the electrical operating conditions of both the input and output circuits must be properly selected to achieve good performance such as wide dynamic range and good linearity. The first objective of this project is to investigate the CCD performance under different operating conditions.

A 9-bits two-phase surface channel CCD was used. Its output circuit is a gated floating diode followed by a Metal Oxide Semiconductors Field Effect Transistor (MOSFET). The input circuit used two gates and one diode in a manner known variously as the scuppering, surface potential equilibration and fill and spill techniques. It was found that the CCD can be operated in several modes of different gains varying from 1.5 to 30. The output voltage has a maximum swing up to 12 volts. Depending on the gain, the dynamic range of each mode varied from a fraction of a volt to seven volts with linear operation over a fraction of its range. Approximately, the product of gain and dynamic range is equal to the output voltage swing. Based on these results, four steps of consideration have been recommended to select the proper operation conditions for implementing a recursive CCD filter. Efforts are under way to investigate the feasibility of applying this type of filter to Moving Target Indication (MTI) radar.

Publication and Conference Presentation:

T. F. Tao, "Sampled Analog Recursive CCD Comb Filters and Their Applications." Paper presented before the 1975 International Conference on Applications of CCD at their October 1975 meeting in San Diego, California, and published in the Proceedings.

COMPUTER STUDIES OF CAPTURED AIR BUBBLE BOATS

Investigators: G. J. Thaler and A. Gerba, Professors of Electrical Engineering

Support: Naval Sea Systems Command

Objective:

To validate and improve existing simulation program with the ultimate goal of predicting performance of larger vessels now in planning stage, and to study specific performance characteristics affecting successful completion of proposed missions.

Summary:

The basic program has been rescaled to model the XR-3 testcraft, and program validation has been successfully carried out as far as can be correlated with Professor Layton's experimental data. Some program modifications have been required; most of these have been completed.

Heave acceleration studies in Sea States 3 and 4 have been made, and automatic control methods to alleviate these have been explored in student theses.

Calm water studies of power minimization by trade off between thrustpower and bubble power have been made. Optimal operating conditions have been found, but certain anomalous results require further study.

Publications: None

Theses Directed:

U. S. Grant, "Study of Heave Acceleration/ Velocity Control for the Surface Effect Ship," Master's Thesis, December 1974.

G. T. Forbes, "Validation of the Nonlinear Six Degree of Freedom Mathematical Model of the XR-3 Captured Air Bubble Surface Effect Ship in Calm Water," Master's Thesis, December 1974.

R. A. Finley, "Refinements of the Seal Subroutines and Fan Air Flow Maps for the XR-3 Loads and Motions Program," Master's Thesis, December 1974.

W. R. Mitchell, "Investigation to Optimize Captured Air Bubble Surface Effect Ship Digital Simulation for Irregular Sea Conditions," Master's Thesis, September 1974.

PASSIVE AND ACTIVE TRACKING IN RADAR INFRA RED (IR) AND ACOUSTICS

Investigator: H. A. Titus , Professor of Electrical Engineering

Support: Naval Electronic Systems Command

Objective:

Application of Extended Kalman Filtering to Marine Corps Position Location Reporting System (PLRS).

Summary:

In the PLRS system a master computer will keep track of some 350 radio transmitter-receiver units which may be placed in helicopters, aircraft, tanks, and with troops. The essential mechanism for locating is obtained by pulse transient time. Because of obvious problems to be encountered with terrain, the computer may connect to a unit which it desires to locate via several units. These units would act as relay units in the transferral of time pulses. In addition, in order to obtain an initial location, several units are required to be in contact with the unit to be located all via the computer. When a unit location is to be updated, the computer must determine which units it wishes to make contact through to obtain an optimum reduction in the covariance of error associated with the location of the unit in question. The problem is complicated initially by the fact that these relay units themselves have uncertain location with associated covariance of error in position. It is a superb place for the application of Kalman filters.

Publications: None

DEPARTMENT OF MATHEMATICS

The major areas of research in the Department of Mathematics are: (1) Numerical methods, (2) Optimal control and related game theory, (3) statistics, (4) Analysis of Computer Programs, and (5) Personalized System of Instruction (PSI). The individual investigations under each of these are described briefly below.

NUMERICAL METHODS

A number of applications have been developed, particularly for better efficiency in meteorology, in conjunction with the Department of Meteorology, Environmental Prediction Research Facility (EPRF), and Fleet Numerical Weather Control (FNWC). C. Comstock, with a thesis student, has developed a promising finite element method; F. D. Faulkner has modified recently developed fast direct methods for solving elliptic equations for various operational programs; A. L. Schoenstadt has carried out an analysis of several routines for stability, improved speed, effects of neglected non-linear terms, etc., particularly for waves and an air-sea interface programs; and R. Franke has developed a multi-variable interpolation procedure with improved accuracy and computational efficiency.

OPTIMAL CONTROL AND GAME THEORY

I. B. Russak has a continuing program on the theory of optimal control and on the related numerical solution of missile control problems; F. D. Faulkner is investigating game strategies in which unilateral action may increase every person's payoff.

STATISTICS

T. Jayachandran is developing a procedure for computing lower bounds to system reliability; P. C. C. Wang is developing charting techniques to assist management in making decisions with very limited data; P. C. C. Wang has developed some stochastic models for sound propagation in the upper ocean.

ANALYSIS OF COMPUTER PROGRAMS

D. L. Davis is investigating the lattice structure of programs with a view to improving compilation. R. Franke is analyzing algorithms so that a user can determine quickly

the timing and hardware requirements and accuracy, and can apply given algorithms more easily.

PSI IN MATHEMATICS

M. D. Weir is studying the effectiveness of Personalized System of Instruction (PSI), compared with traditional lecture methods, in teaching linear algebra; secondary objectives relate to student's attitudes, time requirements, retention, and transfer.

CONVERGENCE OF A NORMAL MODE EXPANSION

Investigator: C. Comstock, Professor of Mathematics

Support: Naval Air Development Center

Objective:

To answer some questions raised by C. Bartberger and L. Ackler on the convergence of a normal mode expansion.

Summary:

The convergence questions were answered. The detected divergence was not significant for any operational work. Further work was done to show the equivalence of two apparently different normal mode expansions. In addition, extensive discussions were held about technical details of the ray trace routine being written at NADC.

Publications: None

FINITE ELEMENT METHODS IN METEOROLOGY

Investigator: C. Comstock, Professor of Mathematics

Support: Foundation Research Program and Fleet Numerical Weather Central

Objective:

To investigate the suitability of finite elements for solving the non-linear wave propagation problems of meteorology. The "Finite element method" is a relatively new method for solving partial differential equations. When applied to static linear problems in mechanical engineering, it has proven to be the most efficient method yet available, both in accuracy and in computer time. All over the world there is now ongoing research to apply this method to non-static and non-linear problems in engineering.

Summary:

The simplest meteorological model to use is the barotropic model, or "shallow water equations." There are a number of questions to be answered before any computer implementation can be tried. Since the equations are non-linear, an iteration scheme is necessary. For classical methods it is known that some iteration schemes are vastly superior to others. For global meteorology the choice of grid is quite significant. The major effort during this quarter was spent in studying what effect these choices have on the answers one can obtain. A student, Donald Hinsman, with some help from this investigator, has programmed one scheme. His results, completed in September 1975, show a significant improvement over any other known scheme.

Publications: None

Thesis Directed:

D. Hinsman, "Application of a Finite Element Method to the Barotropic Primitive Equations," Master's Thesis, September 1975.

THE MEET OF PATHS PROBLEM AND COMPUTER PROGRAM ANALYSIS

Investigator: D. Davis, Assistant Professor of Mathematics

Support: Foundation Research Program

Objective:

To formulate and develop mathematical structures and algorithms, which can be used to analyze computer programs for the purpose of improved compilation. A specific immediate objective is to develop the lattice theoretic approach to analysis, originally initiated by Kildall of the Computer Science Group at the Naval Postgraduate School (NPS).

Summary:

In 1973, Kildall in his Association for Computing Machinery (ACM) paper "Global Expression During Compilation" presented a unified approach to global program analysis using lattice theory and graph theory. Although his methods can be used to analyze programs for propagated constants, common subexpressions, and redundant register load operations, subsequent researchers such as Kam and Ullman of Princeton and Graham and Wegman, in a series of articles which expand upon Kildall's original approach, showed that for certain extensions of the lattice theoretic framework, the algorithms central to Kildall's approach are no longer effective and in certain cases, the analysis problem is even undecidable, since it becomes equivalent to the so-called Post correspondence problem. In the present research, the author has succeeded in unifying and clarifying the original framework introduced by Kildall and showing in particular, that for a wide class of analyses, the problem is in fact decidable, and there exists a general type of algorithm which generalizes Kildall's original main algorithm. It is also shown that this algorithm is an abstract generalization of the algorithm used to solve shortest distance problems, discovered by Dijkstra in 1959. Finally, it is shown how the efficiency of this algorithm is related to the lattice and graph theoretic structures involved.

Publications: None

THE DIRECT SOLUTION OF SOME EQUATION OCCURRING IN METEOROLOGY

Investigator: F. D. Faulkner, Professor of Mathematics

Support: Naval Environmental Prediction Research Facility and Fleet Numerical Weather Central

Objective:

To develop faster methods for the numerical solution of the differential equations known by the names of Poisson and Helmholtz.

Summary:

In many or most meteorological prediction problems the solution of these equations requires the major part of the computing time. In the Mediterranean model and in some cloud models, the over-relaxation method used earlier sometimes converged so slowly that the program was halted.

New methods for solving Poisson's equation have been developed recently and have been programmed very efficiently by Dr. Roland Sweet at National Center for Atmospheric Research (NCAR). These were modified to treat the Helmholtz equation in an iterative solution. The biggest and most complex problem is the Fleet Numerical Weather Central (FNWC) Global Model (Ref., Leo Clarke or LT Rodger Langland). This is running, and it is doubtful that it would be feasible without the use of this Helmholtz solution.

There are many other problems where these techniques can be applied. The complexities of both the meteorological programs in which these are used and the routines are such that a mathematician familiar with the routines needs to work with a meteorologist to adapt the routine to the program. It was necessary to work closely with LT Langland to model as closely as possible the anticipated data and adjust the parameters in the routine.

Two reports are in progress. One deals with the special problems associated with the Global Model. The other treats the general solution of Helmholtz's equation. A preliminary report has been written with Dr. Thomas Rosmond at EPRF.

Publications: F. Faulkner and T. Rosmond, "Direct Solution of Elliptic Equations by Block Cyclic Reduction and Factoralization," EPRF Technical Note No. 20, April 1975.

THE SPECIFICATION OF ALGORITHMS

Investigator: R. Franke, Assistant Professor of Mathematics

Support: Naval Electronics Laboratory Center

Objective:

To determine a method specifying algorithms in a manner which would facilitate the determination of their requirements in terms of timing and hardware and to encourage more widespread usage of the implemented algorithm.

Summary:

A study of methods of specifying, or describing, algorithms was undertaken. It is desired to have a specification from which a potential user can determine timing and hardware requirements and accuracy, and from which the implementer can create a program which will perform in exactly the specified manner. This will encourage use of standard algorithms by other than the originating agency.

A format for such specification was proposed. A number of examples were presented and followed by a discussion of shortcomings and problems related to giving such a specification.

Publication: R. Franke, "The Specification of Algorithms," Technical Report NPS53Fe75071, July 1975.

SMOOTH MULTIDIMENSIONAL INTERPOLATION

Investigator: R. Franke, Assistant Professor of Mathematics

Support: Foundation Research Program

Objective:

To generalize a previously proposed method (due to A. D. Maude, "Interpolation-mainly for graph plotters," The Computer Journal, 16 (1973), 64-65) for local smooth interpolation in several variables and to analyze the error involved in such methods.

Summary:

A class of methods for local, smooth interpolation in several variables was proposed. The method is essentially one of blending local interpolation functions so as to obtain a global approximation which is smooth and whose value can be obtained from function values at nearby points. Because the approximation takes the form of a convex combination of local interpolation functions, the error term has the same form as the local interpolation functions.

For various forms of local interpolation functions the accuracy and computational time were compared with other methods for a variety of functions of two variables. As expected, the results showed the method to be relatively efficient in terms of computation time. All methods tested were reasonably accurate for most functions, but most obtained relatively inaccurate results on at least one case, indicating they are to be used with some caution.

Publications: Richard Franke, "Locally Determined Smooth Interpolation at Irregularly Spaced Points in Several Variables," Technical Report #NPS53Fe 75041, April 1975. Submitted to The Computer Journal.

AN EVALUATION OF PROCEDURES FOR COMPUTING LOWER BOUNDS FOR SYSTEM RELIABILITY

Investigator: T. Jayachandran, Associate Professor of Mathematics

Support: Foundation Research Program

Objective:

(a) To determine the effect of ordering the component failure data from smallest to largest on the lower bound for system reliability, (b) To determine a measure of the amount of data unused in calculating the Lieberman-Ross bound, (c) To evaluate the accuracy of the approximately optimal procedure of Mann and Grubbs (M-G), (d) To 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, (e) To 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 general plan of attack is to use simulation procedures to achieve the objectives. The variables that will be used in the simulation are (a) the number of components m in the system, (b) the failure rates λ_i, $i = 1, 2, \ldots, m$ of the components in the system, (c) the failure distributions of the components, and (d) the number of items n_i of each component that are to be life tested. For each choice of values for these variables random failure data are generated on the computer and the L-R and M-G procedures are applied. This process will be replicated about 500 to 1000 times and the computed lower bound will be compared with the true system reliability as determined by the failure rates λ_i selected for the simulation. These comparisons will provide the answers to the objectives of the project.

Publications: T. Jayachandran and L. R. Moore III, "The Performance Characteristics of Some Reliability Growth Models," Technical Report NPS53Jy74122. Submitted to IEEE for publication.

Thesis Directed:

Chang Heup Choi, "Prediction Intervals for Correlated Samples," Master's Thesis, 1974.

MINIMUM STORAGE SOLUTION OF CAPACITATED ROOTED TREES

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

Support: Naval Postgraduate School

Summary:

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

Publications: None

CONTINUED RESULTS CONCERNING THE IMPROVEMENTS REALIZABLE THROUGH THE USE OF VARIABLE THRUST TOGETHER WITH ENGINE GIMBALING FOR A PARTICULAR INTERCEPTOR MISSILE

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

Support: Pacific Missile Range

Objective:

To examine the potential performance limits of advanced conceptual air-to-air interceptor missiles for the Navy.

Summary:

Some interceptor missiles possess a programmed thrust magnitude history together with gimbaled engine to provide steering. In this investigation, work was continued on a topic initiated by the author during July and August of 1973 in examining one particular missile in order to determine whether its performance could be improved by allowing variable thrust magnitude together with engine gimbaling to provide control. The results showed that performance may be significantly improved with this concept which may provide the prototype of a new version of interceptor missile.

Publications:

I. B. Russak, "Preliminary Results Concerning the Improvements Realizable Through the Use of Variable Thrust Together with Engine Gimbaling for a Particular Interceptor Missile," Technical Report NPS53Ru74061, June 1974.

I. B. Russak, "An Indirect Sufficiency Proof for Problems with Bounded State Variables," Technical Report NPS53Ru75061, June 1975.

I. B. Russak, "Relations Among the Multipliers for Problems with Bounded State Constraints, Technical Report NPS53Ru75062, June 1975.

I. B. Russak, "Preliminary Results Concerning the Improvements Realizable Through the Use of Variable Thrust Together with Engine Gimbaling for a Particular Interceptor Missile," Technical Report NPS53Ru74061, June 1974.

SECOND ORDER NECESSARY CONDITIONS FOR PROBLEMS WITH STATE INEQUALITY CONSTRAINTS

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

Support: Foundation Research Program

Objective:

To obtain a set of second order necessary conditions for minimizing a general cost function for a canonical problem in optimal control which involves constraints of the form

$$\psi^{\alpha}(t,x) \leq 0 \qquad \alpha = 1, \ldots, m .$$

Such second order necessary conditions complement other conditions obtained by the investigator in achieving practical solutions to these problems.

Summary:

A set of second order necessary conditions is obtained for the above problem by using the techniques of the calculus of variations to show that a certain functional is non-negative on a class of variations of the solution. The problem considered has practical applications in a wide variety of fields.

Publication: I. B. Russak, "Second Order Necessary Conditions For Problems With State Inequality Constraints," SIAM Journal of Control, Vol 13, No. 2 (February 1975).

SECOND ORDER NECESSARY CONDITIONS FOR GENERAL PROBLEMS WITH STATE INEQUALITY CONSTRAINTS

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

Support: Foundation Research Program

Objective:

To obtain a set of second order necessary conditions for minimizing a general cost function for a very complex problem in optimal control involving constraints of the form

$$\psi^{\alpha}(t,x) \leqq 0 \qquad \alpha = 1, \ldots, m \ .$$

Summary:

By using transformation techniques, the results obtained in a previous article by the investigator are extended to include a highly complex problem in optimal control in which many other constraints (besides the above listed ones) are present. The problem considered is so general as to include most of the usual problems encountered in optimal control.

Publication: I. B. Russak, "Second Order Necessary Condition For General Problems With State Inequality Constraints," Journal of Optimization Theory & Applications, October 1975.

RELATIONS AMONG THE MULTIPLIERS FOR PROBLEMS WITH BOUNDED STATE CONSTRAINTS

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

Support: Foundation Research Program

Objective:

In previous work the investigator established certain first order necessary conditions for minimizing a general cost function in optimal control problems with constraints of the form $\psi^{\alpha}(t,x) \leq 0 \quad \alpha = 1, \ldots, m$. The conditions involve certain multiplier functions and constants. It is desired to obtain relations among these multipliers so as to aid in realizing numerical solutions.

Summary:

By using the techniques of the calculus of variations it is shown that the following relations exist between the multiplier functions: $\mu_{\alpha}(t^{o}) \leq K^{\alpha}$ with $\mu_{\alpha}(t^{o}) = K^{\alpha}$ if $\psi^{\alpha}(t^{o}) < 0$ (where t^{o} represents the initial time of the problem). The problem considered is of sufficient generality to include many practical applications in a wide variety of fields.

Publications: None

AN INDIRECT SUFFICIENCY PROOF FOR PROBLEMS WITH BOUNDED STATE VARIABLES

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

Support: Foundation Research Program

Objective:

To obtain sufficient conditions for minimization of a general cost function in a complex problem in optimal control involving constraints of the form $\psi^{\alpha}(t,x) \leq 0 \quad \alpha = 1, \ldots, m.$

Summary:

A set of sufficient conditions for the above problem is obtained by strengthening the first and second order necessary conditions previously obtained by the investigator for problems of this type, and the existence of a proper strong relative minimum is established. The problem considered is sufficiently general to include a variety of applications such as optimal ship routing problems where land constraints take the form of the above listed inequalities and where there are also present other constraints such as constraints on fuel and where some function (e.g. time) is to be minimized.

Publication: I. B. Russak, "An Indirect Sufficiency Proof For Problems With Bounded State Variables." Accepted by Pacific Journal of Mathematics.

THE COMPUTATIONAL STABILITY OF TECHNIQUES FOR NUMERICAL WEATHER PREDICTION

Investigators: A. L. Schoenstadt, Assistant Professor of Mathematics and R. T. Williams, Professor of Meteorology

Support: Foundation Research Program (Schoenstadt)
Fleet Numerical Weather Central and Environmental Prediction Research Facility (Williams)

Objective:

To investigate increases in the maximum allowable time step, before onset of computational instability, when the normal centered-difference (leapfrog) procedure is modified by averaging on certain spatial derivative terms.

Summary:

Shuman, "Resuscitation of an Integration Procedure," National Meteorological Center Office 54 (1971) has proposed a gradient averaging modification to the normal centered difference (leapfrog) scheme for the primitive equations of numerical weather prediction. Where successful, this modification would allow a longer time step, and hence reduce computational time. In this investigation, the effect of this gradient averaging on the computational stability of the linearized shallow water equations, both with and without a mean flow, was studied. In the case with no Coriolis force and no mean flow, an exact analytic expression for the maximum stability region was derived. This expression validated previous numerical results, and predicted a theoretical upper limit possible of twice the time step for the normal leapfrog scheme. When the effect of a mean flow is added to this model, the condition for stability was interpreted in terms of the roots of a cubic polynomial, and an approximate expression for the stability region was derived. The analysis showed that, although doubling of the time step was no longer possible, a significant increase was still allowable in most cases of interest. The effect of the gradient averaging technique on the time-averaged filtering suggested by Robert was also examined, and a potential improvement demonstrated numerically.

Publications: A. L. Schoenstadt and R. T. Williams, "The Computational Stability Properties of the Shuman Pressure Gradient Averaging Technique." Technical Report, NPS53Zh51Wu75091, September 1975. Submitted to Journal of Computational Physics, 1975.

ANALYSIS OF EFFECT ON NON-LINEAR TERMS IN THE YEFIMOV MODEL

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

Support: Foundation Research Program

Objective:

To determine the importance of the non-linear terms neglected by Yefimov, and to compare the results with observational studies published subsequent to Yefimov's paper.

Summary:

In 1970, Yefimov proposed a linearized model to describe the effect of a fully developed water wave field on the overlying turbulent air flow. A computer code developed by B. Stauffer and K. Dunning and based on the solution techniques proposed by Richtmyer and Matsuno was reprogrammed to remove certain logical errors, then utilized to solve the equations derived from Yefimov's model by retention of the non-linear terms. The resulting numerical solutions, over a broad range of relevant parameters, were then compared both to Yefimov's linear predictions, and the observational studies of K. Davidson. The results showed the effect of the non-linear terms was to strongly damp the wave-induced wind field, with reductions in amplitude by a factor of two or more common. The results also showed local agreement with Davidson's observations, although the agreement over the full range of parameters was not particularly satisfactory. The study concluded that the influence of the non-linear terms neglected by Yefimov was, in fact, quite important, but that the addition of the non-linear terms alone did not fully explain the observed effects.

Publications: A. L. Schoenstadt, R. T. Williams, K. L. Davidson, B. C. Stauffer, and K. G. Dunning, "A Numerical Model for the Effect of Ocean Waves on the Adjacent Airflow," Technical Report NPS53Zh75102, October 1975. Submitted to the Journal of Physical Oceanography.

STOCHASTIC MODEL ON SOUND PROPAGATION IN THE UPPER OCEAN

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

Support: Office of Naval Research

Objective:

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

Summary:

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

Publications:

P. C. Wang, "Stochastic Models of the Scattering of Sound by Bubbles in the Upper Ocean," Quarterly of Applied Mathematics, January (1975).

P. C. Wang, "Asymptotics of Stirling Numbers of the 2nd Kind," Proceedings of the American Mathematical Society, 42 (1974) and 48 (1975).

OPTIMAL DECISION CHARTING TECHNIQUES FOR WEAPON SYSTEMS

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

Support: Foundation Research Program

Objective:

To model a complex system stochastically and provide a framework that statistical analysis will be applied to generate graphs, which summarize the relevant data and lead to a mathematical optimization problem with solutions.

Summary:

Preliminary model developed, indicates that trade-offs can be studied through a set of first order partial differential equations with variable coefficients. The case where the partial differential equations with constant coefficients can be treated with the Newton-Raphson method to obtain solution. More complicated forms of coefficients will require additional attention to the analysis of solving a partial differential equation of the first order.

Publications: None

AN INVESTIGATION OF THE PERSONALIZED SYSTEM OF INSTRUCTION FOR THE TEACHING OF MATHEMATICS TO NAVAL OFFICERS

Investigator: M. D. Weir, Associate Professor of Mathematics

Support: Foundation Research Program

Objective:

To investigate the use of Personalized System of Instruction (PSI) as an alternative method for teaching linear algebra to Naval Officers. A specific objective is to determine if PSI is at least as effective as the traditional lecture-recitation method. Secondary objectives relate to student attitudes toward PSI, time requirements for course completion, transfer, and retention. This is a continuing project.

Summary:

A Study Guide was written for Computational Linear Algebra. The Guide itself was then tested on a small group of Naval Postgraduate School (NPS) students (12) adjusted and revised, and then re-tested on a larger group of students (35). Satisfied with the validity of the Guide as a teaching instrument, an experimental and control group of approximately 15 students each was set up: The experimental group in the PSI mode and the control group in the traditional lecture-recitation mode. Both groups had one common instructor, Associate Professor Alan Shorb. (Professor Shorb was entirely familiar with PSI having attended the NPS PSI workshop. His attitude toward PSI vice lecture-recitation was neutral and impartial.) Both groups were initially tested by two standardized tests (aptitude and personality) written and validated by Communication Technology Branch (CTB)/McGraw Hill, and a linear algebra diagnostic test. Furthermore, each student's prior mathematical background was taken into account. This initial data was subjected to three statistical tests, including an analysis of variance. On all accounts the two groups were shown to be statistically indistinguishable across all input variables. The two groups were then given the linear algebra course. For output variables we measured final examination scores (a common final, departmentally approved, was given to both groups), course grades, student attitudes (measured by a course questionnaire), and overall semester Grade Point Average (GPA) (excluding the linear algebra grade: this provides a measure of transfer). The output variables were also subjected to the same statistical tests. Results show there is a statistically significant difference between the two groups across the output variables: students subjected to PSI perform better than the control students.

Publications: None

INVARIANT INTEGRATION ON TRANSFORMATION SEMIGROUPS

Investigator: C. O. Wilde, Professor of Mathematics

Support: Foundation Research Program

Objective:

To determine conditions under which a theory of invariant integration is available for compact transformation semigroups.

Summary:

The problem involves an underlying set and a family of functions which map the set into itself. In many applications the underlying set is equipped with a topology relative to which the self-maps are continuous; and the set, together with the σ-algebra of Borel sets, becomes a measurable space upon which useful measures are defined. It is then possible to integrate real or complex measurable functions in the Lebesgue sense, and a fundamental type of problem is to determine when integration of these functions is invariant over the translation operators induced by the self-maps of the set.

Self-maps of a set can be composed, and usually no generality is lost if it is assumed that the family of self-maps form a composition semigroup. The interplay between these set-theoretic, topological, measure-theoretic and algebraic structures provides a potential source of valuable results, including solution of systems of differential and integral equations.

In view of the classical theory of topological groups, it was reasonable to study the case where the underlying topological space is compact, and where the semigroup of self-maps is an equicontinuous family (which essentially amounts to an assumption of compactness on the semigroup relative to the compact-open topology). By studying a number of specific examples, it was found that the existence of an invariant integral is related to the existence of a nonempty closed subset of the underlying set that is mapped onto itself by each of the functions in the semigroup of self-maps. It was possible to show that every closed fixed set contains a minimal closed fixed subset which, along with some additional results obtained, suggested that an invariant integral exists if and only if the underlying set can be partitioned by minimal closed fixed sets. Although some progress was made toward establishing this conjecture, results capable of proving or disproving either necessity or sufficiency were not obtained. Thus,

the basic problem remains open. This problem should be pursued because an affirmative solution would be useful itself for solving equations and could also lead to further interesting and useful results.

In the course of this research, the investigator found another problem that could lead to some interesting results. There is a condition on semigroups known in the literature as the strong Folner condition, and a second condition that may be called the Sorenson condition (after the man who first explored it). Careful study shows that these conditions have a rather qualitative characteristic in common. In addition, the literature shows that the semigroups known to have [not have] the strong Folner condition are precisely those known to have [not have] Sorenson's condition. Still further, the basic techniques for establishing these conditions in the literature are the same, and the only known examples where the conditions do not hold are exactly the same for both. This is strong evidence to indicate that these conditions are equivalent.

Publications: None

DEPARTMENT OF OPERATIONS RESEARCH AND ADMINISTRATIVE SCIENCES

Operations Research and Administrative Sciences is a large, multi-disciplinary department responsible for academic programs in Operations Research and a variety of Administrative Sciences. The Department's research program reflects these disciplines and interacts strongly with the graduate degree programs which they support. Much of the research is devoted to developing analytical and quantitative approaches to Navy and Department of Defense problems of resource allocation and operations. The principal areas of concentration within the Department's research program are the following: (1) The Weapon System Acquisition Process, (2) Manpower/ Personnel Management, (3) Military Operations Research, (4) Health Care Delivery Systems, (5) Organizational Issues, (6) Optimization, (7) Stochastic Modelling, and (8) Human Factors. The present focus of the individual research tasks within these areas is summarized below:

ACQUISITION

Research in systems acquisition supports our curricular program in Systems Acquisition Management as well as Navy and Department of Defense (DoD) objectives. Specific projects include reliability improvement warranty policies, under study by R. R. Judson; cost escalation in contracting by C. R. Jones and M. G. Sovereign; and the requirements determination process, specifically for the advanced Naval gun, being developed by M. B. Kline and others. Student theses have addressed the requirements determination process, Congressional impact on acquisition management, costing and profit policies, procurement and contract administration, test and evaluation procedures, and life cycle management.

MANPOWER/PERSONNEL MANAGEMENT

Departmental research in manpower and personnel management ranges from behavioral studies to quantitative manpower flow models and data analysis. Problems of manpower retention and utilization have provided a unifying theme for research in this area. J. K. Arima's work deals with resource allocation and effectiveness measurement in Navy recruiting activities. D. P. Gaver has examined the readiness of shipboard organizations as a function of equipment complexity and manpower quality. Flow models for manpower planning for the Marine Corps Headquarters

have been developed by K. T. Marshall. These latter models are in active use by the Marine Corps. R. W. Butterworth and P. Milch are developing models for enlisted personnel advancement planning. R. Weitzman is investigating improved methods for test scoring.

MILITARY OPERATIONS RESEARCH

Fundamental and applied research in a number of widely different areas characterize this area. R. N. Forrest and others continue to conduct studies of submarine vulnerability, as well as research into search and detection theory. F. R. Richards and H. J. Larson have engaged in statistical reliability studies on site at the Operational Test and Evaluation Force - Pacific. M. G. Sovereign and others have developed methodology for campaign analysis. Basic research in Lanchester theory for the analysis of land combat is the continuing activity of J. G. Taylor.

HEALTH CARE DELIVERY SYSTEMS

Recognition of resource requirements and other critical problems in military health care delivery has prompted a number of research projects. R. W. Butterworth, W. C. Giauque, M. G. Sovereign and D. R. Whipple have studied hospital organization and operations, measurement of the quality of health care, physician supply, and planning, programming and budgeting in the Naval Bureau of Medicine and Surgery.

ORGANIZATIONAL ISSUES

These studies are concerned with issues of technology transfer, organizational slack, decision making, organization size and complexity, and organizational variables as they influence Navy project management. Investigators include J. W. Creighton, S. M. Dean, C. K. Eoyang, W. C. Giauque and W. J. Haga.

OPTIMIZATION

G. H. Bradley, G. G. Brown and J. K. Hartman are conducting fundamental research in mathematical optimization. Their work has resulted in a network programming code which is approximately 50 times faster than existing public or proprietary codes. It is available to any organization in Department of Defense or government.

STOCHASTIC MODELLING

Research under the general heading of stochastic modelling includes computer software reliability as it is influenced by program structural features, conducted by N. F. Schneidewind and others, phased mission reliability by J. D. Esary and students, mathematical models for computer configuration evaluation conducted by D. P. Gaver for the Defense Communications Agency, demand forecasting techniques evaluated by P. W. Zehna, and basic research in probability modelling of, and statistical inference for, point stochastic processes by P. A. W. Lewis and by D. P. Gaver, conducted under National Science Foundation (NSF) sponsorship.

HUMAN FACTORS

The Man/Machine Design Laboratory personnel have been engaged, with students, in a variety of funded and unfunded projects. The principal faculty researchers are D. E. Neil and G. K. Poock. Funded projects include accident data analysis for the Naval Safety Center and basic research on biorhythms; unfunded work includes ecperimentation with Kirlian photography.

A SYSTEMS ANALYSIS OF NAVY RECRUITING

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

Support: Naval Personnel Research and Development Center

Objective:

To provide a systems analysis of Navy recruiting at a logical, descriptive level to be used by personnel and manpower researchers as a background for research in specific areas of personnel acquisition.

Summary:

An extensive schedule of interviews, on-site inspection of activities, and a study of recruiting documentation brought out the complex relationships between the needs of the Navy, the characteristics of the civilian population, and the effort required by the Navy Recruiting Command to fulfill its recruiting mission. The recruiting command was found to be hierarchically and geographically organized under traditional military concepts and operating in the manner of a sales organization. The sales model proved to be superficial, because Navy recruiting turned out to be a procurement function with specific procurement programs and quality criteria. Total manpower requirements and requirements for specific programs initiated activity in the system. But the simultaneous constraints on ethnic, educational, and mental qualifications and the requirement for a level flow and even distribution of new accessions to three recruit training centers provided the primary stresses on the system. Assigned goals and production of recruits were highly correlated in sub-elements of the system. When procurement was difficult, overall manpower goals were attained by sacrificing quality. The flow requirements to the recruit training centers were sacrificed toward attainment of the quality criteria. A concept of net productivity was required, since 10 to 15 percent of the input to the recruit training centers dropped out of service before completing their 9 weeks of basic training.

Publications: None

Thesis Directed:

J. B. Best and W. J. Wiley, "U. S. Navy Recruiter Attributes and Attitudes: A Survey Analysis," Master's Thesis, June 1974.

J. W. Corsey, Jr., "An Analysis of Enlisted Recruit Processing Flows," Master's Thesis, March 1975.

SMALL ARMS FIELD EXPERIMENTATION PROGRAM

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

Support: U. S. Army Combat Developments Experimentation Command

Objective:

By a series of limited-purpose, live-fire field experiments, to develop knowledge regarding factors that affect the effective utilization of small arms.

Summary:

The fourth in this series of experiments was conducted to improve the precision of fire using the 16-gage, riot shotgun. If this weapon were made more precise, fewer unintended casualties would result; i.e., it would be less lethal when used for guard duty and crowd control, while the effectiveness for its intended purpose would be improved. Circular bracketing sights of two different sizes were created and attached over the bead sight of the riot shotgun. One size bracketed the width of three shot groups of 00 shot, and the other, six shot groups. The experimental sights were compared against the control weapon (bead sight) by live-fire at silhouette targets at ranges of 20 and 40 yds. using 00 shot. The large circular sight decreased the radial miss distance of shot-group centers by 30 percent at 40 yds. over the control sight. Both experimental sights obtained twice as many pellet hits on target as the control weapon at 40 yds. Thus, appropriate sights on the riot shotgun can decrease unwanted spread of fire and increase hits on the intended target. The findings of the experiment are also applicable to the military use of shotguns or similar weapons in combat.

Publications: J. K. Arima, "Improvement of Small Arms Pointing Fire Using Bracketing Sights: A Field Experiment Program," Technical Report NPS-55Aa74111, November 1974. Also published in Journal Supplement Abstract Service Catalog of Selected Documents in Psychology, 5 (1975).

Conference Presentation:

J. K. Arima and R. D. Read, "Controlling the Riot Shotgun." Paper presented at the annual meeting of the Western Psychological Association, Sacramento, CA, April 1975.

Thesis Directed:

R. D. Read, "Field Test of An Experimental Bracketing Sight for the 12-Gage Riot Shotgun," Master's Thesis, September 1974.

STATISTICAL MODEL FOR BOMBING ACCURACY EVALUATION AND PREDICTION

Investigator: D. R. Barr, Associate Professor of Operations Research and Administrative Sciences

Support: Naval Electronic Systems Command

Objective:

To develop evaluation methodology and models for use in determining measures of effectiveness of air-to-surface weapon delivery systems.

Summary:

Several sequential tests of hypotheses about the circular error probable (CEP) of a bomb delivery system, were developed and compared. Statistical analyses of test results with the AN/TPQ 27 system were used to identify system characteristics and identify possible sources of error. Use of systems such as the AN/TPQ 27 in a radar bomb scoring role was investigated.

Publications:

D. R. Barr and M. Jordan, "A Power Distribution Model for Weapon Accuracy," Technical Report NPS55Bn74011, 1974.

D. R. Barr, "Two Sequential CEP Tests," Technical Report NPS55Bn74061, 1974.

D. R. Barr and T. Burnett, "A Sequential Median Test With Application to CEP Testing," Technical Report NPS55Bn75071, July 1975.

Theses Directed:

K. Keene, "Radar Bomb Scoring with Computer Controlled Bombing Systems," Master's Thesis, September 1974.

M. Jordan, "Methods and Models for Estimating the Accuracy of Air-to-Surface Weapon Delivery," Master's Thesis, March 1973.

AD-A031 842 NAVAL POSTGRADUATE SCHOOL MONTEREY CALIF F/G 5/1
A SUMMARY OF THE NAVAL POSTGRADUATE SCHOOL RESEARCH PROGRAM.(U)
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A COSTING AND PLANNING MODEL FOR GRADUATE EDUCATION

Investigators: M. K. Block and D. C. Burns, Professors of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To formulate a logical cost model of graduate education. Background research to involve a rigorous exploration of conceptual problems in existing educational cost models. Data for Block/Burns cost model to be derived from Naval Postgraduate School (NPS) operations.

Summary:

During fiscal year 1975 the investigators have conducted a review of educational costing models and educational organization accounting systems described in the literature. This review provided us with much helpful guidance and resulted in our making some significant changes to the NPS costing model.

The NPS costing model, developed by the investigators during 1974, continues to be in a state of evolution. During the past fiscal year, significant improvements have been made in the model including a simplification which eliminates several time-consuming re-allocation steps. These modifications enhance the model's capability for providing us with variable support cost information.

During the past months, the investigators have completed a current analysis of variable support costs at NPS. At the present time, they are involved in an extension of this variable cost analysis project which should result in an improved NPS system for isolating the costs which NPS incurs in hosting some of its major tenant activities.

Publications: None

INTEGER LINEAR PROGRAMMING AND NETWORK OPTIMIZATION

Investigator: G. H. Bradley, Associate Professor of Operations Research and Administrative Sciences

Support: National Science Foundation

Objective:

To investigate the algebraic structure of interger linear programming problems and to develop algorithms to compute optimal solutions to these problems, and finally, to investigate algorithms to solve large scale network optimization models including the capacitated transshipment, transportation, and assignment problems.

Summary:

There are many equivalent ways to represent the set of solutions to a linear inequality in 0-1 variables; the amount of computation needed to solve an integer linear programming problem is related to this representation. The research completely characterized the equivalent representations and developed an algorithm to construct the most efficient representation. Computational results for over 200 inequalities showed the effectiveness of the algorithm.

The algebraic structure of fixed order enumeration methods for integer linear programming was studied to characterize the periodic behavior of these algorithms. Improved algorithms that exploit this structure are being developed.

In response to an invitation from the editor of the Transactions of the American Institute of Industrial Engineers, a comprehansive survey of deterministic network models and algorithms was prepared for a special issue of the journal. The survey reviewed research, evaluated algorithms and suggested directions for future research.

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

Publications: G. H. Bradley, P. L. Hammer and L. Wolsey, "Coefficient Reduction for Inequalities in 0-1 Variables," Mathematical Programming 7 (December 1974).

G. H. Bradley, G. Brown, and G. Graves, "GNET, A FORTRAN Primal Network Code," copyright 1975.

G. H. Bradley and M. Shubik, "A Note of the Shape of the Pareto Optimal Surface," Journal of Economic Theory, 8 (August 1974).

G. H. Bradley, "Survey of Deterministic Networks," 1975 issue of American Institute of Individual Engineers Transactions, September 1975.

Conference Presentation:

G. H. Bradley, G. Brown and G. Graves, "A Comparison of Storage Structures for Primal Network Codes." Paper presented at the Operations Research Society of America national meeting, Chicago, May 1975, and invited by Management Science.

Thesis Directed:

Y. P. Cheong, "Formulation and Solution of Network Models," Master's Thesis, September 1975.

STRUCTURE AND ERROR DETECTION IN COMPUTER SOFTWARE

Investigator: G. H. Bradley, Associate Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To relate the error detection process in the testing of large computer software programs to the structure of the software, and to give guidance to managers of large software projects on how the early design of the software relates to the time to test the software.

Summary:

An analytical and simulation model was developed to relate structure to error detection. The software is represented as a directed graph with nodes as branch points and arcs as modules of the program. Errors occur in arcs, and testing is modeled as the traversal of the graph from a start node to an exit node. Given this model of software project, it is possible to develop analytical results for the expected number of errors detected for a sequence of tests. The analytical results involve the computation of the fundamental matrix of a Markov chain. The simulation is used to develop results on the variance of the detected errors and to incorporate conditions that cannot be handled analytically.

Publications: G. H. Bradley, T. Green, G. Howard, and N. Schneidewind, "Structure and Error Detection in Computer Software," Proceedings of the Spring Conference of the American Institute of Industrial Engineers, May 1975.

LARGE SCALE NETWORK OPTIMIZATION

Investigator: G. Brown, Assistant Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To study mathematical methods for efficient optimization of large scale pure network models including capacitated transshipment, transportation and assignment problems.

Summary:

Various methods for network optimization by manipulation of efficient storage structures have been evaluated mathematically and numerically. For this class of pure network problems, an extremely effective algorithm has been developed. The results of this investigation have been used to develop GNET, a FORTRAN program for capacitated pure network optimization. Test problems as large as 10,000 constraints (nodes) and 35,000 variables (arcs) have been solved at computation costs as much as 50 times cheaper than "contemporary" linear programming codes, and 5 times as fast as "efficient" special purpose network codes. Solutions now take minutes, rather than hours, and are exact numerically. The coyprighted program is now available to other researchers and Department of Defense (DOD) agencies.

Publications: G. Bradley, G. Brown and G. Graves, "GNET, A FORTRAN Primal Network Code," copyright 1975.

Conference Presentation:

G. Bradley, G. Brown and G. Graves, "A Comparison of Storage Structures for Primal Network Codes." Paper presented at Operations Research Society of America, national meeting, Chicago, May 1975.

Theses Directed:

Y. P. Cheong, "Formulation and Solution of Network Models," Master's Thesis, using GNET, September 1975.

NAVY ENLISTED PERSONNEL MODELLING PROJECT

Investigator: R. W. Butterworth, Associate Professor of Operations Research and Administrative Sciences

Support: Naval Personnel Research and Development Center

Objective:

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

Summary:

A task to investigate the possible clustering of enlisted ratings for personnel loss forecasting models was completed. Ratings were clustered according to their loss behavior, in a hierarchical fashion, and a measure of the loss forecasting error from clustering was made. The results generally indicated that clustering offered no substantial benefit in this regard, and was not recommended. The study did result, however, in a systematic approach to clustering ratings by their loss behavior, which could be used in other such problems as the identification of ratings to which a particular personnel policy affecting losses might be applied.

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

The latest task has been the development of MINIFAST, an interactive computer model of the personnel system, similar to FAST. This model will augment the Navy's current capabilities, particularly during the Program Objectives Memoranda (POM) cycle when future personnel requirements are being decided quickly, and a real time model is necessary. Development of MINIFAST began only during the last quarter of this fiscal year, and is now the current objective of our project. Operational use of MINIFAST by the Navy is anticipated in the current calendar year.

Publications: R. W. Butterworth, "Clustering Navy Ratings by Loss Behavior," Technical Report, NPS55Bd75062, June 1975.

Thesis Directed:

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

MILITARY HEALTH CARE SYSTEMS STUDIES

Investigator: R. W. Butterworth, Associate Professor of Operations Research & Administrative Sciences

Support: Foundation Research Program

Objective:

To extend the computational results in queuing theory, and to test the applicability of these results on a real modelling problem in military health care. In particular, the Acute Minor Illness Clinic (AMIC) system for handling walk-in patients in a hospital was to be studied, and this numerical method applied in a queuing model of this clinic.

Summary:

A new method for computing approximate solutions to certain inhomogeneous queuing problems was developed. The AMIC system at Ford Ord Hospital was studied, data collection made, and a mathematical model formulated for this clinic system. The queuing method was incorporated into an overall model for the AMIC system. A validation effort was begun to determine the method's accuracy on a real problem. This project is continuing with a more detailed study of the method using a simulation model of the clinic. Preliminary results indicate that the method is quite accurate when the mean system size remains below 10 persons, due to the methods imposition of a limit of 32 persons. An improvement in the method, allowing the algorithm to adaptively track the probability mass and avoid an artificial queue limit, is planned for the future. The model assumes an inhomogeneous Poisson arrival stream, exponential holding times, and an inhomogeneous schedule for servers.

Publications and Presentations:

R. W. Butterworth, "Determining Staffing Levels for Outpatient Walk-In Clinics." An invited presentation at the Forum on Ambulatory Care Systems, National Cooperative Services Center for Hospital Management Engineering, San Francisco, California, June 1975.

R. W. Butterworth, "On Congestion in Outpatient Walk-In Clinics," Technical Report NPS55Bd75061, June 1975. Submitted to Operations Research.

Theses Directed:

David Van Asdlen and Leonard Wahlig, "A Numerical Solution for Time Dependent, Multi-Channel Queues and an Application to the Acute Minor Illness Clinic, Silas B. Hays Hospital, Fort Ord, California," Master's Thesis, 1974.

Bruce Culmor, "A Simulation of the AMIC System," (Title Approximate), Master's Thesis, 1974.

A SIMULATION MODEL OF ORGANIZATIONAL SLACK

Investigator: C. K. Eoyang, Assistant Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To develop a simulation model of manpower changes in organizations.

Summary:

A Behavioral Model of Manpower Decision-making is developed and exercised. The simulation incorporates a weak statement of Parkinson's Law which claims that the demand for labor is partially dependent upon the number of employees already on board. Additional features include exponential forecasting and variable delays in hiring and firing. A central feature of the model is the existence of organizational slack which is defined as the number of people in excess of what is necessary to satisfy market demands. Various sensitivity analyses are conducted and the Model's implications are discussed.

Publication: C. K. Eoyang, "Systems Analysis and the Dynamics of Manpower," Technical Report NPS55Eg75061, June 1975.

Conference Presentation:

"Systems Analysis and the Dynamics of Manpower." Paper presented to the XXII International Meeting of the Institute of Management Sciences, Kyoto, Japan, July 1975.

PROBABILITY MODELS FOR RELIABILITY ANALYSIS

Investigator: J. D. Esary, Professor of Operations Research and Administrative Sciences

Support: Office of Naval Research

Objective:

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

Summary:

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

Mixtures of Life Distributions: Mixtures of life distributions arise when manufacturing processes produce items with different innate survival potentials, or when the service environments of identical items vary. The properties of mixtures of life distributions are relevant to the use of "burn-in" as a quality control measure. This study has presumed an initial population of devices with constant failure rates, and has focused on the composition of the population of survivors after a period of service or burn-in. The principal results have been a strong technical interpretation of how the "fittest" items survive. These results contain some previously known properties of such mixtures. Future work in this area is concerned with the effect of improving the initial mix on the mix in the population of survivors.

Publications: D. R. Campbell, "Stochastic Ordering in Residual Mixing Distributions," Technical Report NPS64Cm74071, July 1974.

J. D. Esary and A. W. Marshall, "Some Classes of Distributions Closed Under the Formation of Coherent Systems," Reliability and Biometry: edited by F. Proschan and R. J. Serfling and published by The Society for Industrial and Applied Mathematics, Philadelphia, 1974.

J. D. Esary and A. W. Marshall, "Families of Components and Systems, Exposed to a Compound, Poisson Damage Process," Reliability and Biometry: edited by F. Proschan and R. J. Serfling and published by The Society for Industrial and Applied Mathematics, Philadelphia, 1974.

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

Thesis Directed:

H. Ziehms, "Reliability Analysis of Phased Missions," Doctoral Dissertation, December 1974.

NAVAL EFFECTIVENESS AND VULNERABILITY STUDIES

Investigator: R. N. Forrest, Associate Professor of Operations Research and Administrative Sciences

Support: Strategic Systems Project Office

Objective:

To develop and improve specific Navy effectiveness and vulnerability models.

Summary:

This work dealt with the following subjects: Phased Mission Reliability: In a phased mission, the relevant system configuration changes during consecutive time periods (phases). Several important Navy systems are required to perform phased missions for which reliability considerations are significant. Optimal Stopping Times: Certain activities require that the activity be stopped at some time. Work was done which addressed this problem as it relates to submarine trail. Search Detection and Localization Modeling: Work was done on the problem of analytically modeling submarine search, detection, and localization. Consideration was given to non-acoustic as well as acoustic Anti-Submarine Warfare (ASW) detection systems. A three-dimensional search model was developed which has application to Magnetic Anomoly Detection (MAD) and Optical Ranging and Detection System (ORADS) search. Surveillance Modeling: The number of targets under surveillance by a search system generally fluctuates as targets are found and subsequently lost. Work was done which addressed this problem as it relates to submarine surveillance. A particular stochastic process was assumed to describe submarine surveillance and specific results were then derived which relate to the potential effects of submarine surveillance.

Publications: R. N. Forrest, "Submarine Search Models," Technical Report NPS55Fo75041, December 1974.

R. N. Forrest, "Some Notes on Search, Detection and Localization Modeling," Technical Report NPS55Fo75041, April 1975.

Theses Directed:

D. L. Peck, "Verification of the Exponential Approximation of First Passage Times in a Birth/Death Model for Dynamic Surveillance in ASW," Master's Thesis, March 1975.

SENSITIVITY OF GORDON AND NEWELL, AND BUZEN, (GNB) MODELS OF COMPUTER CONFIGURATIONS

Investigator: P. Gaver, Professor of Operations Research and Administrative Sciences

Support: Defense Communications Agency, Federal Computer Performance Evaluation and Simulation Center

Objective:

To assess the effectiveness of simple mathematical models in describing the behavior of programs processed in a multiprogramming environment. The purpose of the model is to predict computer resource utilization and program delays under alternative system configurations, and, in particular, to suggest how increased resources will improve turnaround time.

Summary:

A simple analytical model (due to Gordon and Newell) was adapted to describe several simple computer configurations involving one Central Processor (CPU) and several disk drives. Actual monitor data, obtained through Joint Technical Support Activity (JTSA) was used to fit and to validate the model. The descriptions of resource utilization were generally acceptable and gave excellent predictions of turnaround for job groups. Queuing at the resources (e.g. the CPU) was less well described. Continuing work is devoted to improving the latter feature, and to accounting for the effect of more peripheral types (e.g. tape drives) and of time sharing.

Publications: D. P. Gaver, "The Construction and Fitting of Some Simple Probabilistic Computer Models," Technical Report NPS55Gv75011, January 1975.

MATHEMATICAL STUDIES OF SHIP MANNING

Investigator: P. Gaver, Professor of Operations Research and Administrative Sciences

Support: U. S. Navy Personnel Research and Development Center

Objective:

To predict the readiness of a ship's department (e.g. communication department on a Knox class destroyer) as the latter depends upon the equipment complement and the quantity and quality of maintenance manpower.

Summary:

An inventory has been made of the various types of failure-prone equipment present on a destroyer. Their failure rates and repair times have been estimated, both from Maintenance Material Management (MMM) fleet-reported data, and from data obtained from engineering tests. General versions of "repairman" type probability models have been structured to describe the probability that the equipment in various combinations will be unavailable, given assigned manpower. The models will be useful for predicting availability changes when manpower is changed. The effect of the availability of spares will also be built into the models.

Publications: None

Thesis Directed:

C. Perrin, "The Influence of Manpower Upon a Destroyer's Communications Department System Availability," Master's Thesis, September 1975.

DECISION-MAKING IN THE NAVAL EDUCATION AND TRAINING SYSTEM

Investigator: W. C. Giauque, Assistant Professor of Operations Research and Administrative Sciences

Support: Naval Training Equipment Center

Objective:

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

Summary:

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

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

A MULTIATTRIBUTE UTILITY APPROACH TO MEASURE QUALITY OF HEALTH CARE

Investigator: W. C. Giauque, Assistant Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

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 substantially 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: None

Thesis Directed:

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

COMPUTER ASSISTED DISTRIBUTION AND ASSIGNMENT OF ENLISTED PERSONNEL

Investigators: C. P. Gibfried and K. T. Marshall, Professors of Operations Research & Administrative Sciences

Support: Naval Personnel Research and Development Center

Objective:

To assess the Computer Assisted Distribution and Assignment (CADA) system developed by Naval Personnel Research and Development Center (NPRDC) in terms of its applicability to the Navy's current enlisted personnel assignment system, its data base, and its computer support (both hardware and software).

Summary:

The six year historical development of CADA was reviewed, and the goals and objectives of the project were discussed with personnel from NPRDC and from the Bureau of Personnel. CADA's system analysis and design effect were studied along with the programs which were developed to bring the system to fruition. As a result of the investigation, a series of recommendations were made to NPRDC.

Publications: None

DEVELOPMENT OF DATA BASE ON FORMAL STRUCTURAL VARIABLES OF RESEARCH, DEVELOPMENT, TESTING AND EVALUATION

Investigator: W. J. Haga, Associate Professor of Operations Research and Administrative Sciences

Support: Manpower Research Data Analysis Center

Objective:

To use formal structural variables in the defense organization of research, development, testing and evaluation (RDT&E) functions as surrogate indicators of distinctions between direct output elements and superfluous or redundant overhead elements.

Summary:

A method of gathering hard copies of manpower documents that capture staffing and division of labor for a complete unit or activity in the Navy has been found. Comparable documents for the Army and Air Force have not yet been discovered. Sources of data tape equivalents to hard copy documents have been for the Navy reports. The percentile role differentiation indicator (PRDI) procedure has been developed by Louis R. Moore III for generating probabilistic distributions of organization role differentiation for given sizes under five general assumptions. LT Moore was expected to refine the programming of the PRDI for the processing of raw data from defense RDT&E unit manpower documents. However, a contract for this work has not been approved.

Publications:

L. R. Moore III and W. J. Haga, "Probabilistic Baseline Generator for Role Differentiation in Formal Organizations," Technical Report NPS53M175021, February 1975.

L. R. Moore III and W. J. Haga, "Probabilistic Baseline Generator for Role Differentiation in Formal Organizations." Reviewed in Journal of Mathematical Sociology.

EVOLUTION OF SYSTEM SIZE AND COMPLEXITY

Investigator: W. J. Haga, Associate Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To predict bureaucratic complexity as a function of size according to a harmonic series distribution.

Summary:

Data were collected from a California public school district, a weapons system acquisition command, and nine naval air patrol squadrons to test a harmonic series distribution model as a predictor of the degree of complexity of an organization as it grows and then declines across time. Because of special inherent properties of the harmonic series model, it did not provide sufficient utility as a predictor of complexity to become a basis for formal theory construction.

Publications: None

Theses Directed:

E. Moore, Jr., "Structural Evolution: the Effect of Organization Size on Complexity Across Time," Master's Thesis, June 1974.

R. H. Spencer, Jr., "Time Series Test of a Harmonic Series Model of Organization Differentiation," Master's Thesis, March 1975.

S. R. Alexander, "The Structural Evolution of Naval Air Squadrons," Master's Thesis, March 1975.

M. Tanner, "Structural Evolution of a Procurement Command," Master's Thesis, March 1975.

R. L. Chappell, "Time Series Application of a Percentile Role Differentiation Indicator," Master's Thesis, March 1975.

GLOBAL OPTIMIZATION OF NONLINEAR PROGRAMMING PROBLEMS

Investigator: J. K. Hartman, Associate Professor of Operations Research and Administrative Sciences

Support: *Foundation Research Program*

Objective:

To investigate a class of linear approximating problems and to develop solution algorithms which take advantage of the relationships between the original and the approximating problems.

Summary:

Several well known nonlinear programming algorithms operate by solving a sequence of linear approximating problems. In particular, the "Grid Linearization" algorithm is such a method that has been developed for solving convex nonlinear programs.

This research has concentrated on the type of linear approximating problem used for the convex Grid Linearization method, and has examined its properties when applied to nonconvex problems instead. The result of the effort is a new algorithm for nonconvex optimization which may have advantages over existing methods.

The algorithm is a branch and bound method which solves a linear approximating problem at each stage. Bounds and refinements to the linear approximation are simultaneously generated by dual subproblem optimizations which involve minimizing single variable nonconvex Lagrangian functions over closed intervals. Some progress has been made on assessing the convergence properties and computational efficiency of the procedure, and further work on these questions is planned.

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

UTILIZATION AND TECHNOLOGY TRANSFER OF RESEARCH, DEVELOPMENT, TESTING AND EVALUATION (RDT&E) INVESTMENT

Investigators: J. A. Jolly and J. W. Creighton, Professors of Operations Research and Administrative Sciences

Support: Naval Facilities Engineering Command

Objective:

To determine levels of technology transfer and utilization (TTU) that must be achieved by NAVFAC's programs in order to achieve R&D performance levels in line with other roughly comparable organizations whose R&D is at a high level of performance.

Summary:

This is a continuing project now in its fourth year. A one-day briefing on Technology Transfer Projects at the Naval Postgraduate School (NPS) was given at the Naval Material Command Headquarters on June 9, 1975. Over 120 high-level Naval personnel attended. The titles and a brief summary of several of the papers presented at this briefing clearly describe the work on technology transfer done at the NPS over the past fiscal year.

"Measuring the Effectiveness of a Rapid Response Technology Transfer Program": The Navy's Civil Engineering Laboratory at Port Hueneme has established a technology transfer office to enhance the use of their developed technology by the Navy's civil engineering offices. Specific benefits were measured to determine the value of the operation of this office. The benefits as compared to the costs demonstrated a return on investment of 172%.

"A Case Study of the Power Line Disturbance Monitor": The Navy's Civil Engineering Laboratory developed a monitor to measure the magnitude, duration, and direction of transits in a utility power line that could affect sensitive electronic equipment. After an appropriate contract to build five units for the Navy was completed, the same company began to manufacture the units for commercial sales. The net result was a lower cost to the Navy for all future units.

"The Linker Role in the Technology Transfer Process": The secondary use of technology that was originally developed for a specific mission use is often dependent upon an individual who is an advocate of the idea. This type of individual is sometimes called a linker and serves an important

role in any organization. The study indicated that the distribution of the linker type of person is independent of the fact that an organization may be all military or all civilian.

"A Study of the Technology Transfer Capability of Eleven Organizations": During the earlier research on technology transfer we developed a model of the factors that are important in terms of causing technology transfer to take place. The model has nine factors. These factors range from INFORMATION DOCUMENTATION to the REWARD SYSTEM for using a new idea. An instrument was developed and eleven organizations were measured in terms of their environment and ability to enhance the transfer of technical information. The eleven organizations, eight of which were Navy operated, demonstrated a wide difference in their technical information transfer environment and ability. This was a preliminary study and the findings must be refined before they will have practical use.

Publications:

J. A. Jolly and J. W. Creighton, "Technology Transfer and Utilization Methodology: Further Analysis of the Linker Concept," Technical Report NPS55Jo74061, 1974.

J. A. Jolly and J. W. Creighton, "Technology Transfer and Utilization: A Longitudinal Study Using Benefit Analysis to Measure the Results from an R&D Laboratory," Technical Report NPS55Jo75033, 1975.

Theses Directed:

R. D. Parrish and D. G. Knappe, "Specifications as a Barrier to the Transfer and Utilization of New Technology into Navy Construction: A Critical Review, Thesis Report NPS55Jo75032, 1975.

E. H. Tempest and L. A. VanRoy, Jr., "The Power Line Disturbance Monitor: A Cast Study of the Navy's Continuing Efforts in the Field of Technology Transfer, Thesis Report NPS55Jo75031, 1975.

C. R. Fontz and M. P. Shoemaker, "Technology Transfer as Applied to Chief Radiomen in the U. S. Navy and Compared to Naval Officers of the Civil Engineering Corps, Thesis Report NPS55Jo75034, 1975.

ESCALATION FOR LONG-TERM NAVY CONTRACTS DURING HIGH INFLATION

Investigator: C. R. Jones and M. G. Sovereign, Associate Professors, Operations Research and Administrative Sciences

Support: Chief of Naval Operations

Objective:

To develop acceptable methods for reducing price level uncertainty under long-term contracts for the contractor while lowering the overall contract cost to the Navy.

Summary:

To meet this objective two major efforts were undertaken. One of these efforts concerned the refinement and application of the model of a representative defense contractor to the world of price uncertainty and escalation provisions. The other effort involved the study of the issues and choices involved in the use of escalation provisions in Navy contracts.

Using model specification of a representative defense contractor, optimal decision rules are developed when there is price uncertainty and with and without escalations provisions. Price uncertainty is assumed to be due to a general economic inflation of all prices, with the future rate of inflation being uncertain. Two types of escalation provisions are modeled. Type one involves the use of a general price index (e.g., the implicit gross national product (GNP) deflator) with all cost-based government payments except fee escalated. Type two involves the use of an index composed of prices of direct use in the contractor's operations with all cost-based government payments except fee escalated. The analysis of type two assumes that the contractor does not use the index to further corporate goals by failing to obtain inputs at least cost. The types of escalation provisions are compared with each other as well as with the case of no escalation provision. This comparison is made by deriving optimal decision rules for each type of escalation provision and no escalation provision and then noting the differences and similarities of the optimal decision rules. Though the escalation provisions are frequently viewed as a method of equitably treating a contractor for events beyond the contractor's control, it is also useful, within the context of the Department of Defense (DoD), to view such provisions as a control device to induce contractor behavior of a useful nature to DoD.

The study of the issues and choices involved in the use of escalation provision for Navy contracts begins with the identification and exposition of the four major issues involved. These issues are: (1) Why is the change in input prices a particular problem for Navy contracts?, (2) Why is escalation a good procedure for dealing with the problem?, (3) What are the possible side effects of using escalation procedures?, and (4) How is the trade-off between administrative cost, accuracy and contractor incentives (moral hazard) reached? For each separate issue as well as for the set of interrelated issues, a discussion indicating its general applicability as well as its specific applicability to individual cases is given. After the discussion of issues, the area of implementation of escalation is considered as a series of four questions: (1) What prices should be covered?, (2) How should the price changes be measured?, (3) When should the measurements be made?, and (4) How should the price changes be compensated? These questions are given general answers in each case and the set of questions as a whole is also considered.

Publications: M. G. Sovereign and C. R. Jones, "Escalation Provisions for Navy Contracts: Issues and Choices," Technical Report (NPS-55Zo75051), May, 1975.

Thesis Directed:

D. H. Vigrass, "Overhead of Newport News Shipbuilding and Dry Dock Company," Master's Thesis, March 1975.

MODELING A DEFENSE CONTRACTOR

Investigator: C. R. Jones, Associate Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To develop a model of a representative defense contractor including Research Development Test & Evaluation (RDT&E) activities, production activities, and financial activities in a world of uncertainty.

Summary:

A model is specified for a representative defense contractor. The contractor is assumed to maximize the expected utility of managerial emoluments, performance of the contractor's product and corporate annual net income over a finite planning horizon. This maximization is constrained by the technology of research and development, test and evaluation, manufacturing and a centralized warehouse-inventory operation. There are commercial sales as well as a number of on-going and potential Department of Defense (DOD) projects. An extensive accounting model of the contractor is included. Corporate financial management involves the issuing and retiring of short and long-term debt and equity in addition to the choice with respect to dividends and retained earnings.

The inputs of the contractor include plant and equipment (both contractor and government supplied), engineering labor (both contractor and government supplied) in Test and Evaluation (T&E), engineering support labor (both contractor and government supplied in T&E), administrative labor, manufacturing labor, weapon system operators (both contractor and government supplied in T&E), material, purchased parts, subcontracted items, and government furnished items. The outputs are a homogeneous product for commercial sale in a competitive market and weapon systems for sale to the government in rival markets for "new" proposals and a bilateral monopoly market in the case of sole sourcing.

Risk is introduced by considering each possible alternate event due to such factors as rival's actions, technological risk, capital market conditions, and variations in government and commercial sales to be grouped in states-of-nature. Thus, the contractor is assumed to plan for a variety of future state-of-nature (contingencies) and chooses a complete plan (inputs, outputs, financing, proposal bids, etc.) for each contingency.

Future research on this project will include characterizing the contractor's response to changes in various aspects of the world beyond the direct control of the contractor as well as refining the basic model. Also work will begin on modeling the government side of the DOD-Industry relationship. It is expected that theses work by officers will be included in this effort.

Publications: C. R. Jones, "A Representative Defense Contractor: Model Specification I," Technical Report, NPS55Js75061, June 1975.

Theses Directed:

D. Clark, "An Integrated Model of a Representative Defense Contractor," Master's Thesis, March 1975.

L. Garcia and J. Ward, "The United States Shipbuilding Industry: Structure, Conduct and Performance," Master's Thesis, March 1975.

WARRANTIES: TECHNIQUES FOR ACHIEVING IMPROVED RELIABILITY/MAINTAINABILITY

Investigator: R. R. Judson, Adjunct Professor of Operations Research and Administrative Sciences

Support: Office of Naval Research

Objective:

To develop new techniques which will allow the Navy to attain reliability and at the same time to reduce the maintenance costs of Navy equipment.

Summary:

To meet the objective, the first five of approximately 16 faculty research and student thesis tasks were accomplished. These include: (a) conceptual model for the entire research program, (b) an evaluation of the legal lessons learned in warranties usage, (c) current Department of Defense (DOD) warranties policy review with anticipated supplier responses for various warranty situations, (d) model for decision-making for logistic strategy of deciding user or supplier support, (e) criteria for use of reliability improvement warranties.

Publications: R. R. Judson, "Warranties Research Plan," DOD Research Conference, Ft. Lee, VA, September 1974. Published in Conference Proceedings.

Theses Directed:

D. A. Yatras, "A Generalized Approach for Evaluation Logistics Strategies During Advance Procurement Planning," Master's Thesis, March 1975.

D. J. Allen, "Application of Reliability Improvement Warranty (RIW) to DOD Procurements," Master's Thesis, March 1975.

R. L. Noble, "Armed Services Board of Contract-Appeals and Comptroller General," Master's Thesis, March 1975.

ADVANCED NAVAL GUN SYSTEM (ANGS) STUDIES

Investigators: M. B. Kline, W. C. Giauque and J. P. Hynes, Professors of Operations Research and Administrative Sciences

Support: Naval Sea Systems Command

Objective:

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

Summary:

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

Accomplishments to date have been the following: (1) a generalized conceptual phase methodology has been developed leading from intelligence, operational need, and technological, inputs to the defining of a quantified operational requirement, (2) ANGS decision model derived from the basic methodological model has been structured, (13) an inventory has been made of existing damage models and their applicability to strike warfare. As a result of this examination it was discovered that existing damage models start with a description of the target and our weapon capability and determine the damage that occurs when these are opposed in combat. We are looking for the inverse of this, i.e., given the target parameters and the damage (mission kill) we would like to determine what weaponry it will take to effect this damage. In other words, existing models flow from attack to results, we want to go from desired results back to weapon requirements. We have termed this an "inverse damage model," (4) development of a model relating mission effectiveness to target damage to kill mechanisms and finally to weapon payload requirements has been started along with an example of its application to a specific target.

Publications: None

TEST AND EVALUATION

Investigator: H. J. Larson, Professor of Operations Research and Administrative Sciences

Support: Operational Test and Evaluation Force, Pacific

Objective:

To assist Operational Test and Evaluation Force, Pacific (OPTEVFORPAC) with their test and evaluation efforts by examining their problems in direct on-site contact with their own personnel.

Summary:

The principal research activity was an investigation of discrete reliability models, which could be applied to systems for which the number of cycles to failure are of prime importance (such as the major caliber lightweight gun). The researcher prepared a paper describing some properties of specific discrete models and suggested some continuous approximations which could prove useful.

He also proposed a new measure of availability for a ship's radar, suggested a way in which missing data could be accounted for in a project measuring the jitter of a radar, and consulted with the Navy analysts on a number of different projects.

Finally, he also taught a seminar on Design of Experiments for analysts at Deputy Commander (OPTEVFORPAC). About seven officers attended these 5 or 6 meetings. He prepared rather extensive course notes for those in attendance.

Publications: None

STOCHASTIC POINT PROCESSES

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

Support: Office of Naval Research

Objective:

To investigate certain aspects of stochastic models for point processes. In addition, certain statistical procedures for non-homogeneous point processes and for superpositions of renewal processes will be studied.

Summary:

It is now possible to generate time series with exponential marginal distributions and the structure of any ARMA model. These schemes have been written up in a report for the ORSA Conference in Las Vegas (November 1975) which emphasizes the simplicity with which they, the processes, can be generated on a computer and used in simulations to give realistic models. They are already being used in this way in models for management information systems.

The probabilistic properties of these models are being worked out. The methodology should be extendable to more complicated structures and to the processes with Gamma, Weibull and mixed exponential distributions.

The estimation and testing problems for the EAR1 and EMA1 processes have been solved and details are being worked out by a Ph.D. student. The key lies in the fact that the processes are not time-reversible and therefore higher order joint moments and spectra give important information about the structure and parameters of the process.

In dealing with the data arising within management information systems, previous results have been extended on estimating and testing rates in non-homogeneous Poisson processes. It is now possible to fit exponential polynomial rate functions with orders as high as ten.

In addition to developing linear models for time series and point processes, the problem of efficient generation of non-homogeneous Poisson processes must be considered. A very efficient scheme has been developed for the log-linear rate function (exponential polynomial of order one) and these results are being extended to higher order schemes and to cyclic models. (A combination of growth and cyclic effects is very common in practice.)

Publications: P. A. W. Lewis and A. J. Laurance, "Properties of the Bivariate Delayed Poisson Process," Journal of Applied Probability, 12 (June 1975).

P. A. W. Lewis and G. S. Shedler, "Simulation of Non-Homogeneous Poisson Processes with Log-Linear Rate Function," Technical Report, NPS-55Lw75061, June 1975. Accepted for Biometrika.

P. A. W. Lewis and A. J. Laurnce, "A Moving Average Exponential Point Process (EMA1)," Technical Report, NPS55Lw75061, June 1975. Submitted to the Journal of Applied Probability,

P. A. W. Lewis and T. A. Jacobs, "A Mixed Auto-regressive-Moving Average Exponential Sequence and Point Process (EARMA 1,1)." Accepted by the Journal of Applied Probability.

COMPUTER ASSISTED DISTRIBUTION AND ASSIGNMENT OF ENLISTED PERSONNEL

Investigator: K. T. Marshall, Professor of Operations Research and Administrative Sciences and C. P. Gibfried

Support: Naval Personnel Research and Development Center

Objective:

To assess the Computer Assisted Distribution and Assignment (CADA) system developed by Naval Personnel Research and Development (NPRDC) in terms of its applicability to the Navy's current enlisted personnel assignment system, its data base, and its computer support (both hardware and software).

Summary:

The six-year historical development of CADA was reviewed, and the goals and objectives of the project were discussed with personnel from NPRDC and from the Bureau of Personnel. CADA's system analysis and design effect were studied along with the programs which were developed to bring the system to fruition. As a result of the investigation, a series of recommendations were made to NPRDC.

Publications: None

MANPOWER PLANNING MODELS

Investigator: K. T. Marshall, Professor of Operations Research and Administrative Sciences

Support: Headquarters, U. S. Marine Corps

Objective:

To develop the theory of modeling manpower systems, with particular reference to hierarchical military structures, and to provide a series of on-line interactive computer models to answer specific requests of the Marine Corps.

Summary:

Emphasis during the past twelve months has been on modeling specific enlisted force characteristics, including re-enlistments, lateral movements between skill categories and first term/career force mix. The simple Markov Chain models have been modified, resulting in a theory for chains with a two-characteristic state space with special structure. Matrix decomposition has led to efficient computational methods being developed. A research monograph on manpower modeling is currently being written.

Publications:

K. T. Marshall and W. J. Hayne, "Two-Characteristic Markov-Type Manpower Flow Models," Technical Report NPS55Mt74071, July 1974. To appear in Naval Research Logistics Quarterly.

K. T. Marshall and K. C. Grinold, "Manpower Planning Models - I Basic Concepts," Technical Report NPS55Mt74122, December 1974.

K. T. Marshall and R. C. Grinold, "Manpower Planning Models - II Cross-Sectional Models," Technical Report NPS55Mt75021, March 1975.

RELATIONSHIP OF BIOLOGICAL PERIODICITY TO HUMAN PERFORMANCE

Investigator: D. E. Neil, Assistant Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To examine the relationship between the theory of "Biorhythms" and various forms of human behavior.

Summary:

The project was designed to take the concept of "Biorhythms" into the laboratory. The actual procedure involved the daily testing of subjects on an information processing task for a period of 77 days. Data were collected at the same time each day to control for circadian variation. Environmental influences were controlled by conducting the experiment in a temperature-acoustic controlled chamber. Analysis of the data involved the determination of the distribution form and the degree of variation in information processing rate, reaction time, and movement time. Periodicity was examined using Fast Fourier Transforms. Results indicated that human performance does in fact fluctuate over time, and further, of the 12 harmonic identified through Fort Fourier Transform, nine were within one day of the theoretical "Biorhythm."

Publications: D. E. Neil and F. L. Sink, "A Laboratory Investigation of the Theory of Biorhythm." Accepted by the Journal of Aviation, Space, and Environmental Medicine.

Conference Presentation:

D. E. Neil, "Biorhythm." Paper presented at Office of Naval Research Meeting on Brain Mechanism and Behavior, Monterey, California, July 1975.

AN INVESTIGATION OF THE CAUSES OF INCREASED MAJOR AIRCRAFT ACCIDENTS IN SPECIFIC MONTHS

Investigator: G. K. Poock, Associate Professor of Operations Research and Administrative Sciences

Support: Naval Safety Center

Objective:

To identify reasons for high major aircraft accident rates in some months of the year versus other months. The long term goal is to identify factors causing accidents and find solutions to lower said accident rates.

Summary:

In fiscal year (FY) 1975, the main effort was concentrated on obtaining data from the Safety Center, writing computer programs, etc. Initial runs have been made on the data using regressive techniques, parametric statistics and non-parametric statistics. An overall view of the accident trends in the Navy has been obtained and correlations of accident rates with certain parameters range as high as .73. With this knowledge as background, the investigation will devote FY 1976 to specific analysis of various commands and aircraft types.

Publications: None

Thesis Directed:

J. S. Maxwell and L. V. Stucki, "Analysis of the Variable Behavior Manifested in all Navy/Marine Major Aircraft Accident Rates," Master's Thesis, September 1975.

TEST AND EVALUATION

Investigator: F. R. Richards, Associate Professor of Operations Research and Administrative Sciences

Support: Operational Test and Evaluation Force Pacific

Objectives:

(1) To assist personnel at DEPCOMOPTEVFORPAC in the statistical analysis of various tests and evaluations of Navy weapons systems. (2) To develop procedures and mathematical models for testing and measuring software reliability. (3) To examine methods for measuring the effectiveness of complex multifunctional weapons systems.

Summary:

Seminars were presented to analysts and project officers on the statistical techniques of linear regression, hypothesis testing, sequential testing, reliability, and analysis of variance. The investigator served as consultant in the design and analysis for a variety of projects.

Procedures for testing the quality of computer software and collecting data were determined. Various mathematical models were developed for measuring the reliability growth that takes place as software errors are discovered and eliminated.

Quantitative techniques for determining the military utility of complex multi-functional or multi-attribute weapon systems were surveyed, and proposals for developing measures of effectiveness were reviewed. An attempt to develop a general methodology that analysts could use to determine a single overall measure of the military utility of a total system based on the available measures of various attributes of the system was unsuccessful because of the many differences in the weapon systems and the subjectivity required for such assessments.

Publications: F. R. Richards, "Computer Software: Testing Reliability Models, and Quality Assurance," Technical Report NPS55Rh74071A, July 1974.

DEVELOPMENT OF A COMPUTER CENTER PERFORMANCE AND RESOURCE ALLOCATION MODEL

Investigator: N. F. Schneidewind, Professor of Operations Research and Administrative Sciences

Support: Naval Weapons Center

Objective:

To develop models for computer center performance prediction and resource utilization optimization.

Summary:

An analysis was made of the correlation between performance and resource usage variables in multiprogrammed processing. This analysis was performed in order to (1) determine the mix and characteristics of jobs which lead to high performance, (2) provide regression equation predictors of performance for specified resource usage and (3) provide performance and resource coefficients for use in a linear programming resource allocation model. The linear programming model is used to select an optimum job mix subject to production, resource usage, and budgetary constraints.

Future plans call for refining the regression equations with finer resolution data and validation of the model by comparing predicted with actual performance.

Publications:

N. F. Schneidewind, "Analysis of Computer Performance in Multiprogrammed Environment," Technical Report NPS55Ss7505, May 1975.

N. F. Schneidewind, "Analysis of Computer Performance in Multiprogrammed Processing," Proceedings of the Ninth, Tenth and Eleventh Meetings Computer Performance Evaluation Users Group, September 1975.

SYSTEM TEST METHODOLOGY

Investigators: N. F. Schneidewind, Professor of Operations Research and Administrative Sciences
G. H. Bradley and G. T. Howard, Associate Professors of Operations Research and Administrative Sciences

Support: Naval Air Development Center

Objective:

To develop methodology and tools for conducting system tests of avionics or other complex hardware/software systems.

Summary:

Two areas which received major emphasis were prototype testing and maintenance testing. A methodology for conducting prototype tests was developed. In addition, a simulation model was prepared for aiding the designer and tester in identifying and diagnosing faults which may occur during prototype testing.

A maintenance testing methodology (fault tree analysis), which involves the use of tests to partition faults into subsets, was developed for identifying faults. In addition to the above areas, research was undertaken to develop models for investigating the relationship between error detection capability and program structure in computer software, using simulation and analytic approaches. The models would be employed during software design for indentifying program structures with poor error characteristics and during test planning for allocating test resources in accordance with error characteristics.

In addition to the progress and final reports, computer program source decks and operating instructions for the models were provided to the sponsor.

Future plans call for (1) testing of the models against actual computer program structure and error data, (2) continued development of software error forecasting models, and (3) extension of the fault tree analysis methodology to computer software.

Publications:

G. H. Bradley, T. F. Green, G. T. Howard and N. F. Schneidewind, "Structure and Error Detection in Computer Software," Proceedings of the American Institute of Industrial Engineers (AIIE) National Conference, May 1975.

N. F. Schneidewind and T. F. Green, "Simulation of Error Detection in Computer Programs,"

Proceedings of the Simulation of Computer Systems, National Bureau of Standards and Association for Computing Machinery, August 1975.

N. F. Schneidewind, "Analysis of Error Processes in Computer Software," Proceedings of the International Conference on Reliable Software, sponsored by ACM/IEEE/NBS/NSF, April 1975.

G.H. Bradley, G. T. Howard, N. F. Schneidewind, G.W. Montgomery and T. F. Green, "System Test Methodology, Vols. I and II, Technical Report NPS-55Ss75072A,B, July 1975.

FINITE-MEMORY K-HYPOTHESES PROBLEM

Investigator: B. O. Shubert, Associate Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To investigate the statistical problem and the algorithm for testing K hypotheses under finite memory constraint. In particular, it is to explore to what extent some results obtained recently for the two-hypotheses problem can be generalized to the case of more than two hypotheses.

Summary:

Several new results were obtained which can be summarized as follows: (a) A general lower bound on the error probability was derived. The bound is expressed in terms of the largest eigenvalue of a matrix associated with the algorithm; (b) This result was used to obtain a bound on the error probability for the 3-hypotheses case; (c) A counter example was found to a conjecture concerning the optimal structure of the algorithm; (d) As a by-product two results were obtained concerning the stationary distribution of certain finite Markov chains.

Publications:

B. O. Shubert, "A Flow-Graph Formula for the Stationary Distribution of a Markov Chain." To appear in IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC-5, 1975.

B. O. Shubert, "Some Remarks on the Finite-Memory K-Hypotheses Problems," Technical Report, NPS55Sy74101, 1974.

CONCEPT ANALYSIS

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

Support: Office of Naval Research

Objective: To study and analyze Military Health-Care Problems.

Summary:

A thorough search of the literature on both physician and professional personnel supply decisions was made. This was digested, and appropriate portions incorporated into a preliminary sketch of a testable economic model. This outline then was modified and restructured, based on both the informational realities of data collection and the investigator's experience in previous research in the health care delivery area. Although a simultaneous equation model was specified and data collection begun, further modifications to the Model Structure were necessary to ensure valid predictions of physician supply in the years ahead. This phase continues in fiscal year (FY) 1976. In addition, the data collection proved to be particularly difficult because of the general non-dissemination of the data appropriate for the question. With a few exceptions, the data are now available to go to the regression and hypothesis testing phase of the project.

The "CHAMPUS project" has not been as actively pursued both because of a major hitch in the originally proposed data source availability and also the time demands of the "physician supply" project. The availability of data for area-specific (i.e., by zip code) CHAMPUS costs has been hindered thus far by the simultaneous (and superceding) demands upon OCHAMPUS/Denver by the Office of Management and Budget (OMB) study. Thus, we have been limited thus far to an intensive background study of the general program and its costs (from published "Phaseback data") in order to assess the feasibility and desirability of switching the retired and dependent care to CHAMPUS.

Publications: L. Maassen and D. Whipple, "A History of Military Dependent Medical Care Programs," Technical Report NPS-55Wp75081, August 1975.

L. Maassen and D. Whipple, "CHAMPUS Organizational Structure and Operations Description," Technical Report NPS-55Wp75091, August 1975.

L. Maassen and D. Whipple, "The CHAMPUS Budgeting and Programming Process," Technical Report NPS55Wp75092, August 1975.

Conference Presentation:

D. Whipple and M. Block, "On An Aspect of the Supply of Physicians to the Civilian and Military Sectors," NPS Working Paper, presented at the Society of Government Economists Meeting Washington, D. C., March 1975.

Theses Directed:

L. Maassen, "The Civilian Health and Medical Programs for Uniformed Services (CHAMPUS)," Master's Thesis, June 1975.

P. Johnson, "Physician Supply: A Review of the Literature and An Analysis of Physician Supply Functions," Master's Thesis, September 1974.

W. Mackey and R. Without, "Physician Supply: An Econometric Approach," Master's Thesis, March 1975.

METHODOLOGY AND PRACTICE OF CAMPAIGN ANALYSIS

Investigators: M. G. Sovereign, S. H. Parry, C. A. Peterson, J. B. Tysver, A. R. Washburn and R. N. Forrest, Professors of Operations Research and Administrative Sciences and LCDR R. Bedow

Support: Chief of Naval Operations

Objective:

To investigate existing campaign analyses and the state of the art of methodology supporting these analyses for the purpose of preparing a course in the topic for Operations Analysis (OA) students.

Summary:

A series of weekly seminars was held by the faculty to explore the modeling of warfare as represented in the Mission Effectiveness Analysis of General Purpose Forces (S) recently prepared by OP-96 for the Secretary of Defense. A course was then given by the investigators using the references cited above and two major studies: The Navy Fighter Study and Seamix I. It was found that a general methodology exists for campaign analysis based on unit engagement analysis and battle analysis. However, the amount of detail which can be addressed at the campaign analysis level requires rather heroic assumptions. Treatment of tactics and counter-measures is particularly difficult. Only relative results of campaign analysis appear credible, but these may be useful.

Publications: None

OPTIMAL FIRE-SUPPORT STRATEGIES

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

Support: Office of Naval Research

Objective:

To develop a better understanding of how to determine quantitatively "good" time-sequential allocations of military resources in combat, and to complete the reporting of previous research results on the quantitative analysis of optimal air-war strategies.

Summary:

An invited tutorial was delivered at the 46th National Meeting of the Operations Research Society of America (ORSA) on 17 October 1974. The mathematical theory of differential games was used to study the structure of optimal allocation strategies for some time-sequential combat games with combat modeled by Lanchester-type equations of warfare. Results of previous research were reported: optimal air-war strategies were studied within the context of land-war objectives and compared to those for a model which does not explicitly consider the ground war; several differential-game models were used to study optimal fire-support strategies in an attack scenario. For an existing differential-game fire-support model it was determined for what class of criterion functionals (i.e., objectives) the optimal fire-support strategies are independent of the force levels. In a similar differential game the dependence of optimal fire-support strategies on the functional form of the combat attrition model was examined by considering slightly different combat dynamics. Previous research had also developed a mathematical theory for the solution to deterministic Lanchester-type "square-law" attrition equations for combat between two homogeneous forces with temporal variations in fire effectivenesses. These results were issued in report form. New research was initiated on optimal fire-support strategies in several situations of tactical interest.

Ten one-sided time-sequential combat optimization problems were studied via combining Lanchester-type equations of warfare with optimal control theory. Various new results (for example, the optimal time-sequential fire-support policy for supporting an attack (approach to contact) is different in structure from that for the defense of such an attack; also, if suppression is a linear function of the kill rate of the supporting weapon system, then it has no effect on the optimal fire-support policy when enemy survivors are valued in

direct proportion to their rate of destruction of friendly value) were obtained. The dependence of the structure of optimal time-sequential fire-support policies on the quantification of military objectives was examined. The splitting of supporting fires between enemy units in an optimal policy was shown to depend on whether the objective is to attain an "overall" military advantage or a "local" advantage. These new results will be reported during the next fiscal year.

Publications: J. G. Taylor, "Appendices C and D of Application of Differential Games to Problems of Military Conflict: Tactical Allocation Problems-Part III," Technical Report NPS55Tw74112, November 1974.

J. G. Taylor and G. G. Brown, "A Mathematical Theory for Variable-Coefficient Lanchester-Type Equations of 'Modern Warfare,'" Technical Report NPS55Tw74111, November 1974.

Conference Presentation:

J. G. Taylor, "Lanchester-Type Models of Warfare." Invited tutorial, presented before the 46th National Meeting of the Operations Research Society of America (ORSA), October 1974.

OPTIMIZATION OF COMBAT DYNAMICS WITH EMPHASIS ON FIRE-SUPPORT STRATEGIES

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

Support: Foundation Research Program

Objective:

To develop quantitative justification of the principles of war (including the quantitative determination of optimal time-sequential allocations of military resources in combat). Such principles have traditionally been the basis for the development of military tactics. Attaining such a general objective is an interdisciplinary problem. It involves both the modeling of combat processes and tactical decision processes and the optimizing of these tactical decision processes which affect the combat dynamics. The latter generates interest in dynamic optimization problems. Thus, ancillary objectives are as follows: (1) extending the state-of-the-art of both the theory and application to military problems of generalized control theory (i.e. optimal control/differential game theory), and (2) developing a better understanding of the dynamics of Lanchester-type combat (particularly combat between two homogeneous forces).

Summary:

Concerning optimization theory, first order necessary conditions of optimality were developed and applied to a two-person zero-sum deterministic differential game with bounded state variables. Such differential games arise in the study of optimizing tactical decisions. The importance of multiplier conditions associated with the state constraints in determining optimal strategies for Lanchester-type differential games (i.e. two-sided, time-sequential allocation problems in which the system dynamics are given by Lanchester-type equations of warfare) was shown. Previous analyses of such problems had overlooked these important conditions. Earlier work by the investigator had shown that the functional form of attrition between two forces is a significant factor affecting optimal combat strategies. Consequently, the behavior of solutions to Lanchester-type equations of warfare for combat between two homogeneous forces were further studied. A "local" condition of winning (in the sense that the force ratio is changing to the advantage of one of the combatants) was shown to apply to all deterministic Lanchester-type models with two force-level variables. General outcome-prediction relations were developed from this "local" condition and applied to a nonlinear combat model including fire support. It was shown

that one can determine whether or not it is beneficial for the victor to concentrate forces (i.e. initially commit as many as possible to battle) in Lanchester-type combat between two homogeneous forces by considering the instantaneous force-change ratio. The optimal force-concentration decision was shown to be sensitive to the decision criterion. These results provide a better quantitative understanding of the principles of war. This work suggests that in our nuclear age with supporting weapons of great effectivenesses, concentration of forces may no longer be a "military invariant." A mathematical theory was developed for predicting force annihilation from initial conditions without explicitly computing battle trajectories from deterministic Lanchester-type "square-law" attrition equations for combat between two homogeneous forces under changing conditions. Optimal time-sequential fire support strategies were studied through a two-person zero-sum Lanchester-type deterministic differential game. New results on the structure of optimal fire-support strategies were obtained for several sets of circumstances.

Publications:

J. G. Taylor, "Necessary Conditions of Optimality for a Differential Game with Bounded State Variables," IEEE Transactions on Automatic Control (to appear, Vol. AC-20, No. 6, 1975).

J. G. Taylor, "A Tutorial on Lanchester-Type Models of Warfare." Accepted for Proceedings of 35th Military Operations Research Symposium, to appear, 1975.

J. G. Taylor, "A Note on the Relationship Between the Force Ratio and the Instantaneous Casuality-Exchange Ratio for Some Lanchester-Type Models of Warfare." Accepted by Naval Research Logistics Quarterly.

Theses Directed:

L. Pigue, "A Proposed Target Acquisition and Information Model," Master's Thesis, 1974.

W. Hanna, "Further Comparison of Stochastic and Deterministic Models for the Optimal Control of a Lanchester-Type Attrition Process," Master's Thesis, 1974.

F. Hartman, "An Investigation of Field Artillery Techniques and Fire Support Decisions," Master's Thesis, 1974.

R. Hill, "A Further Examination of Optimal Fire Support Strategies," Master's Thesis, 1974.

R. Adkins, "Analysis of Unit Breakpoints in Land Combat," Master's Thesis, 1975.

F. G. Zophy, "Methodology for the Evaluation of Air Defense System Effectiveness," Master's Thesis, 1975.

M. Oh, "Optimal Time-Sequential Distribution of Supporting Fire Against Two Enemy Ground Units," Master's Thesis, 1974. (J. Taylor and F. Faulkner Joint Thesis Advisors).

ELECTRICAL ENERGY ALLOCATION AT NAVAL SHORE FACILITIES

Investigator: K. Terasawa, Assistant Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To investigate the extent to which select public utility companies might reduce, or allocate electric power to naval shore facilities, and to examine allocation plans within certain naval shore facilities and to propose a general model for the development of allocation plans for navy activities.

Summary:

Dependency of naval shore facilities on public utilities for electricity will continue. Such continued dependency is sound, at least insofar as the bases and utility companies that were surveyed on the West Coast are concerned. The one possible area of difficulty is that a base may be affected if a rolling blackout is implemented.

With regard to internal management of electricity aboard a base, the following conclusions were reached: (1) Metering is required for proper control. As a minimum, it should be possible to determine the amount of electricity used by each tenant command aboard the base. (2) Then it should be possible to develop a "KWH-Budget" based on past electrical utilization, "targets," and constraints such as reduced levels of consumption that may be requested by the local utility company caused by fuel shortages. (3) An analytic approach can be used when less than optimal amounts of electricity are anticipated to be available. Under such conditions, the effectiveness of the base can be expected to be the trade-off for the reduction in electricity.

Throughout the research close cooperation with the Civil Engineering Laboratory at Port Hueneme was maintained.

Publications: None

SOME OPERATIONS ENGINEERING CONSIDERATIONS FOR NAVY HARBOR OIL SPILL REMOVAL PROGRAM

Investigator: M. U. Thomas, Associate Professor of Operations Research and Administrative Sciences

Support: Naval Facilities Engineering Command

Objective:

To review operations engineering considerations for the Harbor Oil Spill Removal/Recovery System Development Program. This is a continuing program. Specifically, for fiscal year (FY) 1975 the objectives were: (1) to develop a program model for oil spill abatement, (2) to review output needs from the Navy Environmental Pollution Data Base, (3) to examine human engineering and factors pertinent to harbor oil spill removal/recovery systems.

Summary:

An orientation and fact-finding phase was completed to gain an understanding of the current state of the Research and Development (R&R) program. This resulted in a descriptive modeling endeavor which ultimately led to the identification of some program gaps. Among these were Reliability and Maintainability (R&M) considerations in the Advanced Development Objective (ADO) 41-21X, human activities and factors affecting human performance in the systems, and revised input requirements for the Navy Environmental Pollution Data Base to provide feedback information on clean-up activities.

Publications: G. K. Poock, "Human Factors and Safety Problems on Navy Oil Skimmers," Technical Report NPS-55Pk75011, January 1975.

Thesis Directed:

J. Antonelli, "Updating the Navy Environmental Protection Data Base to Incorporate Oil Spill Clean-up Performance," Mater's Thesis. Published also as Technical Report NPS-55To75061, June 1975.

A MATHEMATICAL MODEL FOR CONSTRUCTION WORKLOAD PLANNING

Investigators: M. U. Thomas, J. K. Hartman, and F. R. Richards, Associate Professors of Operations Research and Administrative Sciences

Support: Naval Facilities Engineering Command,

Objective:

To develop models for aiding in the planning and coordination of workload and resource allocation for executing and administering construction contracts within the engineering field divisions of the Naval Facilities Engineering Command. This is a continuation.

Summary:

During an initial fact-finding phase of the investigation, the current procedures for deciding on workload and resource allocations within field divisions were determined. In addition, the associated variables involved in these processes were indentified. A second phase was envisioned to establish functional relationships among performance measures of workload for deriving decision rules. Unfortunately, an attempt at this latter phase was unsuccessful because of two major obstacles: (1) the dependence on the Babcock curves in virtually all planning activities. Because of this it is impractical to obtain data that is not influenced by previous practices, irrespective of merits, and (2) the general instability in Navy construction over the last few years, along with the lack of appropriate data. As a consequence of these and other difficulties in quantifying workload, the study was terminated with the completion and demonstration of a forecasting model and a description of a comprehensive study and data requirements necessary to deal with the objective of this study.

Publications: None

EQUILIBRIUM EQUATIONS AND A COMPUTATION METHOD FOR MATRIX DIFFERENTIAL GAMES (MDG)

Investigator: A. R. Washburn, Associate Professor of Operations Research and Administrative Sciences

Support: Foundation Research Program

Objective:

To show that Danskin's omega-value of a matrix-differential game can be obtained as a solution of a finite system of equations, each involving a single maximization or minimization, and to propose a computation method based on these equations.

Summary:

There is a subset of differential games, including games of pursuit and evasion, for which there is a saddle point. For such games the notion of "value" is clear, at least in a theoretical sense. However, there are some differential games that have no saddle point. With matrix games, this problem can be gotten around by introducing randomized strategies, but this idea is not appealing for differential games on account of the continuous nature of the decision process. Several notions of value have been proposed for such games, amongst which is Danskin's Ω-value, wherein the parameter σ measures the relative time delay of one player in reacting to decision choices of the other. Matrix Differential Games (MDG) are matrix games for which it is desired to compute an Ω-value, preferably for all σ. The objective has been accomplished. A computer algorithm that solves 50 x 50 games in two minutes is available.

Publications: A. R. Washburn and B. O. Shubert, "Equilibrium Equations and a Computation Method for Matrix Differential Games (MDG)," Technical Report, NPS55Ws74061, June 1974.

PATTERN ANALYSIS APPLIED TO RETENTION DATA: A COMPARISON OF COMPUTER PROGRAMS PAIN AND STRAIN

Investigator: R. A. Weitzman, Associate Professor of Operations Research and Administrative Sciences

Support: Manpower Research Data Analysis Center

Objective:

Pattern Analysis Item Nominator (PAIN) and Structural Analysis Item Nominator (STRAIN) select binary (0-1) items and determine probabilities of success on a criterion (like retention) for individuals who have different patterns of responses to the selected items so that the correlation between the probabilities determined and criterion performance (success or failure) is as high as possible. PAIN determines the proportion of sampled individuals having a pattern who are successful as the probability of success; STRAIN uses estimates of the proportion of individuals who have each pattern to determine probabilities of success for individuals having different patterns. Unlike PAIN, STRAIN can obtain success probabilities for patterns that no one in the sample has. The research described was an attempt to answer two questions: (1) Does STRAIN yield more stable results than PAIN for small samples? (2) Does STRAIN provide accurate estimates of success probabilities when samples are too small for PAIN to determine success probabilities for all possible patterns?

Summary:

Applied to personal-history data of over 60,000 Navy enlisted Electronic Equipment Repairmen, 21 separate analyses using PAIN and STRAIN yielded the following answers to these research questions: To question 1, no; to question 2, yes. While producing no more stable results than PAIN from small samples, STRAIN can provide estimates of success probabilities for patterns that PAIN cannot when samples are so small that no one sampled has the patterns. The personal-history data were limited; however, within this limitation, the results indicated that men in at least the 70th AFQT percentile who enlist in the summer appear to be especially good recruitment risks for assignment in the Navy as Electronic Equipment Repairmen: 46 per cent of these men re-enlisted. Better prediction is no doubt possible from more extensive information.

Publications: None

ANALYSIS OF ELEMENTS OF THE MILITARY HEALTH CARE DELIVERY SYSTEM

Investigator: D. R. Whipple, Associate Professor of Operations Research and Administrative Sciences

Support: Naval Bureau of Medicine and Surgery

Objective:

To facilitate the establishment and effective implementation of Planning, Programming, and Analysis (PPA) within the Bureau of Medicine (BUMED). This necessitated an analysis of what they were supposed to be doing, how it could best be done, and to evaluate the mission statement and staffing proposals, and finally to consider the interpersonal and interorganizational problems associated with such an endeavor. The recommendations of the investigators were to be the guidance upon which their (PPA) organizational structure would be formed.

Summary:

A total review of the proposed organization was accomplished and provided, in working papers and site-visit memos, analyses of potential problem areas and recommendations for change. Much of this was as a result of spending time with the predesignated PPA staff before it became operational as an entity (July 1, 1975). In addition, a two-day seminar involving all PPA personnel was planned and presented which resulted in a formal mission statement. Further, a specific piece of analysis of the recommendation for shifting dependent care totally to CHAMPUS to PPA staff who were working in that particular problem was provided.

The sponsor's evaluation of the efforts of the investigation is revealed in the renewal of the contract for fiscal year (FY) 1976.

Publications: None

MISSILE SYSTEM RELIABILITY PROGRAM

Investigator: W. M. Woods, Professor of Operations Research & Administrative Sciences

Support: Strategic Systems Projects Office

Objective:

To provide technical assistance to Strategic System Projects Office (SSPO) in the Fleet Ballistic Missile Weather Station (FBMWS) subsystem reliability programs for the POLARIS and TRIDENT development and production programs.

Summary:

The principal output was written evaluations of statistical and mathematical procedures proposed for use in the reliability and maintainability programs of the POLARIS and TRIDENT missile systems. These evaluations were contractor sensitive. A comparative analysis of the accuracy of several reliability growth models was developed and introduced as a management tool for possible use in the development program. Active participation in numerous planning meetings and technical review meetings constituted a portion of the workload.

Publications: T. Jayachandran and L. R. Moore, III, "The Performance Characteristics of Some Reliability Growth Models," Technical Report NPS53Jy74122, December, 1974.

SUPPLY SYSTEMS RESEARCH

Investigator: P. W. Zehna, Professor of Operations Research and Administrative Sciences

Support: Naval Supply Systems Command

Objective:

To test the use of alternative techniques as possible replacements for exponential smoothing in the Uniform Inventory Control Point (UICP) demand forecasting program.

Summary:

Using stock-out risk at one extreme and oversupply at the other, the effects of variability in forecasting, even when accurate with respect to the mean were highlighted. Using a normal model, exponential smoothing was identified as a major source of variability. Various forecast methods were compared relative to mean squared error when demand was allowed to vary according to specified patterns using simulation. The same alternatives were compared using real demand data. In almost all cases, exponential smoothing compared quite favorably to the alternatives.

Publications: P. W. Zehna and C. F. Taylor, Jr., "Comparing Inventory Demand Forecasts," Technical Report NPS55Ze75051, May 1975.

DEPARTMENT OF GOVERNMENT RESEARCH PROGRAM

The research program in the Department of Government has been intensified during the past year with foci directed to national and international security affairs, strategic planning, and naval intelligence.

Professor J. W. Amos has conducted several studies on the political and military implications of communists influence in the Near East, the role that the communist parties play in the political, the economic, and the cultural life of the various countries of the Near East and has analyzed the issues that might very well concern the United States. M. W. Janis investigated various aspects of the international law of the seas and the implications for the U. S. Navy. E. J. Laurance researched the patterns, purposes, and effects of arms transfers to lesser developed countries and the use of data analysis in security-assistance policymaking. R. H. Stolfi researched the feasibility of establishing an armament institute as a part of an armment development center and also investigated a standard methodology for forecasting the technical threat from the navies of the Eurasian communist countries.

COMMUNIST PARTIES: THEIR ROLE IN ARAB POLITICS AND IMPLICATIONS FOR AMERICAN SECURITY INTERESTS

Investigator: J. W. Amos, II, Assistant Professor of Government and Humanities

Support: Foundation Research Program

Objectives:

To develop a typology of Arab Communist Party (ACP) organizational, ideological, and membership patterns.

Summary:

Initial research was undertaken concerning the Arab Communist Parties (ACPS) of Egypt, Syria, Iraq, Jordan, and Lebanon. The operating hypothesis was that each of these countries represented a different political/sociological environment for ACPS. Egypt was a one-party state with a homogeneous society; Syria and Iraq one-party states with differing patterns of social fragmentation; Jordan a traditional regime with a bifurcated population; and Lebanon an open political system with a heterogeneous society. As expected, the ACPS differed in each country: the Egyptian Communist Party (ECP) was small, drawn from a limited circle of middle class and upper class populations; the Syrian Communist Party (SCP) was larger, more heavily composed of minorities; the Iraqi Communist Party (ICP) was smiliar to its Syrian counterpart; the Jordanian Communist Party (JCP) was relatively small and split between Jordanian and Palestinian factions; and the Lebanese Communist Parties (LCP(s)) were split along a number of lines which to some extent corresponded with other Lebanese social and political divisions.

Publications: None

PATTERNS, PURPOSES AND EFFECTS OF CONVENTIONAL ARMS TRANSFERS TO LESSER DEVELOPED NATIONS

Investigator: E. J. Laurance, Assistant Professor of Government

Support: Naval War College

Objective:

(a) To search the literature and create a bibliography, (b) to present testable hypotheses, (c) to collate existing unclassified data to test the feasibility of research design, (d) to demonstrate the utility of research as an aid to making arms transfer policy, and finally (e) to develop graduate-level seminar on arms transfers.

Summary:

The objectives cited above were generally attained, i.e., (a) a satisfactory bibliography was assembled, (b) several workable hypotheses were developed (e.g., it was found that (1) the higher the level or arms transfers from Supplier (S) to Recipient (R), the greater the extent of alignment of R with S, (2) the purchase/receipt of arms by R from S is positively correlated with the role of the military in the political system of R, and (3) the higher the levels of arms transfers to R at time (t), the greater the regional interstate conflict at t + 1, (c) an alignment indicator was constructed for a sample of Asian countries, and finally (e) a graduate-level course in arms transfer was created, and is now being taught in the National Security Affairs (Area Specialization) curriculum at the Naval Postgraduate School. Only objective (d) was not completly realized.

Publications: None

Conference Presentations:

The investigator chaired a panel on Arms Transfers at the annual meeting of the International Studies Association in Washington, D. C., 21-22 February 1975. He also presented a paper, "Influence Over the Use of Violence Gained Through Arms Transfer to Developing States," before the annual meeting of the American Political Science Association, September 1975.

AN ARMAMENTS INSTITUTE FOR THE U. S. ARMY

Investigator: R. H. S. Stolfi, Associate Professor of Government

Support: Army Materiel Command

Objective:

To examine the desirability of establishing an Armaments Institute for the Army within the framework of a reorganized Army Materiel Command having a Development Center.

Summary:

By December 1974, the BGEN Lewis Task Force on the Reorganization of the Army, was in the advanced stages of completing a study which would recommend the establishment of a Weapons Developmemt Center. The Center would consolidate many of the Army's research, development, testing, and production facilities into one command at a single location. Several members of the Task Force (BGEN Lewis, COL Doyle, Mr. Dunetz) felt that an armaments institute, which would present knowledge on armaments systems at the university level, might be a viable part of a reorganized Army Materiel Command. The investigator examined the proposal briefly, and in a presentation to BGEN Lewis in the middle of January 1975, at Alexandria, Virginia, stated that the idea of an Armaments institute was timely and would give a cohesiveness and organization to the armaments acquisition process that was lacking. Important questions that had to be addressed varied from those of the use of existing educational facilities, e.g., private colleges and universities, Naval Postgraduate School (Weapons Systems Engineering Curriculum), etc. through questions of the location of an Army institute and the scope of the education. With regard to these kinds of questions, for example, the investigator suggested in the oral presentation to the head of the reorganization task force, that the Army institute be a new institution located away from the area chosen for the Armaments Development Center, to give the academic institute an independent faculty and student tenor removed from the everyday administration imbroglios of a differently oriented administrative machine. Relative to the scope of the education, the oral report to BGEN Lewis suggested a broad orientation which would demand a university of three colleges: (1) Science and Technology, (2) Resources Management, (3) Historical and Political Scientific Analysis.

Publications: R. H. S. Stolfi, Consultant and Contributor to "Final Report of the Army Materiel Command Committee - Armament," December 1974, (Modified and approved for public release well after the date noted above.)

CORRELATION OF THE VULNERABILITY OF TANKS WITH THE COMBAT EMPIRICAL DISTRIBUTION OF IMPACTS IN BOTH THE HORIZONTAL AND VERTICAL PLANES

Investigator: R. H. S. Stolfi, Associate Professor of Government

Support: USA Ballistic Research Laboratories

Objective:

To collect and organize data on tanks damaged in the Arab-Israeli War of October 1973. Data would include especially the number and locations of major caliber (i.e., damaging) impacts on tanks, the types of weapons and projectiles which inflicted the damage, and the various angles (i.e., obliquity, horizontal plane) at which the paths of the projectiles intersected the surface and exterior surfaces of the tanks. The collected data would serve the purpose, with appropriate skilled analysis, of establishing the effectiveness of employment of various weapons platforms (air, ground, naval) and weapons in the tank engagements of October 1973.

Summary:

Both the data collected, and the interpretations of the October 1973 war which are supported by those data were carefully analyzed by the investigator and his conclusion was reported to the sponsor. It may be commented that the data were extensive (impacts against approximately 650 tanks) and served to stimulate several decisive interpretations of the effectiveness of various weapons systems.

Publications: R. H. S. Stolfi, Consultant and Contributor to "Weapons System Evaluation Group, Report on the War in the Middle East," June 1974.

Thesis Directed:

R. De Mont and T. White, "Analysis of the Combat Empirical Tank Damage Data of the October 1973 War," Master's Thesis, September 1974.

CORRELATION OF THE VULNERABILITY OF TANKS WITH THE COMBAT EMPIRICAL DISTRIBUTION OF IMPACTS IN BOTH THE VERTICAL AND HORIZONTAL PLANES

Investigator: R. H. S. Stolfi, Associate Professor of Government

Support: Foundation Research Program

Objective:

To analyze various arrangements of fuel and ammunition inside tanks from the viewpoint of the survivability of those vehicles.

Summary:

The data show that major damage to tanks, especially damage described under the Army Ballistic Research Laboratory system as catastrophic (K = kill), is associted almost universally with explosion or burning of internal tank material and/or components. Analysis, based on the distribution of impacts on tanks damaged in combat, supports a view that substantial increases in the survivability of tanks can be achieved through simple rearrangements of the sensitive material components in all tanks presently in service with the major armies of the world.

Publications: None

REPORT OF THE TASK FORCE ON GUN SYSTEM ACQUISITION

Investigator: R. H. S. Stolfi, Associate Professor of Government

Support: Office of the Director of Defense Research and Engineering

Objective:

To identify the main deficiencies in the system used by the United States in acquiring guns, and to establish specific corrective action to eliminate the verifiable shortcomings.

Summary:

In a memorandum for the Assistant Secretaries of the Military Departments Research and Development, dated 11 November 1974, Dr. Malcolm R. Curie, Director of Defense Research and Engineering, expressed his concern, and that of the Secretary of Defense, over apparent deficiencies in the process used by the Department of Defense in acquiring and fielding gun systems. The memorandum serves as the authority for the presently existing Defense Science Board, Task Force on Gun System Acquisition, whose objective has been to carry out an independent assessment of the apparent deficiencies in the gun system acquisition and in the event of the determination of deficiencies to recommend specific corrective action.

The Report of the Task Force on Gun System Acquisition was presented to Dr. Curie early in August 1975, and, by his direction, is presently being circulated among the Secretaries of the Army, Navy, and Air Force for appropriate final comment. The Report presents as its single, principal finding the fact that "lacking compelling reasons for its existence, clear incentives, proper stimuli and an overall sense of direction, the process of developing and producing gun systems in the United States has ground to a halt." The Report presents a four-point strategy for reviving gun systems acquisition which involves (1) specific commitment of the Secretary of Defense to maintain and exercise the U. S. capability to acquire improved gun systems, (2) improvement of the decision-making process, (3) reduction in the complexity of organizational structures and procedures, and (4) definition and encouragement as appropriate of the roles of the government laboratories and private industry. Within the four-point strategy, the Task Force recommended, (1) a continuous, cyclical process of acquiring guns through the level of functional prototypes, (2) the temporary establishment of a Department of Defense (DOD) Gun Systems Chief, (3) the placing of the Service laboratories under a Director

of Laboratories at the level of the Assistant Service Secretary for R & D, and (4) the elimination of competition between the government laboratories and industry by eliminating the government from advanced development and production, and the equal sharing of R & D funds between the laboratories and industry.

Publications: R. H. S. Stolfi, Consultant and Contributor to "Report of the Task Force on Gun System Acquisition," Defense Science Board, Office of the Director of Defense Research and Engineering, August 1975.

DEPARTMENT OF AERONAUTICS

Research topics in the Aeronautics Department have been related to objectives falling within five principal areas: (1) aircraft structural integrity, (2) propulsion, (3) laser technology, (4) fluid mechanics, and (5) V/STOL and surface effect ship technology.

AIRCRAFT STRUCTURAL INTEGRITY

Included under structures are: experimental studies of hydraulic ram phenomena in projectile-penetrated fuel tanks by R. E. Ball and H. L. Power; measurements of stress patterns around circular holes in plates of advanced composite materials by M. H. Bank; and application of current technology and understanding of fatigue by G. H. Lindsey to develop an inexpensive, compact, lightweight aircraft fatigue monitoring system.

PROPULSION

D. W. Netzer is studying analytically and experimentally the internal ballistics of solid fuel ramjets; he is also assessing emission levels and related air quality effects from jet engine aircraft and test cell operations. A. E. Fuhs continued parametric studies of external burning assisted projectiles (EBAP). M. F. Platzer is investigating complex unsteady transonic and supersonic flows in aircraft propulsion systems. R. P. Shreeve is applying diagnostic mini-computer and micro-processor systems to a variety of turbomachinery problems, including flow in transonic axial compressor stages begun by the late M. H. Vavra. J. A. Miller has begun measurements in an oscillating free stream on a circulation controlled airfoil for a helicopter rotor.

LASER TECHNOLOGY

Under this heading are included investigations on high pressure discharge for electro-aerodynamic lasers and short length diffusers for gas dynamic lasers, by O. Biblarz; cylindrical shock wave diffusers for gas dynamic and chemical lasers, and thermal blooming of slewed high energy laser beams, by A. E. Fuhs. Fuhs is also assessing the weapons role of high-powered lasers on future aircraft.

FLUID MECHANICS

Laser technology is being applied by D. J. Collins in both holographic interferometry and doppler velocimetry to investigate complex low-speed flows and unsteady flows; Collins and D. W. Netzer are also using holographic interferograms to study the internal ballistics of solid propellant guns. T. H. Gawain is continuing numerical calculations to determine the stability characteristics of two classical parallel flows with third-dimensional freedom. O. Biblarz continues in the study of electrode voltage loss mechanism in Magneto Hydrodynamic (MHD) generators.

V/STOL AND SURFACE EFFECT SHIP TECHNOLOGY

This area includes two projects: design of a cockpit display system, by R. A. Hess, to allow piloted V/STOL landings in zero-zero weather; and continuing technology demonstrations and developments with a captured air bubble surface effects ship by D. M. Layton.

AIRCRAFT FUEL TANK RESPONSE TO SMALL ARMS FIRE (HYDRAULIC RAM)

Investigators: R. E. Ball, Associate Professor of Aeronautics
H. L. Power, Assistant Professor of Aeronautics

Support: Naval Weapons Center

Objective:

To obtain fuel tank wall strain data and fuel pressure data caused by a ballistic penetrator and to develop an analytical model and computer program that adequately describes the fuel tank response to the penetrator.

Summary:

Fuel tanks comprise the greatest portion of vulnerable target volume in modern military aircraft. Fuel tanks that are subjected to ballistic impact and penetration by small arms fire (12.7 mm, 50 caliber, etc.) can be severely damaged, with rupture, and large petalling of the tank walls occurring at the entrance and exit points of the bullet. The damage mechanism is known as the hydraulic ram effect, defined as the development of very high pressure waves, of potential destructive intensity in the liquid fuel in tanks by the passage of ballistic penetrators through the fuel.

An analytical and experimental hydraulic ram program has been in existence at the Naval Postgraduate School (NPS) for three years. Fluid pressures have been predicted for 22 caliber bullets fired into a fluid-filled tank using the Yurkovitch theory and the Naval Weapons Center (NWC) code developed by Fung and Lundstrom. These predicted pressures have been compared with actual fluid pressures measured with Kistler pressure gages for several energy levels. The predicted pressures have also been used in conjunction with the computer code SATANS to predict entry wall strain. The predicted entry wall strains have been compared with actual measured strain data for several energy levels and plate thickness.

The NPS has also provided analytical support to NWC in conjunction with their hydraulic ram experimental program on exit wall response. Pressures at the exit wall caused by 12.7 mm projectiles have been predicted using the NWC code. Exit wall response to these predicted pressures has been obtained using SATANS and the nonlinear (geometry and material) finite element code BR-1HR. The latter code was originally developed by Northrup for air blast loads and later was modified by Ball to account for fluid-stucture interaction

(piston theory). The predicted exit wall strains have been compared with the actual strains measured by NWC. Investigations have recently been initiated on dynamic crack propagation in the tank walls, on the effects of foam buffering materials on the damage level, and on the effects of hydraulic ram on fiber-reinforced plastic (composite) tank walls.

Publications:

R. E. Ball, "Aircraft Fuel Tank Vulnerability to Hydraulic Ram: Modification of the Northrup Finite Element Computer Code BR-1 to Include Fluid-Structure Interaction -- Theory and User's Manual for BR-1HR," Technical Report NPS-57Bp74071, July 1974.

H. L. Power, "FY 1974 Experimental Hydraulic Ram Studies," Technical Report NPS-57Ph74081, August 1974.

H. L. Power, "FY 1975 Experimental Hydraulic Ram Studies," Technical Report NPS-57Ph75061, June 1975.

Theses Directed:

J. C. Bitzburger, "Two-Dimensional Analysis of Fluid-Structural Interaction by Method of Finite Differences - Hydraulic Ram, The Fuel Tank Problem," Master's Thesis, June 1974.

C. M. Holm, "Hydraulic Ram Pressure Measurements," Master's Thesis, December 1974.

B. D. Page, "Entry Wall Strain Measurements During Hydraulic Ram," Master's Thesis, March 1975.

AIRCRAFT STRUCTURES RESEARCH: COMPOSITE STRESS CONCENTRATION

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

Support: Naval Air Systems Command

Objective:

To determine the effect on the stress distribution in an advanced composite structure of a hole or thermally degraded region. The immediate objective is to determine experimentally the effect of a circular hole on the stress distribution in a composite plate.

Summary:

A composite materials fabrication laboratory has been established to produce the required specimens in-house. An inexpensive moire experimental technique has been investigated, which shows promise of being useful in later studies.

A photoelastic investigation of stress concentrations around central holes in finite glass-epoxy composite plates under uniaxial tension has shown that the state of stress is not adequately described by theoretical solutions for homogeneous orthotropic plates. The stress concentration is a function of the hole size. Strain-gage investigations of stress concentrations around off-center circular holes in finite glass-epoxy composite plates under uniaxial tension have shown that the response of the composite is qualitatively similar to that of homogeneous isotropic materials, but the results are quite different quantitatively. Agreement with solutions based on classical laminate theory is good.

Testing of specimens with ballistic damage (bullet holes) rather than machined holes is beginning. A ballistic range has been constructed and is now fully operational. Electron microscope studies of fracture surfaces around the holes are underway. In addition, a ball-drop device for production of low-energy impact is under construction and will be used in this investigation.

Publications: None

Theses Directed:

D. L. Saba, "Stress Concentrations Around Holes in Laminated Fibrous Composites," Master's Thesis, June 1975.

R. S. Alves, "Stress Concentration in Fibrous Composite Material," Master's Thesis, June 1975.

C. M. Bruce, "Moire Pattern Analysis of Strain," Master's Thesis, September 1975.

DIFFUSER TECHNOLOGY FOR GAS DYNAMIC LASERS

Investigator: O. Biblarz, Associate Professor of Aeronautics

Support: Naval Air Systems Command

Objective:

To develop concepts for short length diffusers with adequate pressure recovery and reliable starting characteristics for use in gas dynamic lasers. This is both an analytical and experimental study.

Summary:

The conventional rectangular geometry diffuser consists of a ramp followed by a constant area region. It was found that intrusion by the atmosphere into the constant area region of a short diffuser forms a separated region which may be used to advantage. The complex shock-boundary layer interactions were found to have a three-dimensional, unsteady character.

Publications: None

Thesis Directed:

M. M. Oudekerk, "Experimental Investigation of the Starting Process of Short Diffusers for Gas Dynamic Lasers," Master's Thesis, 1975.

ELECTRODE LOSS MECHANISMS IN MAGNETO HYDRO DYNAMICS (MHD) GENERATORS

Investigator: O. Biblarz, Associate Professor of Aeronautics

Support: Air Force Office of Scientific Research

Objective:

To define the nature and extent of voltage drops in MHD generators. Principal loss mechanisms that occur in the vicinity of the electrodes are of two types, sheath or Debye shielding effects and conductivity drops due to the thermal boundary layer.

Summary:

The contribution of the sheath has been largely neglected by other investigators. We have shown that no solution exists to the one-dimensional, collision dominated, non-reacting flux of charges, and we have successfully arrived at two-dimensional solutions. The existing formulations of the boundary layer contribution have been simplified. Future plans include studying effects of the magnetic field and extending our work to ionization and recombination.

Publications:

O. Biblarz, R. C. Dolson, and A. M. Shorb, "Anode Phenomena in a Collision Dominated Plasma," Journal of Applied Physics, 46 (1975).

O. Biblarz and R. C. Dolson, "Voltage Profiles in the Vicinity of Non-emitting Electrodes." Paper presented before the 14th MHD Symposium, University of Tennessee Space Institute. Published in Proceedings, April 1974.

O. Biblarz and R. C. Dolson, "Electrode Loss Mechanism in MHD Generators," Technical Report NPS57Zi75052A, 1975.

HIGH PRESSURE DISCHARGE FOR ELECTRO-AERODYNAMIC LASERS

Investigator: O. Biblarz, Associate Professor of Aeronautics

Support: Foundation Research Program

Objective:

To study discharges in nitrogen and to devise a scheme wherein CO_2 can be injected downstream of the discharge region for laser operation. This is a continuation of the work of Biblarz and Nelson (JAP, 45, 633 (1974)) into the study of discharges of interest to electro-aerodynamic lasers. These lasers operate with mixtures of N_2/CO_2. Since the preceeding work was done with atmospheric air, this study focuses on discharges in nitrogen.

Summary:

Previous work on turbulence stabilization of discharges using ambient air flows was extended to flows with pure nitrogen. As expected, this proved that nitrogen is a better discharge medium because negative ions do not form readily and because no significant chemical activity takes place. For the same test configuration and the same turbulence and flow conditions, the improvement was a factor of 6 in the amount of power accepted by the discharge prior to arcing. This is significant because nitrogen is the appropriate medium for an electric discharge laser. Since our apparatus is an open-flow system, carbon dioxide may be injected downstream of the discharge. We have also concluded from this work that, given a type of gas and a screen configuration, the discharge power per unit volume prior to arcing is only a function of the square of the convective velocity; this is a result of the decay of grid-generated turbulence and of the current-voltage characteristics.

Publications and Presentations:

O. Biblarz and L. J. Aunchman, "Stabilization of a Medium Pressure Discharge by Turbulent Flows." Paper presented before the 27th Annual Gaseous Electronics Conference, Houston, Texas, 1974, the abstract published in The Proceedings and in the Bulletin of the American Physical Society.

Thesis Directed:

J. R. Osani, "High Pressure Electric Discharge Convection Laser, a Preliminary Study," Master's Thesis, September 1974.

INTERNAL BALLISTICS OF SOLID PROPELLANT GUNS - GUN BARREL HEATING & WEAR

Investigators: D. J. Collins and D. W. Netzer, Professors of Aeronautics

Support: Naval Ordnance Station

Objective:

To obtain holographic interferogram of a projectile shortly after launch from a 20 mm gun. Further investigations have been made of the application of holography to the determination of wear in the gun barrel. Flow in the barrel is also to be investigated.

Summary:

Holographic interferograms have been obtained of the projectile after launch. Work is still in progress on this aspect of the investigation. Severe problems were encountered in the wear investigation as reported in the thesis of Naughton listed below.

A gun barrel is in the process of being modified to receive viewing ports for the internal ballistic investigation.

Publications: None

Theses Directed:

R. G. Bettinger, "Application of Holographic Interferometry to the Exterior Ballistic Flow Field in the Muzzle Environment of a Twenty Millimeter Cannon," Master's Thesis, June 1975.

R. J. Naughton, "An Application of Holographic Interferometry to Gun Barrel Erosion," Master's Thesis, December 1974.

LASER TECHNOLOGY APPLIED TO FLOW FIELD VISUALIZATION

Investigator: D. J. Collins, Professor of Aeronautics

Support: Naval Air Systems Command

Objective:

To investigate complex low-speed flows and unsteady flows by using Holographic Interferometry and Laser Velocimetry. The experimental measurements should permit the development of realistic mathematical models of the flow in thrust augmentors and in transonic compressor.

Summary:

A new laser velocimeter has been received, and preliminary work has begun with it. A computer interface for the velocimeter is now under design. Further work with low-speed flows has indicated that live fringe holography using video techniques should give good information on unsteady flows. Holographic Interferograms have been obtained of an oscillatory jet which will be used in the thrust augmentors investigation.

Publications: None

THREE DIMENSIONAL INSTABILITY OF PARALLEL FLOWS

Investigator: T. H. Gawain, Professor of Aeronautics

Support: Foundation Research Program

Objective:

To determine the stability characteristics of plane Poiseuille flow and fully developed pipe flow. The new feature of the present work is that the flow perturbations studied are fully three-dimensional in space and fully complex exponential in both space and time. This greater degree of generality compared with previous theories implies additional sources of possible instability and a corresponding shift in the predicted stability boundaries.

Summary:

Calculations for plane Poiseuille flow, based on the new theory, confirm the expected lowering of the critical Reynolds number. This parameter is shown to depend in a regular way on the spatial growth or decay rates of the imposed perturbations. These results entail some revision of basic concepts regarding the nature of hydrodynamic instability. No calculations have yet been made for pipe flow by the new theory.

Publications: None

Thesis Directed:

W. F. Harrison, "On the Stability of Poiseuille Flow," Engineer's Thesis, June 1975.

A MODEL BASED DESIGN OF A COCKPIT DISPLAY SYSTEM V/STOL AIRCRAFT

Investigator: R. A. Hess, Assistant Professor of Aeronautics

Support: National Aeronautics Space Administration-Ames Research Center

Objective:

To design a cockpit display system (display format, flight director laws, etc.) which will allow the piloted landing of a V/STOL aircraft in zero-zero weather conditions.

Summary:

The mathematical model of the human pilot has been formulated and implemented on the Naval Postgraduate School (NPS) IBM 360 and the National Aeronautics Space Administration (NASA)-Ames CDC 7600 computers. A preliminary display design of longitude control in a landing approach has been completed using UH-1H helicopter as a vehicle. A fixed base simulation was conducted at NPS. The results of the design/evaluation were reported at the 11th Annual Conference on Manual Control. The design study is continuing and will result in a complete set of flight director laws with UH-1H vehicle for approach and landing.

Publications: R. A. Hess and L. W. Wheat, "A Model Based Analysis of a Display of Helicopter Landing Approach." Transactions, Systems, Man and Cybernetics, 1975.

CAPTURED AIR BUBBLE SURFACE EFFECT SHIP TECHNOLOGY PROGRAM

Investigator: D. M. Layton, Associate Professor of Aeronautics

Support: Naval Sea Systems Command

Objective:

To investigate several facets of basic and advanced Surface Effect Ship technology as they apply to Captured Air Bubble vehicles.

Summary:

Five (5) tasks were developed by the Sponsor's Statement of Work and two (2) additional tasks were generated by the Naval Ship Research and Development Center during Fiscal Year (FY) 1975. Five (5) of these tasks were completed during the first half FY 1975 and two (2) tasks; (a) Determination of the effect of seal position and shape on performance, and (b) Determination of the effect of trim and weight variation on performance were completed during Quarters III and IV of FY 1975.

(A) Seal Position and Shape. The natural bowed shape of the air-spring bow and stern seal is accentuated with overpressure in the seal cavity. This results in a deformation of the lower portion of the seal face and as a result, hydrodynamic resistance to the seal motion is increased. Flattening of the seal face by shortening of the downstop restraint cables initially results in a decrease in the seal-water interface with a decrease in the seal drag. However, as the seal is flattened beyond the optimum, the phantom lengthening of the seal face causes the trailing edge of the seal to dig in, thereby increasing the drag of the seal. An optimum position and shape for both the bow and stern seal was determined.

(B) Trim and Weight Variation. Tests at various gross weights and center of gravity locations disclosed that at velocities greater than fourteen (14) knots, minimum drag occurred at a center of gravity one hundred nineteen (119) inches forward of the stern transom, regardless of the loading of the testcraft. At lower velocities there are multiple crossovers of the minima. These results validated model tests and computer simulations conducted by the Naval Ship Research and Development Center, and provide a baseline for trim for future operations of the XR-3 Testcraft.

Publications: None

Theses Directed:

R. W. Maloney, "The Effect of Seal Shape Variations Upon the Performance of the XR-3 Captured Air Bubble Testcraft," Mater's Thesis, March 1975.

W. M. Leins, "XR-3 Center of Gravity Characteristics," Master's Thesis, March 1975.

AIRCRAFT FATIGUE MONITORING

Investigator: H. Lindsey, Associate Professor of Aeronautics

Support: Naval Air Systems Command

Objective:

To apply current technology and understanding of fatigue to improve the Navy's fatigue monitoring system of aircraft.

Summary:

A prototype instrument centered around a microprocessor and intended for mounting in each aircraft in the fleet has been designed, built, and undergone preliminary flight testing in a Cessna 310. The data acquisition system receives continuous analog signals from strain gages located at fatigue critical points. These oscillatory signals are converted to digital form, searched for maxima and minima, which are stored in memory, and then dumped to tape on command. With this device, fatigue data in sequence can be gathered directly from the critical location in a format for automatic data processing.

A second, improved, and more compact version of the data acquisition system is being designed now and will be mounted in a Blue Angel A-4 late in 1975 for flight testing in a high g environment.

Sequence of loading cycles has been shown by some investigators to affect significantly fatigue life for certain loading spectra. The influence of sequence in aircraft spectra is being investigated in this program in both the design and the monitoring phases. Studies of flight-load statistics have been used to generate probable flight-load spectra for a given aircraft type. With this sequence, estimates have been made of the changes in damage calculations, and ultimately in the aircraft life, due to the random variations in the sequence.

The Naval Postgraduate School now has the capability to perform experimental tests on laboratory samples and small components containing fasteners to determine influences of sequence in life.

Publications: None

UNSTEADY PERFORMANCE OF CIRCULATION CONTROLLED AIRFOIL

Investigator: J. A. Miller, Associate Professor of Aeronautics

Support: Naval Ship Research & Development Center

Objective:

To measure the aerodynamic performance of a two-dimensional circulation controlled airfoil in an oscillating free stream. Long-term goals are to provide design data for application of the circulation controlled airfoil as a helicopter rotor system.

Summary:

To date the model, provided by Naval Ship Research & Development Center (NSRDC), has been instrumented and installed in the oscillating flow wind tunnel. At the present time, data gathering and processing systems are being checked out and steady flow reference data are being gathered.

Publications: None

AIR BREATHING COMBUSTION MODELING

Investigator: D. W. Netzer, Associate Professor of Aeronautics

Support: Naval Weapons Center

Objective:

To validate experimentally an analytical model for the internal ballistics of solid fuel ramjet.

Summary:

This investigation is being conducted at the Naval Weapons Center (NWC) in a joint effort by NWC and the Naval Postgraduate School (NPS). The computer program developed at NPS for the internal ballistics of solid fuel ramjets is being checked against experimental data. Model improvement and extension are intended results.

Publications: D. W. Netzer, "Modeling Solid Fuel Ramjet Combustion," 12th Joint Army Navy NASA Air Force (JANNAF) Meeting, August 1975. To be published by Chemical Propulsion Information Agency.

EMISSION LEVELS AND AIR QUALITY EFFECTS FROM NAVAL AIR STATION AIRCRAFT OPERATIONS AND TEST CELLS

Investigator: D. W. Netzer, Associate Professor of Aeronautics

Support: Naval Air Propulsion Test Center

Objective:

To adapt the Air Quality Assessment Model (AQAM) Computer Program developed by the Air Force to Naval air operations, and to use the modified model to assess effects of operations on ambient air quality at several Naval Air Stations, and finally to develop computer programs which can be used to predict the internal aerodynamics and pollution levels from jet engine test cells.

Summary:

Initial modifications have been made to the AQAM model to adapt it to Naval air operations. Modifications included Visual Flight Rules (VFR) approach, touch-and-go, and field corner landing practice. Data collected at Naval Air Station (NAS), Miramar were input into the model. Annual emissions and hourly dispersion calculations have been made and compared for operations with and without hot refueling. The program will be further modified for Naval operations and more detailed NAS operations will be included.

Two computer programs are being developed to predict the internal aerodynamics of jet engine test cells. Parameters being considered are cell augmentation ratio, engine thrust level, exhaust gas recirculation, exhaust stack configuration, and design and location of the augmentor.

Publications: None

A STUDY OF THE INTERNAL BALLISTICS OF SOLID FUEL RAMJETS

Investigator: D. W. Netzer, Associate Professor of Aeronautics

Support: Naval Weapons Center

Objective:

To develop an internal ballistics model and to provide experimental data on the effects of operating conditions and motor configuration on internal ballistics.

Summary:

Experimental investigations in both non-reacting and reacting environments have been conducted. Inlet velocity has no affect on the reattachment point for a fixed inlet step height. Increased step height moved the reattachment point downstream. The reattachment zone moves upstream with wall mass addition. Average fuel regression rates closely follow the theoretical expression derived for kinetically controlled hybrid rocket combustion. Inlet turbulence affects the blow-off by significantly changing the structure of the recirculation zone. Alternate flame stabilization devices provided inadequate substitutes for the rearward facing step design.

A computer model has been developed which can be used to study the effects of operating conditions and motor design on the internal ballistics. Current efforts are directed at validating and improving the model.

Publications:

C. E. Jones, III, J. T. Phaneuf and D. W. Netzer, "An Investigation of the Internal Ballistics of Solid Fuel Ramjets," 11th Joint Army Navy Nasa Air Force (JANNAF) Combustion Meeting, Chemical Propulsion Information Agency (CPIA) No. 261, December 1974.

J. T. Phaneuf, Jr. and D. W. Netzer, "Flow Characteristics in Solid Fuel Ramjets," Technical Report NPS-57Nt74081, July 1974.

UNSTEADY FLOWS IN AIRCRAFT PROPULSION SYSTEMS

Investigator: M. F. Platzer, Associate Professor of Aeronautics

Support: Naval Air Systems Command

Objective:

To develop theoretical models and experimental techniques which can contribute to an understanding of the complex unsteady flow phenomena in aircraft propulsion systems. A specific objective is the analysis of unsteady transonic and supersonic flows in turbomachines and the investigation of unsteady flows in thrust augmenting ejectors.

Summary:

A theoretical analysis of transonic flow past harmonically oscillating unstaggered cascades has been completed and documented. Computed stability boundaries showed blade interference to have a strongly destabilizing effect. A method was developed to investigate the effect of blade thickness on the supersonic entrance flow field of harmonically oscillating cascades with subsonic leading-edge locus, showing thickness to have a significant influence on the stability characteristics throughout the lower frequency range. Also, a computer program was developed to analyze torsional supersonic blade flutter, and flutter boundaries were computed and documented for a variety of parameter combinations. Finally a series of measurements were completed to establish the nozzle efficiencies and jet-spreading characteristics of oscillating primary jets.

Publications and Conference Presentations:

M. F. Platzer, L. J. Deal, and W. S. Johnson, "Experimental Investigation of Oscillatory Jet Flow Effects." Paper presented before the Symposium on Unsteady Aerodynamics, University of Arizona, March 18-20, 1975 and published in The Proceedings.

M. F. Platzer, "Transonic Blade Flutter - A Survey," The Shock and Vibration Digest, Vol. 7 (July 1975).

W. R. Chadwick, J. K. Bell, M. F. Platzer, "On the Analysis of Supersonic Flow Past Oscillating Cascades." Paper presented before the Advisory Group for Aeronautical Research

and Development (AGARD) Conference on Unsteady Phenomena in Turbomachinery, Monterey, September 22-26, 1975 and published in The Proceedings, September 1975.

D. D. Liu and M. F. Platzer, "Approximate Methods for Transonic Flow Past Finite Wedge Profiles." Accepted for publication in Zeitschrift fur angewandte Mathematik und Mechanik (ZAMM).

ENGINEERING SOLUTIONS TO CURRENT PROBLEMS IN TURBOMACHINERY

Investigator: R. P. Shreeve, Associate Professor of Aeronautics

Support: Naval Air Systems Command

Objective:

To obtain immediate solutions to particular development problems in turbomachinery.

Summary:

The simplicity of programming advanced calculators (HP9830A) allows complete engineering solutions to quite complex problems to be obtained quickly, and the results to be presented in graphical form. Examples are given here of problems solved which have contributed to a library of useful short programs. The solutions have generally been communicated as memoranda.

A. Carrier Arresting Gear Development. Departure of the torque - speed characteristic of the Mark 14 rotary arresting gear (under development of Naval Aviation Engineering Center (NAEC) Philadelphia) from the design prediction was interpreted as being due to cavitation within the rotor blading. An analysis was carried out which determined case pressures required to avoid cavitation at different rotor speeds. The results were presented in graphs which illustrated the effects of uncertainties in loss and velocity profile parameters.

B. Turbine Performance Determination. Programs for the analysis of data from a turbine test rig using the central computer were discarded and the analysis repeated and reprogrammed for the Model HP9830A calculator and peripherals. The performances of stator and rotor separately were determined successfully for the first time from force, moment, and pressure measurements.

C. Axial Compressor Design. Prediction of the expected performance of an axial compressor under development for helium, required an examination of radial equilibrium between blade rows. The calculation of cylindrical flow with prescribed total pressure and flow angle profiles was programmed successfully. The program will be extended to include compressibility and curvature within the annulus.

Publications: R. P. Shreeve, "Program to Calculate Non-Uniform Cylindrical Flow in an Annulus," Memorandum GA-RP57406-1, June 1974.

Thesis Directed:

W. R. Solms, "Measurement of Stage and Blade Row Performances of Axial Turbines with Subsonic and Supersonic Stator Exit Conditions," Master's Thesis, March 1975.

TRANSONIC COMPRESSOR INVESTIGATIONS

Investigator: R. P. Shreeve, Associate Professor of Aeronautics

Support: Naval Air Systems Command

Objective:

To investigate in detail the behavior of the flow in transonic axial compressor stages, the ultimate goal of which is to enable an accurate prediction of the performance of advanced compressors through the use of a model which better approximates the real flow behavior. The long and expensive development cycle for new engines would then be reduced.

Summary:

A transonic compressor driven by a 450 horsepower (HP) air turbine has been built and operated to 65% of design speed (31,000 RPM). The compressor is a single "impulse" stage with 11" outside diameter (OD) and a hub-to-tip ratio of 0.5 at the rotor face. In tests completed to date, a preliminary performance map for the stage (including the surge line) has been established, the flow into and out of the rotor has been measured using pneumatic probes, and the pressure and temperature of the flow at the stator exit have been mapped at chosen conditions. As a result of these measurements, changes have been made in hardware and instrumentation in preparing for tests soon to be conducted at increasing speeds, when supersonic flow is expected within the rotor blading. In addition, wall static pressures will be recorded and analyzed using high frequency response (Kulite) transducers with a microcomputer data subsystem. The goal of these and related measurements, is to understand the flow within the rotor. It was difficult to determine the time-averaged flow downstream of the rotor within a machine of this size, using available pneumatic probes. Redundant measurements with different calibrated probes were necessary before reasonable agreement between probes and with flow measurements was obtained.

Publications: R. P. Shreeve, "Flow into a Transonic Compressor Rotor, Part 1 - Analysis," Technical Report NPS57Sf74071, August 1974.

Thesis Directed:

D. J. Anderson, "Velocity Measurements in a Transonic Compressor Using a Calibrated Pressure Probe," Master's Thesis, March 1975.

TEST DATA CONTROL AND ANALYSIS

Investigator: R. P. Shreeve, Associate Professor of Aeronautics

Support: Foundation Research Program

Objective:

To remotely control the acquisition of and to obtain online reduction of data from traversing probe systems.

Summary:

To an unaided investigator, programmable calculators and peripheral equipment offer significant advantages over the central computer system for laboratory test data reduction and presentation. In order to control and analyze data from traversing probe systems and fixed instruments using a Hewlett-Packard Model 9830A system, a programmable data acquisition interface has been constructed using a microprocessor. This arrangement provides a flexible and inexpensive scanning system which relies on programmable software rather than hardware logic, and consequently promises reliability as well as low cost. The system hardware (MIDAS IV) is nearing completion. Machine language programs are being rewritten in Programming Language for Micro Processors (PL/M).

Publications: None

DEPARTMENT OF OCEANOGRAPHY

The research program of the Department of Oceanography may be considered under four headings according to the facilities utilized and the sources of data. These headings are: (1) ship programs, (2) coastal field studies, (3) deep ocean data analyses, and (4) special studies.

SHIP PROGRAMS

There are 4 investigations in this category which make use of the Naval Postgraduate School research vessel ACANIA, a ship supported by the Oceanographer of the Navy. The first of these studies conducted by J. B. Wickham, concerns the mesoscale oceanographic characteristics of the boundary between the California Counter Current and the California Current itself. The emphasis is on seasonal variations.

The second ship study is by S. P. Tucker and involves the definition of the optical properties of the waters in a band 30 nautical miles wide and 200 miles long off the California coast between Point Reyes and Point Buchon. The objective is to understand temporal and special variations in the optical properties in terms of the ordinary oceanographic observables.

Also, from the ACANIA, E. C. Haderlie carries out a survey of the biology of stone and wood boring organisms in the deeper waters of the Monterey Bay. His purpose is to determine the identity and the vertical and horizontal distribution of these borers as well as their growth rates, settlement times, and destructive effects.

In chemical oceanography, the ACANIA is used by E. D. Traganza to collect samples to determine concentrations of zooplankton biomass and the correlations between the biological, chemical, and acoustical properties of the ocean.

Two other faculty members, namely, R. G. Paquette and R. H. Bourke make use of ice breakers furnished by the U. S. Coast Guard to observe and analyze ocean thermal microstructure near the ice margin in the Chukchi Sea.

COASTAL FIELD STUDIES

The first of these studies, conducted under the direction of B. Thornton, concerns the kinematics of breaking waves in the surf zone. It is based on measurements of water particle motion and will provide increased understanding of

the energy distribution within the surf zone and associated phenomena.

Dr. Haderlie has been using concrete wharf pilings and other structures on the coast in identifying organisms responsible for deterioration of engineering materials placed in the sea and in determining the general biology and destructive effects of these organisms.

Another study involving coastal field work is a program in marine fog being conducted by D. F. Leipper and G. H. Jung. This project involves relationships between measurements from the R/V ACANIA and regularly obtained meteorological observations at shore stations. The project also undertakes analyses of data gathered at sea by other means such as through aircraft, satellites, and weather ships. The research has been expanded to include segments in the Departments of Meteorology and also Physics and Chemistry.

E. B. Thornton and N. E. J. Boston are completing an investigation to determine the relationship of fluctuating quantities such as waves, temperature, turbulent velocities, and conductivity to each other and to determine their effect on acoustic transmission over short distances (approximately 2 m). This work has been done at the offshore tower in Mission Bay near San Diego.

DEEP OCEAN DATA ANALYSIS

One program in this category is the study of oceans and severe tropical storms (OSTroC) being conducted by Dr. Leipper. It involves the collection and analysis of observations before and immediately after severe tropical cyclones. The program was initiated in Oceanography and has expanded to include a model development program by R. L. Elsberry in the Department of Meteorology.

Deep ocean weather data from ocean station NOVEMBER are used by G. H. Jung and R. H. Bourke in examining the temperature and salinity fluctuations at the sea surface and in the mixed layer. They are attempting to isolate the nature of the atmospheric processes which may be responsible for creating the observed fluctuations.

SPECIAL STUDIES

J. J. von Schwind is preparing a detailed and systematic treatise covering the geophysical fluid dynamics of the ocean. This treatise will cover the fundamentals, ocean circulation theories and models, elementary and advanced wave theory, internal waves and tides, and advanced topics.

C. Thompson is preparing spectral wave generation ghaphs which will be more operationally useful than those now available. There are to be auxiliary graphs of wave steepness, wave age, and other parameters characteristic of waves undergoing generation.

AIR/OCEAN INTERACTION AT OCEAN WEATHER STATION NOVEMBER

Investigator: R. H. Bourke, Assistant Professor of Oceanography

Support: Foundation Research Program

Objective:

To examine the temperature and salinity fluctuations at the sea surface and in the mixed layer at Ocean Weather Station (OWS) NOVEMBER and to determine and understand the nature of those atmospheric processes which are responsible for creating the fluctuations.

Summary:

The long record of atmospheric and oceanographic observations available for OWS NOVEMBER makes this a good location to conduct studies to examine the response of the ocean to atmospheric fluctuations. The initial effort was to establish the annual temperature and salinity pattern at several depths for each year of available data. This past year's effort has been to create a 24 year time series of sea surface temperature, heat budget terms, and thermal advection using 3-hourly climatological data taken from 1946-1970. Regression and spectral analyses were conducted to establish the degree of correlation of surface salinity and surface temperature to atmospheric variables and the response time involved. Surface salinity was found to be well correlated with surface pressure only, and not with the evaporation minus precipitation difference usually postulated. Surface temperature appears to respond about equally to solar insolation and net heat exchange across the sea surface, lagging both by approximately 60 days at the annual cycle. Three distinct trends have been observed in the measured annual rate of temperature change. These trends are in response to changing patterns of net heat exchange and thermal advection. Thermal advection, typically ignored in air/ocean energy exchange studies, has been found to be as important as net heat exchange in controlling sea surface temperature for extended portions of the year. Future investigation will compare surface salinity and thermal advection rates to establish the proper magnitude and direction of the advection process. In addition, the causes of the year-to-year thermal advection anomalies need to be investigated.

Publications and Conference Presentations:

R. H. Bourke and L. M. Thorne, "The Role of Heat Exchange and Thermal Advection on Sea-Surface Temperature Change at OWS NOVEMBER." Paper presented at Annual Fall Meeting of the

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American Geophysical Union. December 1974. Abstract published in The Transactions, Vol 56 (April 1975).

K. M. Rabe and R. H. Bourke, "A Statistical and Spectral Analysis of the Air-Sea Interactions at OWS NOVEMBER." Environmental Prediction Research Facility, Monterey, Technical Paper 9-75.

Theses Directed:

L. M. Thorne, "The Effects of Heat Exchange and Thermal Advection on the Rate of Change of Temperature at OWS NOVEMBER." Master's Thesis, 1974.

K. M. Rabe, "Spectral Analysis of the Energy Exchange at OWS NOVEMBER." Master's Thesis, 1975.

BIOLOGY OF STONE AND WOOD BORING ORGANISMS IN THE DEEPER WATERS OF MONTEREY BAY AND MONTEREY SUBMARINE CANYON

Investigator: E. C. Haderlie, Professor of Oceanography

Support: Office of Naval Research

Objective:

To determine the identity, the vertical and horizontal distribution, and the substrate preference of major stone and wood borers in the deeper waters of Monterey Bay, and to determine growth rates, settlement time, and destructive effect of these organisms by exposing experimental materials at various depths to be recovered at regular intervals for analysis.

Summary:

This is a long-term study that will require several years to complete. During the past year dredging operations have been carried out to recover representative stone samples, and experimental panels of a variety of materials have been exposed for periodic recovery.

To date numerous species of stoneborers have been collected from shale on the bottom, and these are being identified. Hard chert, previously thought to be impervious to mechanical and chemical borers, has been found to be severly damaged by both types of borers.

Publications and Conference Presentations:

E. C. Haderlie, "Destructive Marine Wood and Stone Borers in Monterey Bay." Presented at the 3rd International Biodegradation Symposium, Kingston, R. I., August 1975, and will appear in the Proceedings.

BIODETERIORATION STUDIES IN MONTEREY BAY

Investigator: E. C. Haderlie, Professor of Oceanography

Support: Naval Facilities Engineering Command

Objective:

To identify the various organisms in the shallow water of Monterey Bay that are responsible for the deterioration of engineering materials placed in the sea, and to determine the general biology and destructive effects of these organisms.

Summary:

This is a long-term project that has been underway for several years. During this past year emphasis has been on the biodeterioration of concrete wharf pilings and the evaluation of tropical woods to wood borer attack.

Publications: E. C. Haderlie, "Fouling Communities in the Intertidal Zone on Wooden and Concrete Pilings at Monterey, California" has been accepted for inclusion in the 4th International Congress on Marine Fouling and Corrosion to be held in France in June 1976 and will be published as part of the Proceedings.

Thesis Directed:

W. Donat, "Subtidal Fauna on Concrete Piles," Master's Thesis, September 1975.

SUMMARIZING RESULTS OF STUDIES OF AIR/OCEAN INTERACTION AT OCEAN WEATHER STATION NOVEMBER

Investigator: G. H. Jung, Professor of Oceanography

Support: Foundation Research Program

Objective:

To summarize results from three theses over the past two years in publishable form; the studies have included analyses of temperature and salinity fluctuations in the upper 200 meters of the water column; studies indicating atmospheric variables associated with those long-term fluctuations; and calculations of heat budget and thermal advection associated with periods of anomalous sea-surface temperature at this ocean location.

Summary:

During 1968-70, concurrent temperature and salinity fluctuations observed between the permanent thermocline region and the sea surface were examined for periodicity and variability. Surface temperatures showed annual periodicity with a mean range of 5.6°C, with great variability from year to year. Anomalous temperature decreases often accompanied decreases in salinity. At 50 meters, the annual temperature maximum lagged the surface maximum by one to three months, with a smaller annual range of 3.8°C. Temperatures at the surface and at 50 meters were nearly identical during the autumn-winter phase of the annual cycle, although there was high correlation also during the spring transition period. Little correlation occurred between surface and 200-meter temperatures, which showed little annual periodicity; 200-meter salinity behaved similarly. Surface temperature and salinity were poorly correlated in most periods.

Salinity at both the surface and 50 meters had a semi-annual period; possibly periodic horizontal advection of low salinity water occurred into this region; during a short interval annually, low temperature-high salinity water appeared to upwell through the thermocline.

The rate of temperature change resulting from effects of horizontal heat advection and heat exchange across the sea surface was studied between 1954-70. Surface heating and warm advection combined to produce ocean-temperature increases from March-June; from June-September surface heating was opposed by cold advection; from September-October, surface heating opposed cold advection; and from October-March, surface cooling and cold advection combined to produce ocean

temperature decreases. Salinity variations usually were consistent; cold advection had associated lower salinities and conversely; only in September-October was cold water associated with higher salinities, which suggested that vertical advection (upwelling) occurs then. A helpful and convenient method to identify and describe sea-surface temperature anomalies involves comparison of monthly temperature changes due to surface heat exchange and advection with annual average values.

Spectral analysis and other statistical measures were used to describe the interactions of the air-sea interface, especially in terms of those parameters closely associated with fluctuations of daily average surface temperature and surface salinity. For 1968-70, surface salinity surprisingly was poorly correlated with evaporation, evaporation minus precipitation, and precipitation; this suggests that these were unimportant in controlling surface salinity here. Of the tested parameters, surface pressure was the most strongly correlated with surface salinity, suggesting a relation to positioning of the transition zone separating subarctic from subtropical waters.

For the yearly cycle, net radiation appeared to be a measure of advection present, and these are of comparable magnitude. The yearly cycle was dominant in spectral analyses of the 24-year time series (1947-70) for heat budget parameters studied (sea-surface temperature, air temperature, wind speed, etc.). The series for back radiation, cloud cover, wind speed and its square also showed semi-annual and seasonal cycles.

Only solar radiation and advection in the net heat-exchange terms were of suitable phase and coherence at the yearly cycle to be valid predictors of sea surface temperature. Other heat transfer parameters appeared to have less effect on fluctuations of sea-surface temperature. Several of the parameters, such as air temperature, were also highly coherent, and usually had smaller associated lags.

Publications: None

OBSERVATION ANALYSIS AND FORECASTING OF MARINE FOG

Investigators: D. F. Leipper and G. H. Jung, Professors of Oceanography,
R. J. Renard, Professor of Meteorology, and
G. E. Schacher, Associate Professor of Physics and Chemistry

Support: Naval Air Systems Command

Objective:

(A) To develop an approach to derive economically a credible global climatology of marine fog occurrence and to improve the capability of analyzing the areas of marine fog, (B) to analyze statistically data including radiosonde observation (RAOBS) from three typical west coast stations. Particularly to seek those factors affecting the height and strength of coastal inversion and to relate the processes which appear to be occurring to the various stages in a west coast fog-stratus sequence. To document the importance of fog in naval operations. To study fog at a weather ship location, (C) to undertake work at sea so that offshore conditions may be inferred from regularly available observations along the coast. To begin measurements of turbulent parameters in fog situations at sea.

Summary:

A. Climatology (Renard): The climatology of marine fog over the open ocean is poorly documented, and with reference to a source widely used by the Navy, the climatology is incorrect. The Naval Postgraduate School (NPS) group has developed a unique approach to deriving marine fog frequencies by synthesizing the information to content of the visibility-weather group elements of the marine synoptic report into a computerized specification of the percentage of the synoptic period experiencing fog. Some 12 years of North Pacific ship-report data (over a half million reports, 30-60N) for the major fog season months of June, July, August and September have been processed to derive credible fog frequencies. As a prototype study the results have universal application to all ocean areas.

Until such time that marine-fog areas can be initially specified accurately and completely, the forecasting of marine fog will remain primitive. Conventional ship data, at best sparse, are not adequate. Therefore, weather satellite observations (Infra Red (IR) and Visual) are being utilized as the source to specify areas of marine fog. A statistical approach to identifying critical brightness (visual mode) and temperature (IR mode) values associated with marine fog appears to have promise.

B. Data Analysis and Ramifications of Fog (Leipper, Jung): The importance of marine fog in naval operations has been documented by consideration of some of its ramifications in two important World War II experiences by evaluating its adverse effects during a recent five-year period in flight and surface ship naval operations and by an overall review of the various types of naval maneuvers which would be influenced by visibility.

For fog forecasting at sea, two specific ocean weather stations were selected and a detailed analysis of events in the fog months of May and June 1953 was prepared. Indicated relationships between sea surface temperature, and dew point and the trajectory of air masses may be useful in improving at-sea forecasts.

In the west coast studies, selected synoptic scale meteorological parameters were examined for possible forecasting relationships. This study focused attention on the problems of obtaining representative data and upon verification procedures for fog forecasts. Also, work continued on the definition of the sequence of events which seems often to occur in the development of west coast fogs. If such a sequence can be verified as a common occurrence, it would provide for considerable improvement over the present widely-used methods of fog forecasting based largely upon persistence.

C. Work at Sea (Leipper, Jung, Schacher): A cruise was conducted in late summer 1974 off the northern California coast. Micrometeorological and micro-physical measurements were made by another (CALSPAN) and will be reported by them. NPS personnel made upper air observations and provided overall synoptic analyses for the time period involved.

Efforts were initiated by Dr. Schacher for the measurement of turbulent parameters in fog situations at sea. His work is being done in conjunction with personnel of the NPS Electro-Optics Laser Technology Project.

Publications: R. J. Renard, R. E. Englebretson and J. S. Daughenbaugh, "Climatological Marine-Fog Frequencies Derived from a Synthesis of the Visibility-Weather Group Elements of the Transient-Ship Synoptic Reports." Technical Report NPS51Rd75041, April 1975.

Theses Directed:

R. E. Englebretson, "A Synthesis of the Elements of Random-Ship Synoptic Reports to Derive Climatological Marine-Fog Frequencies,"

Master's Thesis (Advisor: R. J. Renard) September 1974.

J. S. Daughenbaugh, "Further Development and Applications of the Naval Postgraduate School's Program for Deriving Marine-Fog Frequencies," Master's Thesis, March 1975.

F. Misciasci, Jr., "Fog Occurrence and Forecasting at Two North Pacific Ocean Stations," May and June, 1953, Master's Thesis (D. F. Leipper, Advisor), September 1974. Also Technical Report NPS58Mi74101.

S. E. Wheeler, "Marine Fog Impact on Naval Operations," Master's Thesis, September 1974. Also Technical Report NPS58Wh74091.

THE OCEANS AND SEVERE TROPICAL STORMS

Investigators: D. F. Leipper, Professor of Oceanography
R. L. Elsberry, Associate Professor of Meteorology

Support: Office of Naval Research

Objective:

To study the effect of severe tropical cyclones upon the surface layers of the oceans through a coordinated modeling and data collection effort. The basic hypothesis is that the large-scale changes in near-surface oceanic parameters are relatively slowly changing, except during, and following, periods of intense forcing due to the passage of atmospheric cyclones. A continuing study of the air-sea interaction processes on a synoptic scale during situations of large stress and large upward surface heat fluxes is proposed.

Summary:

Model Development: The first phase of the modeling effort was to develop an interacting hurricane-ocean model capable of simulating the surface heat and momentum fluxes.

Next an oceanic mixed-layer model coupled to the hurricane model was described. In this model time-dependent solutions for mixed-layer depth and temperature were obtained, using equations similar to Kraus and Turner (1967), except that radial advection (using Ekman theory) was included. In contrast to previous model results, this ocean model emphasizes the role of thermally and mechanically generated turbulence in cooling and deepening the upper ocean layer and the horizontal distribution of mixed layer depth is more realistic than in previous models.

The ocean model is currently being improved through the use of the hydrodynamic equations, thus removing the assumption of Ekman-type relations for the advective terms.

Data Collection and Analysis: The observational studies have concentrated on collection and interpretation of historical data. Two approaches have been taken: (1) examination of data from planned ship cruises; and (2) a systematic search of the Fleet Numerical Weather Central (FNWC) files for all Bathy Thermographs (BT's) in the region of western Pacific typhoons. In the first case the emphasis is on a careful study of the best-available, but unpublished, distribution of BT's following a hurrican. These data were

taken by Professor D. Leipper and his associates at Texas A&M following passage of hurricane Betsy.

The second data collection is an attempt to specify thermal structure changes due to typhoon passage using the FNWC historical BT file. A space-and-time-envelope around each typhoon position is specified. The number of BT's for a particular typhoon may range from less than 15 to more than 150, depending on the location and speed of movement of the storm. A number of characteristic quantities are being calculated for each sounding. These quantities are to be composited relative to the storm track to statistically analyze the changes due to storm effects.

Approval was obtained during the last year for a series of expendable bathy thermographs (AXBT) drops in advance of a typhoon, and subsequent drops at the same points after typhoon passage. It was anticipated that the flights could be made by aircraft based on Guam. The prime objective of this experiment was to specify both the pre-storm and post-storm thermal structure with a minimum time lapse. Given the limited resources, the optimum use of the AXBT's appeared to be a sample along a cross-section normal to the storm track. By revisiting the identical locations at least two times after storm passage, the thermal response characteristics would be determined on a much shorter time scale than it has been possible to determine from ship cruise data.

Publications:

R. L. Elsberry, N. A. S. Pearson and L. B. Corgnati, Jr., "A Quasi-empirical Model of the Hurricane Boundary Layer," Journal of Geophysical Research, 79 (July 1974). Also distributed as Technical Report NPS51Es-74011A.

R. L. Elsberry, T. S. Fraim, and R. N. Trapnell, Jr., "A Mixed-layer Model of the Oceanic Thermal Response to Hurricanes." Accepted by the Journal of Geophysical Research.

P. D. Shuman, "1973 Variations of Hurricane Heat Potential in the Philippine Sea and the Gulf of Mexico," Technical Report NPS-58Lr74031, 1974.

Theses Directed:

S. H. Grigsby, "The Response of a Two-Layer Hydrothermodynamic Ocean Model to a Simulated Moving Hurricane, Master's Thesis, 1975.

R. N. Trapnell, Jr., "Ocean Thermal Response to a Moving Hurricane Model," Master's Thesis, September 1974.

ANALYSIS OF MARGINAL SEA ICE ZONE PACIFIC OCEANOGRAPHIC DATA

Investigators: R. G. Paquette and R. H. Bourke, Professors of Oceanography

Support: Naval Undersea Center

Objective:

To analyze oceanographic data obtained near the Arctic Marginal Sea Ice Zone Pacific (MIZPAC) and to examine particularly the distribution of and the causes for thermal microstructure found near the ice margin in the Chukchi Sea.

Summary:

In summer, the water south of the ice is sharply layered with a warm layer, up to 10°C and about 10 meters thick, on top of cold dense water. At or near the ice margin much of the sharp layering disappears, the surface cools and isopycnals and isotherms are disturbed or modified all the way to the bottom, which averages about 45 meters in depth. The melting of ice at the surface produces an elevation of the sea surface of as much as 2 centimeters underneath the ice margin and unusually large oscillations in the temperature profile sometimes appear in mid-depth. These oscillations have been termed mesostructure because they have larger amplitudes than the common conception of microstructure. Where there is a small elevation of the sea surface there is little or no mesostructure. Hence, reasonably rapid melting of the ice must cause the phenomena. When there is little mesostructure the rate of supply of heat to the ice margin must be small, implying either a slow northward flow or a relatively low temperature in the upper layer. There also appears to be a correlation between a diffuse ice margin and mesostructure. When the ice margin is scattered southward into warm water by the wind, accelerated melting must occur; hence more mesostructure. It is postulated that the mixing of water downward is due to the lateral pressure gradient of the sea surface elevation deflecting the northward-flowing upper layers downward. The intrusion of warm water into the colder water at depth is a complex phenomenon. To date it has not been possible to trace a given mesostructure element from its source when instrument lowerings are spaced about one nautical mile. However, the general aspects of the phenomenon on a larger scale are coming into focus.

Publications: None

Thesis Directed:

A. E. Karrer, "The Descriptive and Dynamic Oceanography of the Mesostructure Near Arctic Ice Margins," Master's Thesis, September 1975.

OCEANOGRAPHIC INVESTIGATION OF THE BERING AND CHUKCHI SEAS

Investigators: R. G. Paquette and R. H. Bourke, Professors of Oceanography

Support: Naval Undersea Center

Objective:

To find the distribution of and the causes for thermal microstructure found in water columns near the Arctic ice margin. This project is a continuation of studies made in Fiscal Years 1972, 1973, and 1974 under the general title MIZPAC.

Summary:

The experimental measurements were made with a salinity-temperature-depth recorder (STD) from a Coast Guard icebreaker in July and August 1974. The studies began in the ice-free waters near Nome and continued quickly northward until the ice margin was reached. There a number of crossings of the margin were made, using closely spaced stations, with the expectation that some continuity of the anomalous structural elements could be found along the line of each crossing and that the mechanism by which a warm element intrudes into colder water could be seen. Graphs and tabulations were produced of salinity, temperature, sound velocity and density for 111 STD stations, using a Calma digitizer to convert the original graphical data. Approximately 100 Expendable Bathythermograph (XBT) drops were also graphed and tabulated by a similar technique. The findings from these data are summarized under a later project title: Analysis of MIZPAC Oceanographic Data. This work also led to an investigation of low-frequency acoustic transmission in the marginal ice zone which is reported elsewhere.

Publications: R. G. Paquette and R. H. Bourke, "Observations on the Coastal Current of Arctic Alaska," Journal of Marine Research, 32 (1974).

Conference Presentation:

R. G. Paquette, R. H. Bourke and W. R. Corse, "The Source of Temperature Mesostructure in the Ocean Near the Arctic Ice Margin", Paper presented at the Fall Annual Meeting, American Geophysical Union, San Francisco, December 1974.

Thesis Directed:

W. R. Corse, "An Oceanographic Investigation of Mesostructure Near Arctic Ice Margins," Master's Thesis, September 1974.

OCEAN WAVE GENERATION GRAPHS

Investigator: W. C. Thompson, Professor of Oceanography

Support: Foundation Research Program

Objectives:

To modify and publish the Pierson-Neumann-James (PNJ) spectral wave generation graphs in a more operationally useful form generally following the preliminary design of LT Anderson, and to produce a series of auxiliary graphs of wave steepness, wave age, and other parameters characteristic of waves undergoing generation. Written instructions will accompany the graphs.

Summary:

For the operational purpose of making ocean wave predictions from synoptic weather maps using manual procedures, two methods are readily available in published form to wave forecasters. The PNJ method published in U. S. Navy Hydrographic Office (H.O.) 603 (1955), gives spectral wave information as well as significant height and period; the Sverdrup-Munk-Bretschneider (SMB) method, published by Corps of Engineers, Coastal Engineering Research Center (CERC) (1973), gives the latter quantities only. Manual wave generation by the PNJ method requires the use of four unwieldy graphs of co-cumulative frequency spectra which are inconvenient to use. The primary objective of this applied project is to redesign these four graphs into a more operationally useful single graph (a preliminary hand-drawn version of which was produced under this investigator by LT J. H. Anderson), and to make the graph available in printed form for regular use by practicing forecasters. The PNJ graphs are largely empirically derived and contain irregularities and inconsistencies. In order to eliminate these problems and to transform the data for presentation into the graphical format desired it has been necessary to prepare a series of temporary working graphs for use in constructing the final modified PNJ wave generation graph. This phase is near completion. The next step will be graph layout and construction followed by drafting and printing. Auxiliary graphs, which will be overlays on the primary graph, cannot be constructed until the latter is completed but will require relatively little construction time. This is a continuing project. It is approximately half completed and is expected to require one additional academic quarter.

Publications: None

KINEMATICS OF BREAKING WAVES IN THE SURF ZONE

Investigator: E. B. Thornton, Associate Professor of Oceanography

Support: Office of Naval Research

Objective:

Basic studies are being made on the kinematics of water-particle motion within the surf zone and of breaking waves. These measurements will provide an increased understanding of the energy distribution within the surf zone, water-sediment interactions, breakdown of wave-induced motion to turbulence, and non-linearities involved in describing breaking waves.

Summary:

This research is being accomplished in the field at various beaches around Monterey Peninsula, California for the conditions of spilling, plunging, and breaking waves. Waves and orthogonal water particle velocities are measured at various locations within the surf zone. The spectral characteristics and probability density functions for breaking waves and water particle velocities are calculated. The results show the horizontal velocities in the body of the flow to be primarily wave-induced and highly correlated with the waves. Linear theory was used to estimate the spectral velocity components using the measured wave spectrum; linear theory is shown to underestimate the values at maximum energy-density by 10-80 percent. Celerity calculations between adjacent wave profiles over the coherent frequency range of the spectra indicate waves in the surf zone are non-dispersive. The statistical and spectral measurements show the breaking waves to be strongly nonlinear. An undular bore theory appears to give the best theoretical description of the breaking waves.

Publications: None

Thesis Directed:

F. L. Bub, "Surf Zone Wave Kinematics," Master's Thesis, September 1974.

SMALL SCALE INTERACTIONS IN THE UPPER OCEAN

Investigators: E. B. Thornton and N. E. J. Boston, Associate Professors of Oceanography

Support: Office of Naval Research

Objective:

To determine the relationship of fluctuating quantities such as waves, temperature, turbulent velocities, and conductivity to each other, and to determine their effect on acoustic transmission over short (∿2m) distance.

Summary:

Measurements of a variety of ocean parameters have been made from the Naval Undersea Research and Development Laboratory's Oceanographic Research Tower located 1.5 km off Mission Beach, California (near San Diego). Field experiments were made in October 1971, June 1972, May 1973, and April 1974. Sensors are placed on a 2m x 2m x 2m frame which is attached to a carriage which is lowered to various fixed depths. Time series measurements are then made at those depths. The first two experiments concentrated on wave-wave particle velocity interactions and on acoustic interactions with the environment. The third and fourth experiments concentrated on detailed temperature fluctuation measurements. The fourth experiment also featured additional acoustic measurements and conductivity fluctuation measurements. All significant data from the first three experiments have been analyzed. Analysis of the data from the fourth and last experiment was completed in September 1975. Mathematical models have been developed which explain several aspects of the interactions observed.

Publications: H. J. Medwin, R. L. Routmann and J. R. Fitzgerald, "Acoustic Mini-Probing for Ocean Microstructure and Bubbles," Journal of Geophysical Research, January 1975.

H. Medwin, "Predicting Sound Phase and Amplitude Fluctuations due to Microstructure in the Upper Ocean," Technical Report NPS61Ms-73111A, June 1974.

Theses Directed:

J. B. Hagen, "Acoustic Fluctuations Due to Shallow Water Thermal Microstructure," Master's Thesis, September 1974.

L. K. Kane, "Measurement and Analysis of Temporal Variations of Salinity in Shallow Water," Master's Thesis, September 1974.

INVESTIGATION OF BIOCHEMICAL RELATIONSHIPS FOR DETERMINING CONCENTRATIONS OF ZOOPLANKTON BIOMASS AND ITS CORRELATION WITH CHEMICAL AND ACOUSTICAL PROPERTIES OF THE OCEAN

Investigator: E. D. Traganza, Associate Professor of Oceanography

Support: Office of Naval Research

Objective:

To study biochemical relationships associated with biomass and trophic level in marine zooplankton. This is part of a continuing research program in chemical oceanography.

Summary:

Sonar systems are limited by reverberation associated with marine organisms. One hypothesis is that zooplankton estimates can be useful in predicting the "volume reverberation" by virtue of their importance in marine food chains. In the past there have been no simple, reliable methods which would give estimates of zooplankton biomass. Now there is considerable promise that biochemical relationships of cellular constituents can be used to measure the concentration of zooplankton and identify their trophic level. Work so far has been directed toward adenosine triphosphate (ATP) as a measure of living biomass, carbon as a measure of total biomass, and dissolved phosphorous, salinity, and temperature for describing related environmental variability. Research at sea has included a seasonal study off Monterey, California, and an open ocean transect between Hawaii and Tahiti. Zooplankton were separated in situ into five size fractions. The most interesting result was the relative constancy of the carbon:ATP ratio of the largest size fraction despite a distinct doubly peaked cyclic seasonal pattern for carbon or ATP alone. The changes were in general associated with environmental periods characterized by phosphorous, salinity and temperature. Important questions which are raised are: Can ATP be used to estimate living biomass of the larger size fraction? Does the carbon:ATP ratio vary in other fractions because of a change in species composition, a seasonal build up of residual dead matter, or a biochemical response to the changing environment? An important element in finding the answers to these questions is the continuing development of instrument systems including, e.g., an interface between the ATP photometer and a Wang programmable calculator.

Publications: E. D. Traganza and K. J. Graham, "ATP in Marine Zooplankton," ATP Methodology Conference, San Diego, March 4-6, 1975. Abstract printed by Science Application Incorporated Technology Company, San Diego, 1975.

E. D. Traganza, J. C. Radney and K. J. Graham, "A Convenient Method for the Determination of Carbon in Marine Net Zooplankton." Accepted for publication by Marine Chemistry, December 1975.

E. D. Traganza and J. C. Radney, "Biochemical Relationships of Secondary Biomass and Dissolved Inorganic Nutrients." Abstract in the Proceedings of the American Geophysical Union, Annual Meeting, San Francisco, January 1975.

E. D. Traganza, J. C. Radney and K. J. Graham, "Convenient High Temperature Dry Combustion Thermal Conductivity Instrument for the Determination of Carbon in Marine Zooplankton," Technical Report NPS58Tg75081.

Theses Directed:

J. C. Radney, "Measurement of Zooplankton Biomass by Carbon Analysis for Application in Sound Scattering Models," Master's Thesis, September 1974.

T. Pearson, "A Computer Simulation Model of Seasonal Variations in Ocean Production for a Region of Upwelling," Master's Thesis, September 1975.

W. E. Soloman, "An Evaluation of the Volume Scattering Strengths Used in the Ship, Helicopter Range Prediction System (SHARPS II), Master's Thesis, September 1975.

SIZE AND NUMBER DISTRIBUTIONS OF SUSPENDED PARTICULATES IN THE 1.5 - 35 MICRON RANGE IN CENTRAL CALIFORNIA COASTAL WATERS

Investigator: S. P. Tucker, Assistant Professor of Oceanography

Support: Foundation Research Program

Objective:

The long term objective is to understand the temporal and spatial variations in optical properties of the ocean in terms of non-optical oceanographic observables. The short term objective is to map the distribution of suspended particulates in a 30-nmi wide by 200-nmi long region off the California coast between Pt. Reyes and Pt. Buchon.

Summary:

Raw data from approximately 7000 water samples representing more than 100,000 discrete particle size measurements (made with a 15-channel Coulter counter) are now available together with other, standard oceanographic data such as temperature and salinity as functions of depth; they have been collected on more than a dozen Naval Postgraduate School (NPS) oceanographic cruises during the past five years. Almost all of the particle size data have either been put on punched cards or have been coded for punching. Computer programs for handling and plotting the particle size data have been written as a first step in the preparation of a particle size atlas. The data from four cruises have been machine tabulated and have been graphed in terms of size distributions as functions of depth and of horizontal distance along lines of stations. In addition, isometric drawings have been prepared which show the size distributions as functions of depth and of distance. Of special interest are the observed heavy concentrations of particulates in the upper ocean in areas of localized upwelling. It is expected that this project will be continued to include all particle size data collected to date by NPS and to investigate statistically the influence of the ocean density distribution on particulate distributions.

Publications: None

Thesis Directed:

L. Diddlemeyer, "Distributions of Suspended Particulate Matter Off the California Coast From San Francisco Bay to Cape Martin," Master's Thesis, 1975.

DYNAMICS OF THE OCEANS

Investigator: J. J. von Schwind, Associate Professor of Oceanography

Support: Naval Sea Systems Command

Objective:

To prepare a detailed and systematic treatise covering the geophysical fluid dynamics of the oceans. When complete, the said treatise will include fundamental and advanced topics and be so structured and written as to be particularly useful to technical persons whose work involves the ocean environment but who may have little or no formal education in theoretical physical oceanography.

Summary:

The treatise in its entirety will consist of four major parts: (1) Fundamentals of Geophysical Fluid Dynamics; (2) Ocean Circulation Theories and Models; (3) Elementary and Advanced Wave Theories, Internal Waves, Tides; and (4) Advanced Topics in the Fluid Dynamics of the Ocean. At the present time, the subject matter to be covered is found only in a wide variety of sources, ranging from textbooks and technical journals to personal unpublished notes. To date a portion of the first section "Fundamentals of Geophysical Fluid Dynamics" has been completed.

Publications: None

STRUCTURE OF THE CALIFORNIA COUNTERCURRENT

Investigator: J. B. Wickham, Associate Professor of Oceanography

Support: Foundation Research Program

Objective:

To describe the structure and flow in the latitude of Monterey of the California Countercurrent, including the delineation of mesoscale oceanographic features of the system in the vicinity of its boundary with the California Current. In this portion of the study emphasis is given to the seasonal variation.

Summary:

Data have been analyzed from one year's surveying at approximately one month intervals of a region of the sea between the continental shelf edge and about 90 km. to the west and from the sea surface to depth 500 m., this being the region in which most of the California Countercurrent flow occurs. During the first half of this year of observations (Aug 73 - Aug 74) the data included temperature, salinity, and pressure from which an important component of current can be inferred; but for the remaining half, there was insufficient information to permit calculation of currents. The results of the analysis to date show that the northward flow, the countercurrent, is filamental in each of the months of survey with transverse scales of a few tens of kilometers or less (definition is to 5 km) and average speeds of 20 cm/sec. The filaments are separated by narrower regions of southward geostrophic flow at higher speed, say several tens of cm/sec. The greatest speeds are near the surface for both directions, there being little indication of an "undercurrent." Temperatures in the deeper layers are lowest at the western edge of the region, but the contrast is markedly greater in June through August when a large influx of southern water appears below 300 m. near the coast with a sharply defined boundary about 20 km. to the west. Another feature of interest is a narrow but persistent filament of southern water between depths 100-300 m. near the region's western edge in the months of October 73 through January 74. Additional analysis remains to be completed on a set of data which may show structural changes on a short time-scale.

Publications: J. B. Wickham, "Observations of the California Countercurrent," Journal of Marine Research, 33 (September 1975).

Theses Directed:

R. E. Greer, "Geostrophic Flow in the Vicinity of the California Countercurrent," Master's Thesis, 1975.

R. E. Blumberg, "Seasonal Variations in Water Masses in the Vicinity of the California Countercurrent," Master's Thesis, 1975.

J. G. Hughes, "The Statistics of Sound Speed Variations Near the Boundary of the California Countercurrent," Master's Thesis, 1975.

DEPARTMENT OF MECHANICAL ENGINEERING RESEARCH PROGRAM FY75

The Department of Mechanical Engineering has a diversity of research interest and talent as is evidenced by the variety of projects. The various categories are as follows: (1) materials science, (2) mechanical and component design, (3) heat transfer, (4) structures, vibrations, and solids, (5) guns and missiles, (6) hydrodynamics and fluid mechanics, (7) environment and energy, and (8) laser technology.

MATERIALS SCIENCE

The Naval Postgraduate School (NPS) has a strong commitment in Materials Science with excellent research equipment and dynamic faculty. Professors G. R. Edwards and A. J. Perkins share the research projects in materials approach to ship silencing and shape-memory alloys for naval gunnery. Note that the shape-memory alloys projects contribute to categories 1 and 5 from the list cited above. Materials properties of ferrocement are not well documented with the result that the design of boat hulls is inefficient. Professor E. A. McKinnon investigated the fatigue life of ferrocement formed from two distinct meshes and several mortars.

MECHANICAL AND COMPONENT DESIGN

The ultimate goal of engineering is to design and create devices which accomplish a specified task. Professor E. A. McKinnon and his students designed a new propulsion system for underwater swimmers. Also, Professor McKinnon's interest included energy storage in flywheels. A study of extraction of energy available from temperature difference between the surface and bottom of the ocean was accomplished by Professors R. H. Nunn and M. D. Kelleher. Stringent requirements are placed on Navy ships in regard to discharge of oil in bilge water. Determination of hydrocarbon content measured in parts per million (PPM) requires sensitive and heretofore unavailable instrumentation. Professor T. M. Houlihan developed a suitable monitor which is being transferred to the Naval System Research Development Center (NSRDC) for additional tests.

HEAT TRANSFER

Obviously, heat transfer is an extremely important facet of a Mechanical Engineering department. Transfer of heat is a phenomenon which occurs in all machines including the human

body. Several innovative techniques have been evolved at NPS including use of liquid crystals to determine temperature profiles. Professor P. J. Marto has conducted a research program involving heat transfer in rotating machinery. Professor T. E. Cooper used the low turbulence wind tunnel to investigate heat transfer characteristics of a heated cylinder placed normal to an air stream; the cylinder is adjacent to a wall so that the influence of walls is clearly identified. Ordnance, e.g., gun projectiles and rocket boosters, have temperature limitations. Another investigation by Professor Cooper addresses the question of temperature excursions experienced by ordnance stored in the desert environment.

Heat pipes are an important new development and one being thoroughly studied by Professor Kelleher. In addition, Professors Kelleher and Marto are investigating temperature distributions in electronic equipment. A new Military Specification (MILSPEC) is being prepared by the Department of Defense (DoD) on the subject of cooling electronic equipment. The results of their work will have an impact on the MILSPEC.

STRUCTURES, VIBRATIONS, AND SOLIDS

The faculty in Mechanical Engineering have been pioneers in the finite element method for numerically solving the equations of fluid mechanics and solids. Professor R. E. Newton has made significant progress on the difficult problem of the interaction between blast waves in fluids and structural response. Professor J. E. Brock's research activities are represented in the list of publication which appears as an appendix hereto. Additionally, his work on Stress Analysis of Thermowells (Technical Report NPS-59Bc74112A) has received considerable attention. Two local printings have been exhausted, and many who have asked for copies have been referred to the National Technical Information Service.

GUNS AND MISSILES

Several professors are involved in research relative to guns; these are Professors Nunn, Houlihan, Perkins, Edwards, Salinas, and Fuhs. Professors Nunn and Houlihan have investigated the dynamics of liquid gun propellants. Liquid propellant guns offer potentially many advantages including caseless ammunition; an 8" gun case costs $500. Professor Fuhs* is investigating external burning to

*Professor Fuhs recently joined the Mechanical Engineering Department. Previously, he was a faculty member in Aeronautics.

create base thrust in gun-launched projectiles. The shape-memory alloy project of Professors Perkins and Edwards may provide a new approach to gun barrel liners. Professor Salinas ran several elastic-plastic analyses of obturators for the Naval Weapons Laboratory in Dahlgren. Professor Nunn has investigated the aerodynamics of missiles at high angles of attack.

HYDRODYNAMICS AND FLUID MECHANICS

Several staff members have research interest in this particular area. Professor T. Sarpkaya has investigated the problem of cable strumming, periodic flow about bluff bodies, effects of polymers on the lift and drag characteristics of hydrofoils, the vortex breakdown phenomenon in connection with the flight of delta wing aircraft, and the stability of swirling flows, and the circulation control rotor of helicopters in connection with fluidic devices. An additional area of interest of Professor Sarpkaya is the application of the finite element and boundary integral techniques to the solution of thrust reverser problems. Among the most recent research facilities in hydrodynamics is the large U-shaped water tunnel constructed by Professor Sarpkaya. This facility is unique and provides full simulation of Reynolds numbers encountered in practice. Professor C. J. Garrison has been concentrating his research efforts primarily in the area of free-surface hydrodynamics which includes analytical methods for both the evaluation of wave loads on fixed bodies and the dynamic response of floating bodies in ocean waves. He has also made significant progress in extending his wave/body interaction work to include nonlinear effects. This work has resulted in procedures for computing wave loads on large ocean structures which have now become standard in both the United States and abroad. Some aspects of the work have contributed to the understanding of the dynamic response of ships and other bodies in shallow water. Professor Garrison has concluded an extensive experimental wave channel study of nonlinear wave forces on a bottom-mounted cylinder and has continued his experimental work on the evaluation of the hydrodynamic forces on cylinders oscillating in a fluid at rest. This work is directed toward the determination of the experimental coefficients required in certain types of wave force problems. The emphasis is on the large Reynolds number region for use in application. Professor Kelleher has constructed a curved channel to investigate secondary flows; his research also impinges on heat transfer. Professors Nunn and Houlihan participate in hydraulics research related to control.

ENVIRONMENT AND ENERGY

Three faculty members, Professors Nunn, Houlihan, and Kelleher have contributed to the area of environmental problems and new energy sources. Their attention was focused on bilge water pollution and energy from thermal gradients in the ocean. Another faculty member, Professor D. H. Nguyen, has been conducting extensive research on Nonlinear Nuclear Reactor Dynamics. During FY75, Professor Nguyen's research results include the extremely fast dynamic solutions of the nonlinear nuclear reactor under the combined effect of prompt supercriticality and negative feedbacks, obtained by both analytic and numerical methods. These solutions are vital in the core disruptive accident (CDA) analysis of fast breeder reactors. Professor Salinas actively participated in the application of finite element method to solve a nonlinear reactor dynamics problem.

LASER TECHNOLOGY

Lasers continue to grow in importance in military operations; the trend is toward even greater significance in the future. Professor Houlihan is a team member of the group investigating laser propagation in the marine boundary layer. Professor Fuhs has worked on cylindrical laser diffusers, transonic thermal blooming, and laser applications for future naval aircraft.

AN INVESTIGATION OF MISSILE HEAT TRANSFER CHARACTERISTICS

Investigator: T. E. Cooper, Associate Professor of Mechanical Engineering

Support: Naval Weapons Center

Objective:

To develop a realistic thermal predictive model that will enable one to specify the thermal state of a weapon at any time during its stockpile-to-target sequence.

Summary:

A theoretical model has been developed for predicting the daily temperature distribution in dump-stored ordnance. The model uses as input standard meteorological data, i.e., solar insolation, air temperature, wind velocity, and relative humidity. The model has been used to predict the temperature distribution in Shrike and Sidewinder missiles placed in dump storage in the Mojave Desert during July and August 1974. Theoretical predictions and experimental measurements have been made with the missiles in the following configurations: (1) Missiles directly exposed to environment, (2) Missiles stored in single containers, (3) Missiles stored in multiple storage containers. Although the theoretical predictions are now available, the sponsor has not yet made available experimental data for comparative purposes.

Publications: None

EXPERIMENTAL INVESTIGATION OF THE HEAT TRANSFER CHARACTERISTICS OF A HEATED CYLINDER PLACED NORMAL TO AN AIR STREAM

Investigator: T. E. Cooper, Associate Professor of Mechanical Engineering

Support: Foundation Research Program

Objective:

To determine experimentally the local heat transfer and pressure coefficients on the surface of a uniformly heated cylinder placed in close proximity to a flat plate located in a cross flow of cool air.

Summary:

Local heat transfer and pressure coefficients have been experimentally determined at a Reynolds number of 153,000 on a uniformly heated cylinder placed in close proximity to a flat plate. Measurements have been made as a function of the gap width between the plate and cylinder. This gap width has been varied from zero (plate and cylinder touching) to four cylinder diameters. All tests were conducted with a plate length ahead of the cylinder equal to four cylinder diameters. The length of the plate downstream of the cylinder was purposely made large to maintain a constant effect. In addition to local values, average Nusselt numbers and lift and drag coefficients have also been determined. Future plans call for similar measurements to be made over a range of Reynolds numbers. Additionally, the length of the leading edge of the plate will be varied from two to eight diameters.

Publication and Conference Presentation:

T. E. Cooper, R. S. Field, and J. F. Meyer, "Liquid Crystal Thermography and its Application to the Study of Convective Heat Transfer." Presented at the 15th National Heat Transfer Conference, 10-13 August, San Francisco. Published in the Journal of Heat Transfer, Vol 97, Series C, No. 3 (August 1975).

Thesis Directed:

C. H. Gnerlich, "The Convective Heat Transfer Behavior of a Heated Cylinder Located Near a Plane Surface," Master's Thesis, June 1975.

CYLINDRICAL SHOCKWAVE DIFFUSER FOR GAS DYNAMIC AND CHEMICAL LASERS

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Support: Naval Air Systems Command

Objective:

To determine to what degree significant reductions in laser weight and volume can be achieved by use of cylindrical laser geometry. Prior to this investigation, a multiple-nozzle, cylindrical geometry had never been operated in supersonic flow with a cylindrical shock wave.

Summary:

Apparatus using 4, 5, or 6 nozzle discs was designed. The discs were fed along the centerline from both ends of the stack. The design Mach number was 4.2. Boundary layer bleed was provided in both end walls. The cylindrical nozzles were installed in a plenum which had ejectors for control of the exit pressure. A cylindrical shock wave was established with a region of supersonic flow between nozzle exit and the shock wave. The shock wave was corrugated due to variations in stagnation pressure arising from nozzle boundary layers and wakes. In spite of extensive suction on boundary layer at end walls, the end flow channels were not started. The experiments were a success in that a stable cylindrical shock wave formed by a multiple disc nozzle array was demonstrated. More work is required to establish supersonic flow in the channels next to the end walls.

Publications: None

Thesis Directed:

D. Donoghue, "An Experimental Analysis of a Cylindrical Shock Wave for Use in a Cylindrical Gas Dynamic Laser," Master's Thesis, June 1975.

TRANSONIC THERMAL BLOOMING OF A SLEWED HIGH ENERGY LASER BEAM

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Support: Air Force Weapons Laboratory

Objective:

To study the seriousness of thermal blooming near Mach one.

Summary:

Due to absorption of radiation from a laser beam the index of refraction changes, causing spreading of the beam; this process is known as thermal blooming. When the beam is slewed, as it will be when tracking, there is a relative wind. Depending on the Mach number of the relative wind, the severity of thermal blooming varies. At precisely Mach one, the waves arising from heat addition add. In the linear theory the perturbation grows without limit. Nonlinear effects terminate the growth.

Near a Mach number of unity the equations of gas dynamics are nonlinear. Because the equations are nonlinear, systematic solutions are nonexistent. Many special techniques have been developed for airfoils; however, these methods are not applicable to distributed heat sources, i.e., heat from laser beam. A new approach was developed. Using the equations of gas dynamics in natural coordinates, the nonlinearity can be removed if streamline shape is specified. A pair of simple first order partial differential equations result; these can be easily solved numerically. A check exists for choice of streamline shape; the check is the comparison of heat absorbed from the beam and the heat required to change flow properties. These two heat inputs must, of course, be equal. Streamline shape is adjusted until equality is achieved.

The research has shown that transonic thermal blooming is not as serious as originally feared.

Publications: O. Biblarz, F. Carey, A. E. Fuhs and H. Burden, "Numerical Results for Thermal Blooming in Transonic Slewing," Bulletin of American Physical Society, 19 (November 1974).

A. E. Fuhs, H. Burden and F. Carey, "An Exact Inverse Solution to Thermal Blooming in Transonic Slewing," Bulletin of American Physical Society, 19 (November 1974).

ASSESSMENT OF HIGH ENERGY LASER ROLE ON FUTURE NAVY AIRCRAFT

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Support: Naval Air Systems Command

Objective:

To introduce operational experience into an assessment of potential of high-power lasers on board future Navy aircraft.

Summary:

High-energy lasers (HEL) have not reached the level of technological maturity where selection of type of laser, optics, turrets, etc., is a straightforward process. Naval Air Systems Command (NAVAIRSYSCOM) wants to inject the operational experience of Naval Aviators into the selection process. For example, what about logistics of deuterium fluoride on an Attack Aircraft Carrier (CVA)? What does the carrier landing do to microradian optical alignment? Students involved in the project have a total of 50 man years of carrier experience with F-4, F-8, A-4, A-6, E-2, A-3, and A-5 aircraft. Initially a state-of-the-art gas dynamic laser was designed and packaged for the S-3 A aircraft making it a S-3 L. A joint project was initiated with National Aeronautics Space Administration (NASA) Ames to design an aircraft for a laser platform. The aircraft is the largest aircraft that can be operated from the Navy's 12 carriers. The aim was to incorporate the laser giving the most intensity (kW/cm^2) at a specified range.

Other aspects of HEL on an aircraft have been investigated. The improvement in specific power achieved by use of regenerative heating of nitrogen in a Gas Dynamic Laser (GDL) has been assessed. Future pointing and tracking needs have been studied. An important classified mission for HEL has been investigated.

Publications: None

Thesis Directed:

L. Rhine, "A Regeneration Carbon Dioxide Gas Dynamic Laser," Master's Thesis, June 1975.

EXTERNAL BURNING ASSISTED PROJECTILE

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Support: Naval Ordnance Station

Objective:

To develop a fast subroutine to replace the unwieldy external burning assisted projectile (EBAP) computer code.

Summary:

In prior years a computer program was developed which predicts base pressure for supersonic combustion in the region near the recirculation zone of a projectile. Validity of the predictions was established by a complementary experimental program. The computer program uses the saddle point singularity to uniquely select the base pressure. For Trajectory analysis of an EBAP, base pressure is required as a function of Mach and Reynolds Numbers.

To decrease computer time, selected combinations of values of input parameters have been used for determining base pressure. A regression analysis in several dimensions has yielded a subroutine which gives base pressure prediction in less than a second. Correctness of the predictions hinges on the full EBAP program. The subroutine is well suited for trajectory analysis.

A ramjet program is being developed for the HP9830 desk calculator for use by the personnel at the Naval Ordnance Station. The program models the inlet, combustion chamber and nozzle with base flow to obtain component efficiencies. Efficiencies are used to calculate specific fuel consumption, thrust coefficient and specific thrust. The program can be used in the NOS trajectory computer code. In FY 1975 the ramjet inlet and combustion chamber were modeled.

Another study initiated involves a comparison between guns and missiles. Under what conditions are guns the better weapon and under what conditions are missiles superior. Development of projectile propulsion alters the importance of range in selection of guns or missiles. There are many parameters to be evaluated including cost, time of flight, ordnance storage, response time, rate of fire, launch accuracy, etc.

Publications and Conference Presentations:

A. Roberts and A. E. Fuhs, "Analysis of Propulsion for Gun Launched Projectiles," 12th

Joint Army Navy Nasa Air Force (JANNAF) Propulsion Meeting, October 1975.

W. Smithey and A. E. Fuhs, "External Burning Assisted Projectile." To appear in American Institute of Aeronautics and Astronautics (AIAA) Progress Series. (In press).

Thesis Directed:

W. Smithey, "Projectile Thrust-Drag Optimization with External Burning," PhD Dissertation, June 1974.

SECOND-ORDER THEORY OF WAVE INTERACTION WITH FIXED BODIES

Investigator: C. J. Garrison, Associate Professor of Mechanical Engineering

Support: National Science Foundation

Objective:

To develop a mathematically consistent, second-order perturbation theory for the determination of gravity wave interaction with large bodies of arbitrary shape. The final phase of the work will involve the experimental verification of the theory.

Summary:

The development of the second-order theory of wave/body interaction has been completed. Both the first-order and second-order boundary-value problems have been established, and a numerical approach based on the use of a Green's function has been outlined for solution of both boundary value problems. A computer code has been developed for numerical evaluation of the hydrodynamic pressure and velocity distribution on the surface of the body and the resulting hydrodynamic forces. First-order results have been obtained by use of the computer program, and the results verified by comparison with classical results for a vertical cylinder and a floating hemisphere. The computer program is currently being extended to carry out the numerical solution to the second-order boundary-value problem. The conclusions of the study at this point are that the numerical solution to the second-order problem is feasible and will provide results which are of theoretical interest with respect to the general theory of free-surface hydrodynamics and, more specifically of great practical value in the design of offshore structures.

Publications: C. J. Garrison, "Hydrodynamics of Large Objects in the Sea, Part II: Motion of Free-Floating Bodies," Journal of Hydronautics, July 1975.

DEVELOPMENT OF AN OIL/WATER POLLUTION MONITOR SYSTEM

Investigator: T. M. Houlihan, Associate Professor of Mechanical Engineering

Support: Naval Sea Systems Command

Objective:

To build and to test a prototype of an oil-water monitor, using a carbon analyzer, that met prestated optimal operating conditions. During FY 1974, preliminary research at the Naval Ship Research and Development Center in Annapolis showed that a carbon analyzer system could be used to monitor oil/water separator effluent.

Summary:

The developed monitoring system fulfills the primary specifications regarding response time, operational temperature range, sensitivity, and shipboard reliability. Experimentation showed that the system could accurately detect concentrations of oil over the range 0-50 ppm. The system is unique among oil pollution monitors in that its response is independent of oil type.

Publications: T. M. Houlihan and D. B. Tyler, "Development of an Oil/Water Pollution Monitor," Technical Report NPS59Hm75071A, July 1975.

LASER PROPAGATION IN THE MARINE BOUNDARY LAYER

Investigator: T. M. Houlihan, Associate Professor of Mechanical Engineering

Support: Naval Sea Systems Command

Objective:

To provide the basis for predicting the optical properties of the atmosphere for the militarily important atmospheric window wavelengths. The work involves the relation of optical properties and the relevant meteorological parameters of the marine boundary layer to the observable bulk atmospheric parameters. Optical measurements include modulation transfer function of the atmosphere, image wander, extinction due to absorption and aerosol/fog scattering, and the optical turbulence structure function from scintillation. Micrometeorological parameters include turbulence-induced temperature and humidity fluctuations and aerosol/fog concentrations. All parameters are measured simultaneously under open-ocean conditions aboard the Research Vessel (R/V) ACANIA. Ultimately, optical and turbulence quantities will be related to bulk meteorological data (mean wind speed, air-water temperature difference, sea state) using appropriate similarity parameters.

Summary:

Shipboard observational experiments have accomplished the determination of the height and stability dependences of small-scale turbulence properties. Additionally, optical data has been obtained to relate atmospheric properties to theoretical models for visible (0.63μm) and infrared (10.6μm) propagations. Data in the final stages of analysis will allow conclusions on wind-wave coupling effects to be verified. Likewise, development work is proceeding to broaden the data base to include intermediate infrared wavelength (1.06μm and 3.80μm) transmissions.

Publications and Conference Presentations:

T. M. Houlihan, "Optical Propagation in the Marine Environment." Paper presented at the Fourth California Polytechnical Measurement Science Conference, Section 74-5, and published in the Proceedings, December 1974.

T. M. Houlihan and K. L. Davidson, "Laser Propagation in the Marine Boundary Layer." Paper presented at the annual meeting of

Sea Systems Command. Hydro-Mechanics Advisory Committee (SEAHAC) Annual Meeting, Section 74-8, February 1975, and published in the Proceedings.

A METHOD TO PREDICT THE THERMAL PERFORMANCE OF PRINTED CIRCUIT BOARD MOUNTED SOLID STATE DEVICES

Investigator: M. D. Kelleher, Associate Professor of Mechanical Engineering

Support: Naval Electronics Laboratory Center

Objective:

To formulate a design procedure to be used in the prediction of the thermal performance of printed circuit (PC) board mounted solid state devices. The project consists of an analytical phase which constitutes the actual formulation of the design procedure in the form of a digital computer program with appropriate documentation and an experimental phase which will involve testing of actual PC boards to verify the analytical model.

Summary:

A procedure has been formulated to predict the thermal performance of board mounted solid state devices (specifically 14 and 16 Dual Inline Pins (DIP) and TO-3 and TO-66 transistor cases). The equivalent thermal network has been constructed for a single integrated circuit (IC) element mounted on a PC board. The network for the DIP case is slightly different from the network for the TO case. The thermal network is designed to account for all the possible heat flow paths from the element to the ultimate heat sink. The network is also capable of accounting for the thermal interaction of a given element with other elements on the same board. This interaction is assumed to occur through heat conduction in the electrical connections between elements. Expressions for each of the thermal resistances in these networks has been formulated. This analytical model has been coded in the form of a digital computer program.

To verify the analytical procedure, an experimental PC board has been made. The board has 25 thick film resistors which are 14 pin DIP's. Each element on the board is instrumented with two thermocouples, one on the top and one on the bottom, to measure the average temperature of the element. Tests were conducted in the electronics cooling test facility of the Mechanical Engineering Department. Three different air flow rates and four different power settings to the board were used. Air inlet and exit temperatures were measured as well as the average temperatures of each element on the board.

The computer program which implements the analytical procedure has been run for several cases corresponding to the experimental runs. At the lower power levels, the agreement with

the experimental results is excellent. At higher power levels, the analytical procedure predicts a higher average temperature than is observed experimentally.

Publications: M. D. Kelleher, "A Method to Predict the Thermal Performance of Printed Circuit Board Mounted Solid State Devices," Technical Report NPS59Kk75071A, July 1975.

P. J. Marto, "The Thermal Performance of Air-Cooled Circuit Boards Used in Standard Electronic Package Designs," Technical Report NPS59Mx74051, May 1974.

EFFECTS OF GRAVITY ON GAS-LOADED VARIABLE CONDUCTANCE HEAT PIPES

Investigator: M. D. Kelleher, Associate Professor of Mechanical Engineering

Support: National Science Foundation

Objective:

To investigate the effects of gravity on the performance of gas-loaded, variable conductance heat pipes in which non-condensible gas and the working fluid are of significantly different molecular weights. The investigation is concerned with the nature of the vapor-gas interface region, particularly the phenomena associated with the vertical and horizontal operating positions.

Summary:

The design procedures and analytical tools, which have so far been developed to predict the performance of gas-loaded heat pipes, do not consider many of the circumstances in which the gravitational field could have a profound effect on their operation. The situation in which the molecular weights of the working fluid and the non-condensible gas are very different is one in which the effects of gravity must be given careful consideration.

Two heat pipes have been built and tested. Heat pipe #1 is 1.6 cm in diameter and heat pipe #2 is 5.0 cm in diameter. Each heat pipe is equipped with two pressure transducers, one at the evaporator end and one at the condenser end. In addition, each heat pipe has two stainless steel sheathed thermocouples which penetrate 1.25 cm into the evaporator and condenser of each pipe. Both heat pipes have 24 surface thermocouples spaced at 5 cm intervals along the adiabatic and condenser-reservoir sections. Both heat pipes have also been coated with temperature-sensitive encapsulated liquid crystals so that an deviations from one-dimensional behavior of the temperature distribution could be observed.

Both pipes have been operated using methanol as the working fluid and in the variable conductance mode using both krypton and helium as the non-condensible gases. Each heat pipe has been operated in both the horizontal and the vertical (condenser up) mode.

The measured surface temperature distribution on heat pipe #1 (1.6 cm diameter) shows the characteristic temperature distribution of the gas-loaded heat pipe. The higher temperature region is indicative of the active condenser, the

lower, near ambient temperature region is indicative of the gas-blocked inactive condenser and the intermediate region of changing temperature is indicative of the gas-vapor interface diffusion region. By comparing the horizontal and vertical profiles at the same power input and for the same working fluid-noncondensible gas combination, it is possible to draw some preliminary conclusions about the effects of gravity.

With methanol and krypton, a comparison of the horizontal and vertical profiles indicates that the gas-vapor interface region has been broadened in the vertical case, as compared to the horizontal. At the lower power level, the opposite effect takes place. In the methanol-helium case, changes in the shape of the profile are less apparent. The interface region is shifted toward the condenser in the vertical case, as compared to the horizontal. The lighter helium tends to rise toward the higher condenser.

The surface temperature profiles for heat pipe #2 (5 cm diameter) do not show the characteristic shape which was evident for the smaller diameter heat pipe. The reason for this is apparent from the liquid crystal data. The pipe has been coated with liquid crystal R-38 so that the band which runs diagonally across the pipe from the upper end of the condenser represents an isotherm at about 38°C. This indicates that the krypton and methanol have become horizontally stratified with the heavier krypton lying on the bottom of the pipe. It appears then that the vapor transport and vapor-gas diffusion processes are highly three-dimensional in this case. The surface temperature profiles taken on a single line running the axis of the pipe have very little meaning as far as interpreting the nature of the vapor-gas interface region. It should be pointed out that similar liquid crystal data for heat pipe #1 indicate very little tendency to stratify for either the methanol-krypton case or the methanol-helium case.

Publications: None

PERFORMANCE CHARACTERISTICS OF ROTATING WICKLESS HEAT PIPES

Investigator: P. J. Marto, Associate Professor of Mechanical Engineering

Support: Naval Sea Systems Command

Objective:

To understand the operating characteristics and to predict the heat transfer performance capabilities of rotating wickless heat pipes as used to cool rotating machinery components. The specific purpose of this work is to compare systematically various theoretical models with experimental data obtained.

Summary:

A theoretical model was derived for laminar film condensation on the inside of a rotating, truncated cone. Nusselt's classical analysis was modified to include effects of vapor shear and vapor pressure drop. Performance characteristics have been studied for a variety of operating conditions. An experimental apparatus has been built and tested using water, ethyl alcohol, and Freon 113 as working fluids. Rotational speeds were kept at 700, 1400, 2100 and 2800 RPM. Reproducibility and the influence of noncondensible gases were examined. Wall temperature measurements showed that the evaporator section of the heat pipe performed better at higher heat loads since the inside wall superheat decreased as the heat load increased. The condenser performance improved at higher rotational speeds, and the highest heat transfer rates were obtained using water. Improved performance occurred when the condenser wall material was changed from stainless steel to copper, and also when dropwise condensation was promoted on the condenser surface. A comparison of the theoretical analysis to existing data has shown agreement to ± 20 percent.

Publications: None

FATIGUE BEHAVIOR OF FERROCEMENT

Investigator: E. A. McKinnon, Assistant Professor of Mechanical Engineering

Support: Office of Naval Research

Objective:

To develop stress vs counts curves for various ferro-cements and to determine the combination yielding the best fatigue life. Ferro-cement is a cement mortar with a high relative volume of well dispersed steel wire reinforcement. The material properties of ferro-cement are neither those of the mortar alone nor of the reinforcement and vary as the mortar and reinforcement configuration are changed. Several formulations of ferro-cement were fabricated and subjected to cyclic loads.

Summary:

Although ferro-cement has been used for many years in boat construction, the designs have been limited by lack of data on fatigue life. Several different combinations of mortar and reinforcement were fabricated and subjected to constant amplitude cyclic loads up to ten million cycles. Stress versus cycles-to-failure plots were developed and comparisons between the data for various modifications were made. Monotonic (non-cyclic) tests were conducted on ferro-cement to allow comparisons with work conducted by other experimenters. An investigation of fracture surfaces was made using a scanning electron microscope. The best overall ferro-cement variation tested was ungalvanized mesh with water-cured mortar.

Publications: None

Thesis Directed:

M. G. Simpson, "Fatigue of Ferro-Cement," Master's Thesis, June 1974.

FACTORS AFFECTING THE FATIGUE LIFE OF FERROCEMENT

Investigator: E. A. McKinnon, Assistant Professor of Mechanical Engineering

Support: Foundation Research Program

Objective:

To add to the limited data existing on fatigue, and to determine the effects of precycling on yield, ultimate, and tensile strengths.

Summary:

Ferrocement samples were fabricated with both galvanized and ungalvanized mesh reinforcement. The water fraction of the mortar was varied. The age of samples, i.e., elapsed time since curing, was varied. Ungalvanized mesh gives better properties than galvanized. Older specimens have lower fatigue life below stress levels of 1500 psi; however, above 1500 psi, age does not influence fatigue life. The effects of precycling on the strength of ferrocement were not conclusively determined. Some of the data gathered indicated the precycling effects were negligible, while other data revealed a drop of roughly 10% in yield strength and ultimate strength per decade of cycling.

Publications: None

Theses Directed:

D. P. Sargent, "Factors Affecting the Fatigue Strength of Ferro-Cement," Master's Thesis, 1974.

E. S. Babcock, "The Effects of Precycling on the Strength of Ferrocement," Master's Thesis, 1975.

THE TIME-DEPENDENT NONLINEAR NUCLEAR REACTOR

Investigator: D. H. Nguyen, Associate Professor of Mechanical Engineering

Support: Foundation Research Program

Objective:

To obtain transient solutions of a nonlinear fast nuclear reactor with various temperature-dependent feedbacks.

Summary:

Both analytic and numerical methods have been used to obtain the extremely fast transience of the nonlinear reactor under superprompt criticality conditions. Such a transience is usually completed within several milliseconds.

Closed forms of analytic solutions have been obtained under three different feedback conditions: Newtonian feedback, prompt feedback, and adiabatic excursion. The latter is usually regarded as the primary cause of a core-disruptive accident (CDA). These analytic solutions apply only to the simplified system of unreflected reactor. They provide, nevertheless, the dynamic trend of a nonlinear reactor under fast superprompt accident conditions.

To investigate the more realisitic reflected reactor, the finite element method has been used to detain the solution under the prompt feedback condition. For this case, the dynamic equations are stiff and contain a square nonlinearity. The exact numerical treatment of this nonlinearity requires a large computer storage and time. The method, however, can be used to yield numerical standards.

The numerical method developed in this project serves to verify analytic results obtained earlier. It can also be expanded to handle the real multiregion reactor system under highly discontinuous initial disturbances, providing thereby much-needed answers to the space-dependent fast reactor dynamics problem.

Publications: D. H. Nguyen, "The Time-Dependent Nuclear Reactor with Feedback," Nuclear Science and Engineering, 55, (November 1974)

D. H. Nguyen, with D. Salinas, "Finite-Element Solutions of a Nonlinear Nuclear Reactor Dynamics Problem." Proceedings of the International Conference on Computational Methods in Nonlinear Mechanics, Austin, Texas, 1974.

D. H. Nguyen, "Space-Time Solutions of Nonlinear Reactor Dynamics by Finite Element Method," Transactions of the American Nuclear Society, 21 (June 1975).

DYNAMICS OF LIQUID PROPELLANT GUN LOADING SYSTEMS

Investigator: R. H. Nunn, Associate Professor of Mechanical Engineering

Support: Naval Ordnance Station

Objective:

To simulate and study both analytically and experimentally the behavior of a liquid under conditions analagous to those existing in a rapid-fire Liquid Propellant Gun (LPG) feed system. The results of the study are intended to be useful in the identification of upper and lower bounds for such LPG design and performance parameters as load-time, injection supply pressure, ullage, charge to mass ratio, caliber size, and projectile mass.

Summary:

A one-dimensional model was constructed for the unsteady behavior of the assumed incompressible liquid. An experimental loading system was designed and fabricated to test the model and to identify critical design constraints. The analytical model, well supported by the experimental data (Figure 1), was utilized to conduct parametric studies and to provide guidance to designers of LPG loading systems.

Publications: R. H. Nunn and E. J. Gibson, "Dynamics of LPG Loading Systems," Technical Report NPS59Nn-75061A, June 1975.

THERMOECONOMIC ANALYSIS OF VAPOR POWER SYSTEMS

Investigator: R. H. Nunn, Associate Professor of Mechanical Engineering

Support: Civil Engineering Laboratory

Objective:

To develop and evaluate a method of integrating marginal cost/benefit analysis into engineering design of vapor power systems.

Summary:

A method is presented for determining the relationships between the costs and technical performance of vapor power systems in a manner which permits fundamental design specifications to be made optimally with respect to overall system lifetime costs. Means of applying optimization techniques for large-scale systems to the thermoeconomic analysis of vapor power systems are described and demonstrated with a simplified sample model. The example studied is an environmentally driven ocean thermal gradient system. A sequential unconstrained minimization algorithm is employed for overall system design optimization.

Publications: F. L. Sheppard, J. K. Hartman, M. D. Kelleher, and R. H. Nunn, "Thermoeconomic Analysis of Vapor Power Systems," Technical Report NPS 59Nn75062A, June 1975.

AERODYNAMIC CHARACTERISTICS OF AXISYMMETRIC BODY IN UNIFORM PITCHING MOTION

Investigator: R. H. Nunn, Associate Professor of Mechanical Engineering

Support: Naval Weapons Center

Objective:

To (1) determine the dependence of the aerodynamic loading upon a uniform angular velocity in pitch, and (2) identify specific transition regions in the wake vortex pattern and the subsequent alteration of these patterns due to rotation. The effects on the wake vortex configuration of certain variables such as pitch rate and Reynolds number would indicate significant trends for the design of highly maneuverable missiles.

Summary:

Certain evolving tactical-missile missions require extreme flight agility to accomplish large and rapid changes of direction. Such requirements have prompted an interest in the aerodynamic loading of slender missile configurations at large angles of attack and while undergoing rapid pitching through large excursions in angle of attack.

The results of this investigation show that there is an increment of normal force directly attributable to uniform pitching motion. While undergoing uniform pitching, the normal force curve has a steeper slope, reaches an inflection point at a slightly higher angle of attack, and has a less abrupt inflection. The increment of normal force due to uniform pitching has implications for the calculations of stability derivatives for motions involving large excursions in angle of attack. It appears possible to rotate a body about an axis in such a manner that the increment of normal force due to a constant angular velocity could be nullified. These results have significant implications for experimenters conducting wind-tunnel tests where the model is rapidly rotated in order to obtain "static" data for large variations in angle of attack during a short period of time. Rapidly sweeping the model is a common occurrence when using blow-down type wind tunnels.

Publications: L. H. Smith and R. H. Nunn, "Aerodynamic Characteristics of Axisymmetric Body in Uniform Pitching Motion," Technical Report NPS59Nn75061A, February 1975.

Conference Presentation:

L. H. Smith and R. H. Nunn, "Aerodynamic Characteristics of Axisymmetric Body Undergoing a Uniform Pitching Motion." Paper presented at American Institute of Aeronautics and Astronautics (AIAA) 8th Fluid and Plasma Dynamics Conference, June 16-18, 1975, AIAA Paper No. 75-838.

MATERIALS APPROACHES TO SHIP SILENCING

Investigators: J. Perkins and G. Edwards, Assistant Professors of Mechanical Engineering

Support: Naval Sea Systems Command

Objective:

To investigate experimentally and analytically materials and design factors affecting sound and vibration in shipboard structures and machinery, and to evaluate candidate alloy materials with regard to damping properties as a function of metallurgical processing, applied stress, temperature, and vibration frequency.

Summary:

Mu-Cu alloys have been evaluated in detail; these alloys develop very high damping capacity after proper heat treatment; the attainment of this quality is found to be quite sensitive to heat-treating conditions and to stress during heat treatment. Various methods of evaluating the damping of high-damping materials have been evaluated. The fatigue performance of these alloys has been determined.

Resistivity measurements and internal friction have been utilized to study microstructural changes associated with the acoustic damping. Results have shown that properly treated Incramute I (a commercial Cu-Mn alloy) can develop a specific damping capacity (SDC) as much as four times that of grey cast iron, a material commonly used in heavy industry because of its relatively good damping characteristics. It has been found that SDC is sensitive to stress applied during heat treatment or in service. Typical results are shown in Figure 1, where a correlation between resistivity and low-stress SDC is indicated. These data show that uniaxial tensile stress, applied during either the age or the quench, interferes with the development of high SDC.

Publications: J. Perkins, G. R. Edwards, and N. Hills, "Materials Approaches to Ship Silencing," Technical Report NPS59Ps74061, 1974.

Theses Directed:

N. A. Hills, "A Study of the Influence of Stress and Temperature on the Damping Capacity of Mn-Cu Alloys for Ship Silencing Applications," Mechanical Engineer's Thesis, September 1974.

F. L. Youngblood, "Characterizing and Controlling the Metallurgical Properties of a Cu-Mn Alloy for Ship Silencing Applications," Master's Thesis, June 1975.

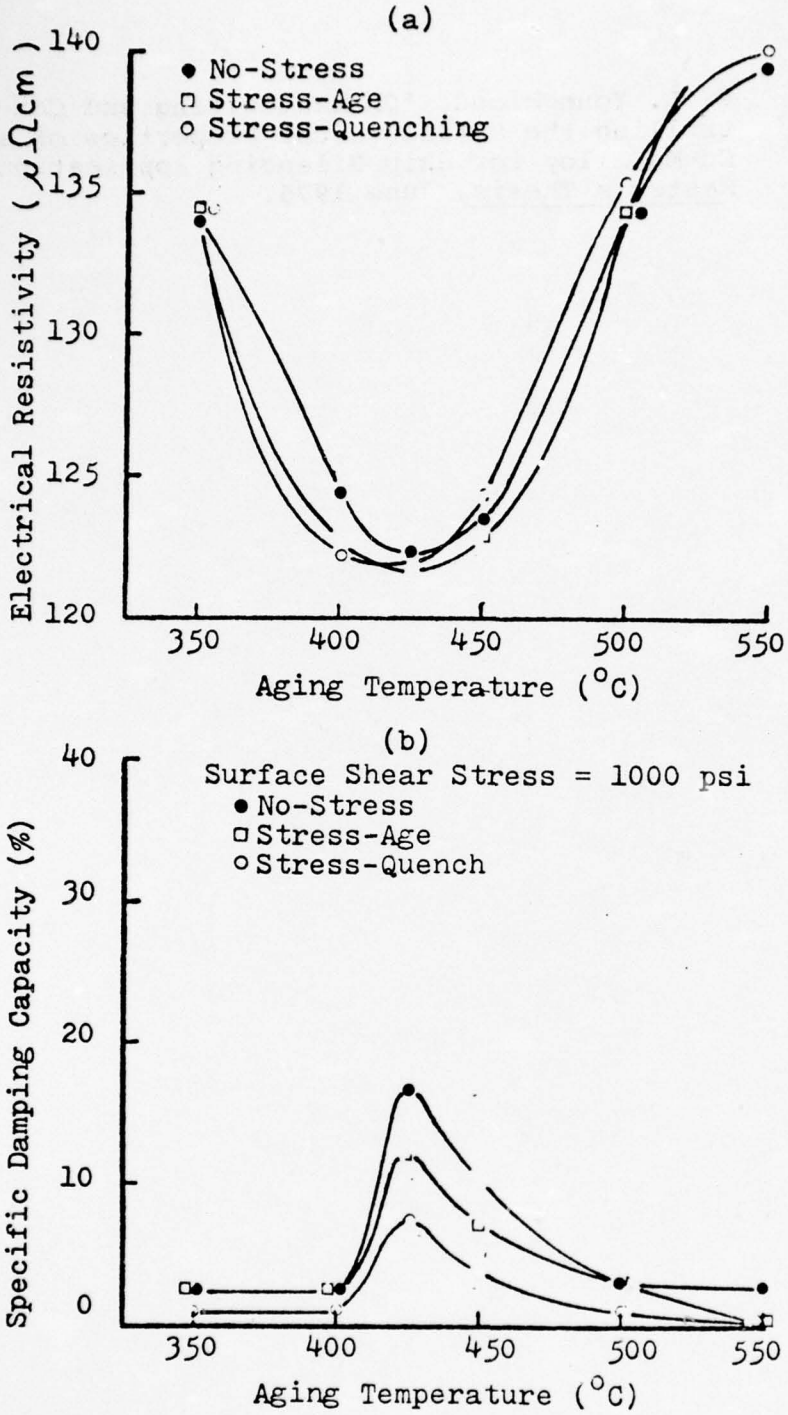

FIGURE 1 (a) SDC related to the room temperature electrical resistivity measured after heat treatment (Incramute I, t_{Age} = 120-min at T 350 °C). (b) SDC versus aging temperature for various aging treatments as measured by 1 ksi surface shear stress.

SHAPE MEMORY ALLOYS AND NAVAL GUNNERY

Investigators: J. Perkins and G. R. Edwards, Assistant Professors of Mechanical Engineering

Support: Naval Weapons Laboratory

Objective:

To characterize the thermomechanical parameters of NiTi alloys exhibiting so-called shape memory effects. This has been approached by means of inducing apparent plastic deformation at various temperatures, and monitoring reversion stress development on heating, with the intent of determining the kinetics of reversion stress and strain recovery. The effect of stress on the reversion temperature range, long-time stability of reversion stress above the reversion temperature range, and stability during low temperature excursions. The evaluation of applicability of this data refers to a classified configuration.

Several master's theses have been completed in conjunction with this project, and considerable data has been developed. Figure 1 exhibits typical reversion stress data, presented as a stress-strain temperature envelope, the surface of which represents an upper bound on shape memory effect (SME) reversion stress. This type of data is extremely useful to consider strain-temperature parameters that optimize thermomechanical performance of an alloy in a given application. The effect of thermal cycling and reversion stress stability with time and temperature have also been studied, and transmission electron microscopic structural correlations have been made.

Publications:

J. Perkins, editor, "Shape Memory Effects in Alloys," New York, Plenum Publishing Co., 1975.

J. Perkins, G. R. Edwards, C. R. Such, J. M. Johnson and R. R. Allen, "Thermomechanical Characterization of Alloys Exhibiting Martensitic Thermoelasticity," in Shape Memory Effects in Alloys, New York, Plenum, 1975.

G. R. Edwards and J. Perkins, "Suggestions for Applying a Phenomenological Approach to Investigation of Mechanical Behavior in SME Alloys," in Shape Memory Effects in Alloys, New York, Plenum, 1975.

G. R. Edwards and J. Perkins, "Characterizing the Shape Memory Effect Potential of Ni-Ti Alloys," Scripta Metallurgica, 1975.

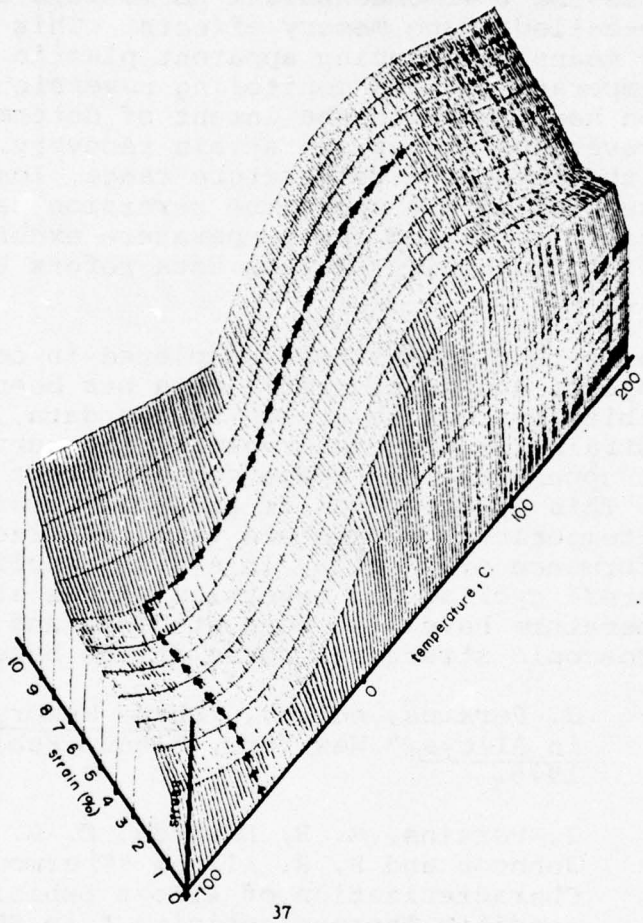

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Figure 1 Three dimension plot of flow stress as a function of strain and temperature for alloy B.

CORROSION STUDIES ON ZINC ANODE MATERIALS

Investigator: J. Perkins, Assistant Professor of Mechanical Engineering

Support: Foundation Research Program

Objective:

To determine the environmental and materials-related electrochemical 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 (1). This represents a macroscopically porous and non-passive 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. Both laboratory and on-site experiments in Monterey Bay are being conducted to delineate critical ranges of various electrochemical variables.

Publications: R. A. Bornholdt and Jeff Perkins, "SEM Examination of Corrosion Product Morphology for Anodically Polarized Zinc," Metallography, 8 (1975).

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 Seawater," Naval Engineers Journal (in press).

Thesis Directed:

R. A. Bornholdt, "Corrosion Product Morphology on Zinc Anodes in Seawater," Master's Thesis, 1974.

Figure 1

ELASTIC-PLASTIC ANALYSIS OF OBTURATORS

Investigator: D. Salinas, Associate Professor of Mechanical Engineering

Support: Naval Sea Systems Command

Objective:

To provide a computer program and an accompanying User Manual for the elastic-plastic analysis of obturators, to Naval Ballistic Laboratories in Dahlgren and China Lake.

Summary:

The importance of an obturator to gun performance is readily established. The function of an obturator is to provide the seal for the launch pressure in a gun barrel. Failure to attain a proper seal results in loss of range and accuracy of the launched projectile.

With a high-pressure environment, common obturator materials such as Monomer Nylon will be stressed beyond their elastic range into their plastic range. The solution of the nonlinear plastic problem is a far more difficult task than is the linear elastic problem.

Yamada et al presented a finite element method for elastic-plastic analysis. This investigator has developed a computer program based on Yamada's scheme. The program has been successfully used for the analysis of several composite materials.

The program has been modified to accommodate the inclined roller support boundary condition associated with obturators. Several analyses were obtained for Naval Weapons Laboratory. The object of this investigation is to compile a User Manual for the program and to supply it, along with the program deck, to the Naval ballistic facilities at Dahlgren and China Lake.

Publications: None

THE APPLICATION OF THE FEM TO PROBLEMS IN FLUID MECHANICS

Investigator: D. Salinas, Associate Professor of Mechanical Engineering

Support: Foundation Research Program

Objective:

To develop a finite element program for the solution of the "added mass" problem for irregular bodies.

Summary:

In a series of recent papers, Bratanow and Ecer have investigated unsteady incompressible flow around stationary and oscillating bodies of arbitrary shape. The analyses have been restricted to two dimensional problems. These investigations have employed the variational formulation of Finite Element Method (FEM), requiring, therefore, linearization of the nonlinear convective terms in the Navier Stokes equations. The employment of a FEM variational formulation is unnecessarily restrictive. A more general formulation for nonlinear problems is a Galerkin FEM. The work is being continued.

Publications: None

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE STABILITY OF LAMINAR JETS

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Support: Harry Diamond Laboratories, U. S. Army Material Command

Objective:

To obtain a closed form solution for the velocity distribution of a viscous jet confined between two parallel plates and to examine the stability of the jet in terms of the aspect ratio of the jet and the Reynolds number.

Summary:

The solution obtained by Schlichting for an unconfined jet has been extended to the case of a confined jet through the use of a suitable perturbation method. The results have shown that the boundary layers developing along the top and bottom cover plates strongly affect the evolution of the velocity profile, and that most of the flow takes place near the axis of the jet. The pressure and momentum recovery factors decrease with increasing aspect ratio. Furthermore, the smaller the aspect ratio is, the more stable is the resulting three-dimensional laminar jet.

Experiments have been carried out on a large flow model through the use of the hydrogen-bubble technique, and the velocity profiles reduced from the photographs of the bubbles have been satisfactorily compared with those obtained analytically. These results will be incorporated into the design of a laminar angular rate sensor known as LARS.

Publications: None

Thesis Directed:

A. Sarich, "A Theoretical and Experimental Investigation of Laminar Angular Rate Sensors," Master's Thesis, December 1974.

UNSTEADY FLOW ABOUT BLUFF BODIES

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Support: National Science Foundation

Objectives:

To determine the forces acting on bluff bodies immersed in time-dependent flows.

Summary:

Experiments were conducted in a recirculating water tunnel, in a small U-shaped water tunnel, and a large U-shaped water tunnel with smooth and rough circular cylinders and spheres in the range of Reynolds numbers from 5,000 to 1,000,000. The velocity in the water tunnel consisted of a harmonically oscillating component superposed on a mean velocity. The drag and lift coefficients have been determined in terms of the Reynolds number and the appropriate flow parameters. The velocity in the U-shaped tunnels consisted of a purely harmonic oscillation. The lift, drag,and inertia coefficients have been determined in terms of the Reynolds number, period parameter, and the relative roughness.

A potential flow model of two-dimensional vortex shedding behind bluff bodies was developed. The free shear layers which emanate from the sides of the body were represented by discrete vortices through the use of the appropriate complex-velocity potential and the Joukowsky transformation between a circle and the body cross-section. The analysis was then applied to predict the kinematic and dynamic characteristics of the flow for various flow parameters.

Publications:

T. Sarpkaya, "An Inviscid Model of Two-Dimensional Vortex Shedding for Transient and Asymptotically Steady Separated Flow Over an Inclined Plate," Journal of Fluid Mechanics, 68, Pt. 1 (1975).

T. Sarpkaya and O. Tuter, "Periodic Flow About Bluff Bodies, Part 1: Forces on Cylinders and Spheres in a Sinusoidally Oscillating Fluid," Technical Report NPS59S174091, September 1974.

CABLE STRUMMING IN CROSS CURRENT - ANALYSIS AND EXPERIMENTS

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Support: Civil Engineering Laboratory

Objective:

To extend Sarpkaya's two-dimensional potential flow model to circular cylinders oscillating longitudinally and/or transversely to the flow, for the purpose of determining added mass, lift, and drag coefficients for oscillating cylinders. Also, to initiate laboratory experiments to check and validate the analytical model.

Summary:

Elastic structures of one or more degrees of freedom can extract energy from the flow about them and can develop catastrophic flow-induced oscillations. The understanding of this energy-transfer process is of paramount importance if one is either to eliminate or minimize it or to design the elastic structure in such a manner that it can withstand the oscillations under the contemplated environmental conditions.

The discrete-vortex model has been applied to the determination of the flow characteristics about cylinders undergoing in-line and transverse oscillations. The results have been expressed in terms of a mean drag coefficient, and Fourier-averaged drag and inertia coefficients. The variations of these coefficients with Reynolds number, period parameter, and the relative amplitude of oscillations have been determined. Experiments have been carried out in a water tunnel with circular cylinders, and the coefficients cited above have been evaluated and compared with those obtained analytically. The results have shown that the mean flow has significant effects on the various coefficients, and that the results of experiments with harmonic oscillations in a fluid otherwise at rest are not applicable to oscillations of a cylinder in a uniform flow.

Publications: T. Sarpkaya, "An Analytical and Experimental Study of the In-line and Transverse Oscillations of a Circular Cylinder in Uniform Flow," Technical Report NPS59SJ75051, May 1975.

Thesis Directed:

J. T. Fry, "Harmonic Motion of Cylinders in Uniform Flow," Master's Thesis, June 1975.

EFFECT OF POLYMERS ON HYDROFOILS

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Support: Naval Sea Systems Command

Objective:

To study the effect of polymer additives on the resistance of hydrofoils.

Summary:

Lift and drag forces and pressure distribution were measured for a series of hydrofoils in homogeneous solutions of polyethylene oxide (WSR-301) with concentrations ranging from zero to 100 wppm and Reynolds numbers (based on the chord length) from 100,000 to 2,000,000. The results have shown that the lift to drag ratio of a foil may increase or decrease depending on the stall characteristics of the foil. For foils such as National Aeronautic Counsel Administration (NACA) 0006 and 65006 which exhibit thin-airfoil stall and a long bubble at the suction side, the instability and transition to turbulence brought about by the polymer help to replace the long bubble by a turbulent boundary layer and partly restore the lift otherwise lost due to the bubble. Furthermore, the relative decrease in the apparent size of the foil as well as the friction reduction with polymer, in turbulent flow over the upper and lower sides of the foil, results in a Reynolds-number-dependent drag reduction. For foils such as NACA 0012, 0024, 4412, which exhibit trailing-edge type stall and a short bubble near the leading edge, earlier transition to turbulence thickens the turbulent boundary layer and gives rise to a thicker wake and thus to a larger circulation defect, i.e., to a reduced lift-to-drag ratio.

Publications: T. Sarpkaya, "On the Performance of Hydrofoils in Dilute Polyox Solutions." Paper presented at the International Conference on Drag Reduction, University of Cambridge, and published in the Proceedings of the British Hydromechanics Research Association (BHRA) 1 (1974).

FLUIDIC CONCEPTS EVALUATION

Investigator: T. Sarpkaya, Professor of Mechancial Engineering

Support: Naval Air Systems Command

Objective:

To investigate low-frequency noise in fluidic elements and to relate the results of this investigation to NAVAIR development objectives.

Summary:

Experience has shown that a wide range of frequencies may be generated in fluidic devices. The high frequencies do not generally present difficulties but low frequencies (i.e., those below 1000 Hz and particularly below 100 Hz) pose problems in the fluidic sensors and circuits being developed for fluidic guidance and control systems. This noise which is associated with various fluid dynamic phenomena, is a limiting factor in optimizing the low-level signal performance of many fluidic components and circuits, particularly analog-type devices. The present investigation dealt with a survey of the previous noise studies, definition of the noise and its related properties, and the design and construction of variable geometry amplifiers and the use of hot-wire anemometer techniques to obtain velocity and noise profile measurements.

The second part of the concept evaluation concerns the design of circulation control rotors (CCR) and the use of fluidic elements in achieving circulation control in helicopters with rigid blades. The section lift, drag, and moment coefficients at any angle of attack has been expressed in terms of five independent flow variables and six main geometric parameters. The flow variables are the momentum coefficient, mass flow coefficient, jet Mach number, free-stream Mach number, and the Reynolds number. The primary geometric parameters are profile family, thickness ratio, slot height to trailing-edge radius ratio, camber, trailing-edge radius to chord ratio, and the slot chordal position. The optimization of the hover and flight performance of the vehicle in terms of these parameters requires a detailed analysis of the blade dynamics and the design of a novel CCR control valving which will minimize vibrations, ballistic damage, and the number of movable parts. A comprehensive analysis has been carried out to achieve these objectives and a non-moving part CCR control valving has been designed.

Publications: T. Sarpkaya, "On the Art of Advancing the Science of Fluidics," Journal of Dynamic Systems, Measurements, and Control, 95 (1975).

DEPARTMENT OF PHYSICS AND CHEMISTRY

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

ACOUSTICS AND FLUID DYNAMICS

Influence of the Upper Ocean Fluctuations on the Propagation of Sound by H. Medwin; Processing of Ocean Acoustic Signals in Response to the Ocean Fluctuations by H. Medwin; High Intensity Acoustic Phenomena by A. Coppens and J. V. Sanders; Drag and Noise Reduction of Underwater Vehicles by J. V. Sanders and K. E. Woehler; Underwater Acoustic Range Studies involving O. B. Wilson, J. V. Sanders, H. Dahl, A. Coppens; Sound Propagation on Wave Guides with Time Varying Rough Surfaces (shallow water Anti Submarine Warfare (ASW)) by A. Coppens.

PHYSICAL METEOROLOGY

This relatively new activity has rapidly evolved to be the strongest single activity and is done in cooperation with the Meteorological Department: Study of the Optical Propagation in the Marine Boundary Layer as a function of turbulence and Aerosols/Fog at Militarily Important Atmospheric Window Wavelengths by E. C. Crittenden, A. W. Cooper, E. Milne, W. Rodeback, R. Armstead; Development and Calibration of Diagnostic Tools for and Field Studies of Atmospheric Turbulence in the Presence of Marine Fog by G. E. Schacher, and E. Milne; Development of Techniques to Measure the Properties of Atmospheric Aerosols in the Marine Environment.

LASER AND PLASMA PHYSICS

Investigation of Laser Produced Plasmas by F. Schwirzke and A. W. Cooper; Laser Spectroscopy of Flames by W. Tolles; Compilation of Laser Effects and Vulnerability Data by J. R. Neighbours.

ATOMIC AND NUCLEAR PHYSICS

Continuation of our Spectroscopic Data Center's Compilation of Near Ultra Violet Spectral Data by R. L. Kelly; Investigation of Giant Multipole Resonances in Various Nuclei by Inelastic Electron Scattering by F. R. Buskirk, E. Dally, J. Dyer, and R. Pitthan.

PHYSICAL CHEMISTRY

Investigation of the Reaction Kinetics and Catalytic Properties of Palladium Complexes by R. A. Reinhardt; Thermodynamics of Internal Ecplosion Processes by G. F. Kinney.

SOLID STATE AND SURFACE INTERACTION PHYSICS

Studies of Radiation Effects on Electronic Components by J. Dyer and E. Dally; Investigation of Sputtering Phenomena from Crystal Surfaces by D. E. Harrison.

MILITARY SYSTEMS TECHNOLOGY

Research projects included under this general heading are those in which deparment members participate in the design, evaluation, and assessment of advanced weapons systems and technology. Professor Reese has concentrated on problems associated with weapons systems, weapons platforms, and surveillance systems while D. E. Harrison has been more involved with problems in command and control and tactics. These projects frequently involve members of other departments and institutions.

EXCITATION OF THE COLLECTIVE HYDRODYNAMIC OSCILLATION OF NUCLEI THE GIANT RESONANCES

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

Support: National Science Foundation

Objective:

To investigate the collective oscillations of the atomic nucleus in some selected isotopes. A specific objective is either to verify or refute the location of the giant monopole resonance which may be thought of as a breathing mode type of oscillation, of which the energy is directly connected with the coefficient of bulk compressibility, a property of nuclear matter of which virtually nothing is known from experiment.

To achieve this goal not only data taking, but also improvement of the electron accelerator facility and the development of data handling techniques play an important role.

Summary:

After successful exploration of ^{197}Au and ^{208}Pb, where several new modes of oscillation (electric monopole, isovector i.e., oscillation of protons against neutrons quadrupole and octupole) were detected, experiments were extended to ^{165}Ho, a strongly deformed nucleus. Investigation of nuclei of this type is very important in order to study collective coupling of different modes. They are expected to split into oscillations along the axis of different lengths of a spherically or triaxially deformed nucleus. In fact, a splitting of the isovector quadrupole resonance was observed for the first time. For the lower-lying isoscalar quadrupole resonance the same effect is smaller and leads to a broadening of the resonance compared to spherical nuclei.

The data reduction program system was improved in order to unravel the very complicated structure of several overlaying resonances. Improvements in shielding brought down the experimental background by a factor of three, installation of a new vacuum system (vacion-pumps) is expected to reduce the down-time due to clystron failure considerably. For this purpose the RF-waveguide part of the system was totally disassembled and shipped to Stanford, in order to be thoroughly cleaned.

Publications: R. Pitthan, F. R. Buskirk, E. B. Dally, J. N. Dyer, X. K. Maruyama, "Evidence for

the Isoscalar Monopole and the Electric Dipole Spin Flip Resonance in Heavy Nuclei," Paper presented at the International Conference on Nuclear Structure and Spectroscopy, Amsterdam, 1974, and published in the Proceedings, II (1974).

X. K. Maruyama, F. R. Buskirk, E. B. Dally, J. N. Dyer, R. Pitthan, "Giant Monopole Resonance in Heavy Nuclei," Bulletin of American Physical Society, 19 (1974).

F. R. Buskirk, E. B. Dally, K. P. Ferlic, X. K. Maruyama, R. D. Waddell, R. Pitthan, "Evidence for the Giant Dipole Electric Spin Flip Resonance from (e,e^1) on ^{197}Au," Paper presented before the American Physical Society and the Abstract published in the Bulletin, 1974.

F. R. Buskirk, "Electroexcitation of Multipolarities 0, 1, 2 and 3 in the Giant Resonance Region of Heavy Nuclei," Invited talk Bulletin of American Physical Society, 20 (1975).

G. L. Moore, F. R. Buskirk, E. B. Dally, J. N. Dyer, X. K. Maruyama and R. Pitthan, "Electroexcitation of ^{165}Ho in the Giant Resonance Region," Paper presented before the American Physical Society, and the abstract published in the Bulletin, 20 (1975).

Thesis Directed:

G. L. Moore, "Electroexcitation of Giant Resonances Between 5 and 30 MeV Excitation Energy in ^{165}Ho," Master's Thesis, December 1974.

MEASUREMENT OF NUCLEAR GIANT RESONANCES BY HIGH ENERGY ELECTRON SCATTERING

Investigator: F. R. Buskirk, Professor of Physics and Chemistry

Support: Foundation Research Program

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) further investigation of the isovector and isoscalar quadrupole resonances and (c) identification of the octapole mode.

Summary:

The efforts have fallen into two broad categories, (a) giant resonance research and (b) Linac improvements.

(a) Giant resonance research was concentrated on the deformed nucleus, holmium (^{165}Ho). The deformed shape of this nucleus can be used as a tool to aid in the identification of resonances which are seen in other heavy nuclei but are not clearly identified. The resonances observed in lead at 8.9 MeV and 10.2 MeV were suspected to be monopole and quadrupole, respectively, but the identification was not certain. In ^{165}Ho the same resonances are seen, and the one at lower energy seem, (from our present measurements) to be narrower than the other, so that we have further evidence for the E0 and E2 character, respectively, of the resonances. Furthermore, the isovectors quadrupole resonance was observed (for the first time) to be split in the deformed nucleus. These results have been reported at meetings, and are also being published.

(b) Linac improvements. The old vacuum system, using oil diffusion pumps caused so much contamination of the Linac waveguides that operation was impossible. Funds for an improved vacuum system, using electric discharge pumps, were provided and these pumps were installed in August 1975. Preliminary trials show that the new system should provide much more reliable and economical operation of the Linac, as was expected. It should be possible to resume experiments in September 1975.

Publications: R. Pitthan, F. R. Buskirk, E. B. Dally, J. N. Dyer, and X. K. Maruyama, "Evidence for the Isoscalar Monopole and the Electric Dipole

Spin Flip Resonance in Heavy Nuclei," Proceedings, International Conference on Nuclear Structure and Spectroscopy, Amsterdam, Vol. II (1974).

X. K. Maruyama, F. R. Buskirk, E. B. Dally, J. N. Dyer, R. Pitthan, "Giant Monopole Resonance in Heavy Nuclei," Bulletin of the American Physical Society, 19 (October 1974).

F. R. Buskirk, E. B. Dally, J. N. Dyer, K. P. Ferlic, X. K. Maruyama, R. D. Waddell, R. Pitthan, "Evidence for the Giant Dipole Electric Spin Flip Rosonance from (e,e^1) on ^{197}Au," Bulletin of the American Physical Society, 19, (October 1974).

F. R. Buskirk, "Giant Resonances in Heavy Nuclei Measured by Inelastic Electron Scattering," Invited Talk, American Physical Society, Anaheim Meeting; Bulletin of the American Physical Society, 20 (January 1975).

G. L. Moore, F. R. Buskirk, E. B. Dally, J. N. Dyer, X. K. Maruyama, R. Pitthan, "Electroexcitation of ^{165}Ho in the Giant Resonance Region," Bulletin of the American Physical Society, 20 (April 1975).

G. L. Moore, F. R. Buskirk, E. B. Dally, J. N. Dyer, X. K. Maruyama, R. Pitthan, "Electroexcitation of the Strongly Deformed Nucleus ^{165}Ho in the Giant Resonance Region Between 7 and 35 MeV Excitation Energy with 60-105 MeV Electrons." Accepted by Physics Review Letters.

Thesis Directed:

G. L. Moore, "Electroexcitation of Giant Resonances Between 5 and 30 MeV Excitation Energy in ^{165}Ho," Master's Thesis, 1974.

FINITE AMPLITUDE ACOUSTIC WAVES IN CAVITIES

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

Support: Foundation Research Program

Objective:

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

Summary:

This work has resulted from a continuing effort over several years to obtain solutions to an empirical nonlinear wave equation describing the behavior of nonlinearly-distorted standing waves in tubes and cavities. The present effort was devoted to solving this wave equation for standing waves in rigid-walled cavities of rectangular geometry. The theoretical predictions of the behavior of the nonlinearly-generated hormonics of a driven standing wave in the cavity were compared with experiment. It was confirmed that the major features of the theory are correct. The frequency dependence of the amplitudes of the harmonics depends on the exact relationships between the observed resonance frequencies and absorption coefficients of the real cavity. This means that calculated resonance frequencies and absorption coefficients of the cavity are not sufficiently accurate to predict the observed behavior of the standing wave. There were some small discrepancies between theoretical predictions and experimental measurements which have not yet been successfully explained, but which may result from small perturbations in the boundaries of the cavity. Present activity in this research project is directed toward solving the nonlinear wave equation for cavities containing simply perturbed boundaries. The results look promising, but quantitative evaluation and experimental comparison remain to be done. Work is also proceeding in the investigation of standing waves in cylindrical cavities, where the cylindrical geometry leads to substantially different properties of the nonlinear standing waves. In this case, the solutions predict that nonlinear distortion of the standing wave should be severely reduced compared to that resulting from a standing wave of the same strength in rectangular cavities. Here, at present the theoretical results are in qualitative agreement with experiment, but there are some significant discrepancies which remain to be explained.

Publications: A. B. Coppens and J. V. Sanders, "Finite Amplitude Standing Waves Within Real Cavities." Accepted by Journal of the Acoustical Society of America.

OPTICAL PROPAGATION IN THE MARINE BOUNDARY LAYER (OPTICS)

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

Support: Naval Sea Systems Command

Objective:

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

Summary:

Knowledge of the optical properties of the atmosphere over-land has been sketchy, and over the ocean, nearly nonexistent. The information is needed for design and determination of the limitations at sea of a wide variety of military applications of electro-optics. The properties of interest are the "seeing" or resolutions through the atmosphere, the scintillations or intensity fluctuations of a transmitted beam, and the extinction or loss of energy from a beam by absorption and scattering caused by fog and aerosols. The "seeing" is characterized by the modulation transfer function (MTF) and the closely related mutual coherence function (MCF) which also determines the signal-to-noise ratio in a coherent detection receiver. Image wander and its frequency spectrum also are involved in seeing. The scintillation is characterized by and is the simplest source of data on the optical turbulence structure function, C_n^2. During the past two years techniques have been developed for measuring these parameters under open-ocean conditions with shore to shore paths and ship to shore paths, using the Naval Postgraduate School (NPS) research vessel ACANIA, for ranges up to 20 km. Both optical and meteorological parameters are measured simultaneously. Measurements have been made under a variety of conditions for wavelengths of .633μm and 10.6μm and have been compared with theory. Extension to all of the principal transmission windows of the atmosphere is under way with lasers at .488 and 1.06μm and broadband measurements in the 3-5μm and 8-14μm windows. A chemical laser for use at 3.8μm is under construction. An experiment was carried out with Lincoln Laboratory at Massachusetts Institute of Technology (MIT) to compare our MTF results with theirs, obtained for the Air Force. Our measurements are made with a scanning telescope, while theirs are made with a shearing interferometer. Results are not complete, but preliminary results indicated substantial agreement.

Publications: A. W. Cooper, E. C. Crittenden, and A. F. Schroeder, "Height Dependence of Optical Scintillation Over the Ocean." Paper presented at the Topical Meeting on Optical Propagation Through Turbulence, Boulder, Colorado, July 1974, and published in the Digest of Technical Papers by the Optical Society of America, 1974.

INVESTIGATION OF RADIATION EFFECTS ON ELECTRONICS

Investigator: E. B. Dally, Associate Professor of Physics and Chemistry

Support: Defense Nuclear Agency

Objective:

To enhance the development of an understanding of nuclear radiation effects on electronics among engineering and scientific graduate students requiring such knowledge.

Summary:

The activities support by this project included the following:

(a) The Course "Radiation Effects in Solids" PH 4750 has been taught to a small group of officers. In the past this course was part of the Nuclear Effects curriculum which led to a Master's Thesis in Physics. This specialized curriculum is no longer offered, but the PH 4750 course will now be offered to students in other curricula to provide some knowledge in radiation effects. Accordingly, the emphasis of the course has been changed to meet the needs of non-specialists.

(b) Radiation damage experiments were developed by LT Robert Wakefield, USN, Professor J. N. Dyer and Professor E. B. Dally as described in the reference. The experiments are intended for a course in Radiation Effects such as PH 4750, mentioned above, and use the Linar as a source of radiation. The titles of the experiments are:

(a) Experimental Procedure for Measuring the Beam Profile.
(b) Transistor Gain Degradation Caused by Radiation.
(c) Loss of Conductivity by Field Effect Transistors Caused by Radiation.

(c) Linac Improvements: Because of a breakdown of the main vacuum system of the Linac, it was not possible to run the experiments mentioned above for the last group of students in PH 4750. Therefore, a Linac improvement program was started in March 1975 and is expected to be complete by September 1975. These improvements, mainly in the vacuum system, have been carried out by Professor E. B. Dally, Professor F. Buskirk and the Linac technicians, D. Snyder and H. McFarland.

Thesis Directed:

R. D. Wakefield, "Some Experiments on Dosimetry and Radiation Damage in Semiconductor Devices," Master's Thesis, 1975.

COMPUTER SIMULATION OF SPUTTERING III

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

Support: Foundation Research Program

Objective:

To investigate, by computer simulation, the sputtering of a copper surface by diatomic molecular ions and the formation of clusters of particles sputtered by atomic ions.

Summary:

(1) The sputtering of a copper surface with molecules has been simulated in a digital computer. The target was a (100) single crystal surface of copper, the ion a pseudomolecule of argon. Ar_2 was chosen so that direct comparisons could be made with earlier Ar-Cu sputtering simulations and because the Ar-Cu interaction potential function is relatively well defined. The molecule was unbound, and the binding energy of the crystal was neglected. This approximation has been justified by earlier sputtering simulations.

The molecular sputtering ratio at a single impact point is a strong function of the orientation of the molecule with respect to its velocity vector and to the target surface. Particular orientations were examined in some detail. Often the 'trailing' argon atom interferes with the sputtering mechanisms which the leading argon atom has initiated. Approximately 30 percent of the time, an atom which would have been sputtered by a single argon atom incident at that point is not sputtered by the molecule. The two argon atoms rarely collide after separating during the initial impact. Often an individual target atom will be struck successively by both argon atoms. When the trailing atom is well behind the leading atom, it makes its initial strong collision in the second atomic layer because the leading atom has moved a surface layer atom out of its way. Behind is used here in the sense of orientation, not in the sense of increased separation.

At one impact point, with a 5 keV molecule the shuttering yield varied from 3 to 14 atoms/ion as a function of the molecular orientation. The mean yield was 8.54 atoms/ion with a standard deviation of approximately 2 atoms/ion. The yield of a single 2.5 keV argon ion at the same impact point was 7 atoms/ion. A 10 keV molecule incident on the same point produced a broader distribution (2 to 15 atoms/ion) and a lower mean yield of 6.07 atoms/ion. The corresponding yield of a single 5 keV argon was 6 atoms/ion.

(2) The formation of clusters of sputtered copper atoms from an argon bombarded (100) copper surface has been simulated with a computer program which includes interatomic attractive forces. Dimer formation is very common. Dimers rarely form from atoms which were nearest neighbors on the target surface; next-nearest neighbor formation is much more common, and combinations of more distant neighbors have been observed. Formation of a dimer by a single atom moving in a channel has not been observed, and could not be forced by artificial means. All multimer formation mechanisms depend strongly upon the relatively low speed of the sputtered atoms and the relatively high speed of the knock-on atoms involved in the sputtering mechanisms. Dimers formed from one first layer and one second layer atom have been observed.

The criterion for dimer formation is that the total kinetic energy of the two atoms in the center-of-mass system of the molecule is less than the magnitude of their binding energy, that is, that the total energy of the dimer is negative.

Strong evidence exists for trimer formation. Pairs of dimers with a common atom have been observed. The total energy of the three-atom combination is negative, but the long term stability of these trimers cannot be guaranteed because they are detected as pairs of coupled oscillators, not as triangular bound structures, so energy transfer between the oscillators may destroy the structure at some later time. Trimers formed from three surface atoms and from combinations of atoms from the first and second layers have been observed.

No quadrimers have been identified, but structures which almost meet the stability criteria have been observed.

Publications: None

Conference Presentations:

D. E. Harrison, Jr. and C. B Delaplain, "Computer Simulation of Multimer Production." Paper presented at the Sixth International Conference on Atomic Collisions in Solids, Amsterdam, the Netherlands, September 22-26, 1975.

D. E. Harrison, Jr., "Fundamentals of Ion-Surface Interactions." Paper presented before the National Science Foundation Seminar on Quantative Techniques in Secondary Ion Mass Spectrometry, 13 October 1975.

COMPILATION OF VACUUM ULTRAVIOLET SPECTRA

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

Support: National Aeronautics and Space Administration

Objective:

To prepare a complete and accurate compilation of atomic spectrum lines with wavelengths less than 2000 Angstroms, based on publications in the open literature.

Summary:

An important part of any field of science is the utilization of measurements which have already been made. Frequently, however, the available information is fragmentary, of questionable value, or is not easily located in the various journals. The Spectroscopic Data Center is a repository of all available information on optical transitions in atoms and ions of the elements through Krypton. These data are continually up-dated and evaluated, so that fragmentary information is put into the larger picture, and doubtful information is eliminated. Compilations are published from time to time, the latest being NRL 7599,"Atomic and Ionic Emission Lines Below 2000 Angstroms," June 1973. This report contains the wavelength, intensity, and classification of 34,700 spectrum lines with wavelengths in the vacuum region, from all observed stages of ionization. Entries are arranged by element and spectrum, with a separate finding list. Following the publication of this report, up-dating the data files has continued. More than 100 new publications with relevant information have appeared. Evaluation of the new and old data is a continuing task, certainly one of the most important. In addition to the compilations published, the files are available to users as magnetic tapes and punched cards. These forms of data file have been used by astrophysicists and plasma physicists.

Publications: None

THERMODYNAMICS CALCULATIONS FOR INTERNAL EXPLOSIVES

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

Support: Naval Weapons Center

Objective:

To make theoretical thermodynamic calculations for the pressure and temperature rises produced by explosions in a confined space.

Summary:

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

A computer program for characterizing these effects has been developed. This involves the solution of twelve non-linear simultaneous equations. The results have been found to agree within experimental uncertainty with observed values for TNT as reported in the literature. These calculations are now to be extended to cover other explosion situations.

Publications: None

ENVIRONMENTALLY ADJUSTED SIGNAL ENHANCEMENT

Investigator: H. Medwin, Professor of Physics and Chemistry

Support: Naval Seas Systems Command

Objective:

To study means for adjusting an ocean acoustics signal in response to the fluctuating medium in order to enhance its strength and to improve its stability.

Summary:

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

Publications: None

Theses Directed:

J. B. Perkins, III, "Amplitude Modulation of Acoustic Signals by Ocean Waves and the Effect on Signal Detection," Master's Thesis, December 1974.

M. H. Tourville, III, "Signal Enhancement of Surface Scattered Underwater Sound," Master's Thesis, June 1975.

UPPER OCEAN PARAMETERS AFFECTING SOUND PROPAGATION

Investigator: H. Medwin, Professor of Physics and Chemistry

Support: Office of Naval Research

Objective:

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

Summary:

During FY 1975 computerized equipment was developed in-situ. The initial data on sound speed dispersion, attenuation and inferred microbubbles in the upper ocean were obtained. The experiment is continuing in search of the interrelations between ocean parameters, bubble presence, and sound propagation under various ocean conditions.

Publications:

H. Medwin, "Predicting Sound Phase and Amplitude Fluctuations due to Microstructure in the Upper Ocean," Journal of the Acoustical Society of America, 56 (1974).

H. Medwin, "Acoustic Fluctuations Due to Microbubbles in the Near-Surface Ocean," Journal of the Acoustical Society of America, 56 (1974).

H. Medwin, J. Fitzgerald and G. Rautmann, "Acoustic Miniprobing for Ocean Microstructure and Bubbles," Journal of Geophysical Research, 80 (1975).

P. C. C. Wang and H. Medwin, "Stochastic Models of the Scattering of Sound by Bubbles in the Upper Ocean," Quarterly of Applied Mathematics, June 1975.

Thesis Directed:

T. B. Huffman and D. L. Zveare, "Sound Speed Dispersion, Attenuation and Inferred Microbubbles in the Upper Ocean," Master's Thesis, December 1974.

LASER EFFECTS HANDBOOK

Investigators: J. Neighbours, F. Buskirk, J. Cooper and D. Harrison, Professors of Physics and Chemistry
R. Armstead and J. Schultz, Associate Professors of Physics and Chemistry
M. Bank, Assistant Professor of Aeronautics
J. Perkins, Assistant Professor of Mechanical Engineering

Support: Naval Sea Systems Command

Objective:

To collect and correlate the results of the materials effects portion of the High Energy Laser Program. The results of the project are to be published as a "Laser Effects Handbook" for distribution to members of the hardness and vulnerability community.

Summary:

As the high energy laser program developed, considerable data on materials effects became available. The hardness and vulnerability community pressed for collection of this data and a Naval Research Laboratory (NRL) Handbook edited by Professor Neighbours was published in early 1974. Since then the handbook project has been transferred to the Naval Postgraduate School (NPS) and each of the above named faculty has worked on a section. The source material is mainly classified; either NPS library materials or reports received by the handbook. In order to ensure timeliness and ease of updating, the handbook is published in sections as they are available.

Publications: A. J. Perkins, J. R. Neighbours, "Response of Particular Materials to Laser Radiation," Technical Report, NPS-61Nb75091, September 1975.

HOMOGENEOUS CATALYSIS BY PALLADIUM COMPLEXES

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

Support: Foundation Research Program

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:

Optimization and characterization of chemical processes are extremely important in this age of dimishing basic resources. A major synthetic route to useful products is the Wacker process in which ethylene is oxidized to acetaldehyde in the presence of a palladium chloride complex ($PdCl_4^{2-}$) and hydrogen ion.

Work in this laboratory is primarily concerned with the first step in the above process in which the olefin is oxidized to a carbonyl compound by the catalyst. By varying the palladium complexes employed as catalyst, the hydrogen ion and anion concentrations and the temperature, one can determine the basic kinetic and thermodynamic properties of the system, establish rate laws, and also organize a reactivity series for the palladium complexes.

Thus far a workable method of analysis has been set up and the rates in the literature have been verified for the olefin trans-2-butene in the presence of $PdCl_4^{2-}$, using gas chromatography to monitor the olefin and product concentrations. Work is currently in progress using $PdBr_4^{2-}$, cis-$Pd(NH_3)_2Br_2$ and $Pd(H_2O)_4^{2+}$ as catalysts. An anion found to be unacceptable for controlling ionic strength was sulfamate $[(NH_3)SO_3]^{1-}$ as it formed an insoluble complex with the palladium.

Publications: None

MEASUREMENT OF THE HIGH-FREQUENCY, COMPLEX VISCOSITY OF DRAG-REDUCING POLYMER SOLUTIONS

Investigator: J. V. Sanders, Associate Professor of Physics and Chemistry

Support: Foundation Research Program

Objective:

To measure the high-frequency mechanical properties of dilute aqueous solutions of polyethylene oxide and of polyisobutylene in cyclohexane.

Summary:

The dynamic viscosity and elasticity of solutions of long-chain polymers measured at high-frequencies can provide information about the constitutive molecules. This information would be of interest to physical chemists studying the basic mechanisms responsible for the drag reduction experienced by underwater vehicles when these polymers are injected into their boundary layers. Measurements of the effects on the speed and attenuation of torsional waves on a rod emersed in a solution allows determination of the dynamic mechanical properties of the solution. Attempts to measure the dynamic properties of dilute (a few weight parts per million) solutions of polyethylene oxide were inconclusive because of the lack of sufficient precision in the measurement technique. It has been determined that the experimental procedures have been refined to a point where further precision can be obtained only by redesigning the entire apparatus. However, work is continuing in an attempt to determine the minimum concentration at which the existing precision will allow accurate determination of the dynamic viscosity and elasticity.

Publications: None

FIELD TESTS OF DISPERSAL OF WARM FOG BY INJECTION OF ELECTRICAL CHARGE

Investigator: G. E. Schacher, Associate Professor of Physics and Chemistry

Support: Naval Weapons Center

Objective:

To test the possibility of using corona discharge to dispense warm fog. These tests were to be conducted in naturally occurring fog in the field. These tests were the last in a series of research projects on this problem which were made for China Lake.

Summary:

These tests were conducted at the municipal airfield at Visalia, California. Visalia is in the Central Valley and experiences high fog occurrence during the winter months; and the flat, open location near the airfield is ideal for these tests. China Lake installed equipment for measuring wind speed and directions, visibility, and fog droplet size spectrum. Our project supplied the corona-charging apparatus mounted on a trailer with a 40 ft mast. Studies were made on two successive nights during good fogs.

The data were taken as follows: the charging apparatus was kept upwind of the visibility and droplet spectrum apparatus and turned on and off periodically. 100,000 volts was used. The purpose was to attempt to correlate charging with an increase in visibility and/or a shift in the droplet spectrum toward larger sizes. A positive correlation would indicate fog clearing caused by the charging. No correlation was observed.

The lack of a correlation does not allow us to conclude that this method is ineffective for fog clearing. The corona charging apparatus consisted of a single point charging head at the top of the 40 foot mast. The targeting using this arrangement is very difficult and one cannot be sure that the corona current flows past the detecting apparatus. In order to perform a definitive experiment in the field, one would need a large array of discharge heads, which would be quite expensive. A more sensible approach would be to perform experiments in the large environmental chamber at China Lake to gather some of the basic information needed to redesign subsequent field experiments.

Publications: None

AGING OF TUNGSTEN HOT WIRES IN THE MARINE ENVIRONMENT

Investigator: G. E. Schacher, Associate Professor of Physics and Chemistry

Support: Foundation Research Program

Objective:

To characterize the behavior of hot and cold resistance wires in measuring atmospheric turbulence in the marine environement.

Summary:

The initial portion of this program is to determine the mechanisms and rate of aging of tungsten hot wires when used on shipboard. We determine wire performance by calibrating their sensitivity to mean wind velocity, and examine their physical degradation with the scanning electron microscope. The aging appears to be entirely due to sea salt deposition on the wires. The salt has two effects: (1) The salt builds up on the wires and increases their drag. Sufficient build up will then cause the wire to mechanically break. (2) It appears that the sea salt which is deposited on the wire chemically attacks it. We observe that good wires which are removed from the ship will break after a time of sitting in the lab, indicating a continued deterioration which can only be caused by the sea salt. We now have data on a large number of wires from cruises aboard the RV/ACANIA in the Pacific and USNS HAYES in the Atlantic, so that this portion of the project is near completion. Future work will center on the frequency response of the wires and on their behavior in marine fog. Efforts continue to find mechanisms for cleaning the wires to prolong their life.

Publications: None

RANGE STUDIES PROGRAM

Investigators: O. B. Wilson, Professor of Physics & Chemistry
D. B. Hoisington, Professor of Electrical Engineering

Support: Naval Torpedo Station

Objective:

To provide background technical support for the Naval Torpedo Station's Range Development Program.

Summary:

Because of the complexity of the project and its duration, a total of seventeen professors and ten naval officer students participated. In order to systematize the operation and to allow each participant to become familiar with the particular aspect of the total problem that he was to work on, the project was divided into seven task-oriented sections as follows: (1) Range Requirements, (2) Signal Coding, (3) Transducers, (4) Ray Tracing, (5) Range Concepts, (6) Non-Acoustic Sensors, (7) Data Transmission, Processing, and Display.

Each section worked on problems related to the fluid for which it was assigned. A detailed analysis of results obtained was prepared by O. B. Wilson, Jr. under the title of "Annual Summary Report, Range Studies Program," and forwarded to Research and Engineering Department, Naval Torpedo Station.

Publications: O. B. Wilson, "Annual Summary Report, Range Studies Program," Technical Report NPS71W175081, August 1975.

COMPUTER SCIENCE GROUP

The research program of the Computer Science Group, an interdisciplinary academic unit, utilizes both the Naval Postgraduate School's computer center and the Group's own modern computer laboratories to support work in (1) Interactive graphics, (2) Signal processing, (3) Microprocessing, (4) Real-time processing, (5) Application problem solving and applied management techniques, (6) Compiler optimization, (7) Operating systems design and implementation, and (8) Microprogramming.

This highly productive research program has permitted the development of a number of functional laboratories. These include a Digital Logic Laboratory specializing in digital circuitry; a microcomputer laboratory where computers are built from Large Scale Integration (LSI) chips and the Postgraduate School's own computer laboratory which boasts a multi-processor system with a significant graphics capability. An additional processor will be installed during FY 1976 which will be capable of emulating various computer systems through the use of dynamic microprogramming and permit research in computer architecture.

INTERACTIVE GRAPHICS

Interactive graphics research has stimulated the development of a carrier aircraft distributed management information system for aircraft handling officers on aircraft carriers by G. A. Rahe, G. M. Raetz, and D. E. Harrison, Jr.; the development and evaluation of Navy's standard minicomputer (AN/UYK-20) to display controller applications by G. A. Rahe and B. E. Allen; and the application of graphical techniques of acoustic signal analysis to seismic data by G. A. Rahe.

SIGNAL PROCESSING

This research area includes techniques developed for anti-submarine warfare and identification of nuclear explosions by G. A. Rahe, performance evaluation of the S-3A signal processing system by V. M. Powers and the design, procurement, and acceptance testing of an Anti Submarine Warfare (ASW) test-bed multiprocessing system and the systems software research of B. E. Allen and G. L. Barksdale, Jr.

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MICROPROCESSING

U. R. Kodres has done significant research in a variety of areas using an interconnected network of microcomputers. Specific research has been accomplished in the development of an airborne navigational system, a ballistics computer designed to calculate the impact point of a bomb released by an airplane, and a tracking computer which predicts the position and velocity of an aircraft by using a fire control radar as an input. V. M. Powers has explored the use of microcomputers and shipboard navigation and for use at remote weather stations, and G. A. Kildall has investigated the design and development of a portable microcomputer system to aid Navy divers in determining the safe ascent depth during dives.

REAL-TIME PROCESSING

V. M. Powers has studied the hardware requirements to update the real-time processing and display of range tracking information.

APPLICATION PROBLEM SOLVING/APPLIED MANAGEMENT TECHNIQUES

C. P. Gibfried has worked with both the Naval Personnel Research and Development Center and the Bureau of Personnel in identifying practical methods of applying sophisticated computer programming techniques to the Navy's enlisted personnel distribution and assignment system.

COMPILER OPTIMIZATION/MICROPROGRAMMING/OPERATING SYSTEM DESIGN AND IMPLEMENTATION

While no specific projects have been undertaken in these areas, independent work accomplished in compiler optimization, operating system design and implementation and the application of microprogramming techniques indicate that each of these may be a fruitful area for further study.

A METHOD OF ESTIMATING THE QUANTITY OF KNOWLEDGE REQUIRED FOR A PROPOSED APPLICATION OF ARTIFICIAL INTELLIGENCE

Investigator: G. D. Gibbons, Assistant Professor of Computer Science Group

Support: Foundation Research Program

Objective:

To produce a workable quantitative definition of knowledge as used in current applied Artificial Intelligence (AI) systems, demonstrate its appropriateness as a measure of human knowledge, and show how to use it to estimate the size of the knowledge base that would be required to implement a proposed new AI application.

Summary:

Newell and Simon (1972) present the "chunk" as a suitable elementary unit of information in terms of which memory capacities and read-write times can be measured in human beings. I hypothesized that corresponding unit of information could be found in the computer, and that therefore one could build a technique of comparing human and computer knowledge quantitatively.

The current hypothosis of the computer "chunk" is simply the pointer: a word of computer memory containing the address of another word (or sometimes a symbol, such as a character or a number). A rough method of estimating the size of a computer knowledge base has been formulated. In pointers, of course, it is simply the number of words of memory occupied. However, such an estimate must be refined in order to be useful. Such refinements include compensating for such factors as how concise and structured the knowledge base is, how compiled it is, and what the quality of the theory on which it is based is.

Two experiments are in progress to investigate the quantification of human knowledge. Both are intended to exploit the finding reported by Newell and Simon that human long-term memory storage seems to take approximately five seconds per chunk. This relatively slow rate (other human memory functions occur in milliseconds or tens of milliseconds) means that acquiring a knowledge base takes substantial time for a human being.

The first experiment involves a student learning a moderately complex symbolic task, while keeping an accurate log of his

study, and obtaining all his information and instruction in writing. The log and the learning materials will be analyzed to determine the approximate number of chunks that he could have acquired during his training, and any structural information that they may reveal. Inasmuch as there is an AI program that performs the same task, this experiment should yield at least one data point for comparing human and computer knowledge bases.

In the second experiment, an interactive program tells a subject a number of facts and then asks him questions about those facts, prompting him when he errs, and monitoring the session to measure the rate at which he is acquiring information. Several devices are used to insure that the subject is using long-term memory. First, of course, he is prevented from seeing any but the current sentence of output. Second, the facts are presented in various forms: first, using familiar words and ideas such as "a person has two arms," and later, in another session, with variables substituted for familiar vocabulary - "An X has two y." Analysis of the results of these experiments should yield insights about how to estimate the relationship between computer and human knowledge bases.

Publications: None

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A SUMMARY OF THE NAVAL POSTGRADUATE SCHOOL RESEARCH PROGRAM.(U)
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A MICROCOMPUTER-BASED NAVY SCUBA DIVING COMPUTER

Investigator: G. A. Kildall, Associate Professor, Computer Science Group

Support: Naval Undersea Center

Objective:

To design and develop a portable computer system to aid Navy divers in determining the safe ascent depth at any time during a dive. The safe ascent depth is that depth to which a diver can ascend without contracting the "bends" after operating at various depths. Specifically, the prototype computer system was implemented using the recently available microcomputer technology.

Summary:

A theoretical model of nitrogen absorption by human tissue was developed by the Naval Undersea Center. This model was programmed and tested on a large scale computer system, and subsequently modified to approximate more closely actual results. The model was then programmed in the high level microcomputer systems language PL/M, and tested in a microcomputer developmental system. Special-purpose hardware was then constructed which included an 8-bit microcomputer central processing unit (CPU), and minimal read-only memory and random-access memory. Input/output circuitry was developed for monitoring the time and depth of the dive, along with a light-emitting diode display.

The resulting prototype was contained on a 7" x 9" wirewrap card, which is compact enough to be carried with the diver's equipment. In operation, the diving computer continually computes partial pressures of nitrogen in several tissues, ans displays the safe ascent depth determined by the controlling tissue.

Publications: None

Conference Presentations:

G. A. Kildall, "Microcomputer Software Design-A Checkpoint," Paper presented at the AFIPS National Computer Conference, Anaheim, California, 1975.

NO-DROP BOMB SCORING SYSTEM

Investigator: U. R. Kodres, Professor, Computer Sciences Group

Support: Naval Weapons Center

Objective:

To develop a microcomputer-based simulation of the bomb drop which may be used to eliminate dropping practice ordnance over a target.

Summary:

The system was demonstrated as an operational system on November 9, 1975, at the China Lake target range. A total of 6 practice bombs were dropped during this demonstration which fell within the pattern of dispersion of the predicted locations. Support for a more extensive test of the system is anticipated.

Publications: None

Theses Directed:

A. Pease, "A No-Drop Bomb Scoring System Using Microcomputers," Master's Thesis, June 1974.

H. A. Juplin, "The Ballistics Processor a Multiple Processor, Airborne Tactical System," Master's Thesis, June 1975.

APPLICATION OF REAL-TIME PROCESSING AND DISPLAY SYSTEMS TO RANGE TRACKING

Investigator: V. M. Powers, Assistant Professor, Computer Science Group

Support: Naval Torpedo Station

Objective:

To investigate the capabilities and specifications of systems and devices for real-time processing and display of range tracking data.

Summary:

Specifications for the procurement of a new display system were reviewed at the Naval Postgraduate School (NPS), and suggestions were made. A mid-year working paper gave some considerations for the design of a real-time range computer and display system. A subsequent student thesis developed some of these concepts further and described a computer graphics simulation of the basic 3-D display ideas. Partially as a result of this work, the Naval Torpedo Station is currently reevaluating procurement plans.

Publications: None

Thesis Directed:

L. N. Schofield, "Design Approach for a Computer Graphics System Applicable to Torpedo Tracking and Evaluation," Master's Thesis, June 1975.

MICROCOMPUTER STUDIES

Investigator: V. M. Powers, Assistant Professor, Computer Science Group

Support: Naval Electronic Systems Command & Fleet Numerical Weather Central

Objective:

To investigate different applications of microcomputers to the Navy. The Naval Electronic Systems Command (NAVELEX) sought to explore the use of microcomputer hardware and software in shipboard navigation. The Fleet Numerical Weather Central (FNWC) sought to demonstrate the feasibility of using a microcomputer-based floppy disk operating system as the hardware/software foundation of a remote weather information station.

Summary:

These research projects continued to demonstrate the applicability of microcomputers to the Navy. The NAVELEX micronavigator project represented an idea which was relatively straightforward in technology, but more difficult to relate to operational application and organization. The FNWC data terminal was more easily related to its application, but technologically more challenging. A microcomputer-based control and storage-prototype module has been demonstrated.

Publications: None

Theses Directed:

R. H. Ekstrom and W. H. Reinhardt, "A Microprocessor-based Communications Information System," Master's Thesis, June, 1975.

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

ANTI-SUBMARINE WARFARE SIGNAL PROCESSING AND DISPLAY LABORATORY

Investigators: G. A. Rahe, Professor, Computer Science Group
G. L. Barksdale, Assistant Professor, Computer Science Group, B. E. Allen, Instructor, Computer Science Group

Support: Naval Electronic Systems Command, Naval Air Systems Command and Naval Material Command

Objective:

To design, procure, and install an Anti-Submarine Warfare (ASW) Signal Processing and Display Laboratory at the Naval Postgraduate School. This laboratory facility is to provide a testbed for the evaluation of existing and proposed signal processing and display techniques applicable to a broad spectrum of ASW related problems.

Summary:

Installation of equipment for the ASW Signal Processing and Display Laboratory was begun in September 1974, with phased equipment deliveries scheduled through the first quarter of FY 1976. Integration and system development efforts have continued throughout FY 1975. As of 30 June 1975, the following subsystems have been installed and are being evaluated for acceptance: (1) CSP-30 signal processing controller with 44K word memory, (2) CSP-4001 array processor, (3) DEC PDP-11/50 data acquisition controller with 96K word memory, (4) DEC PDP 11/50 display controller with 48K word memory, (5) display subsystems: EPC gram writer, Ramtek raster display (color and monochrome), Vector General 3D3I vector display, Tektronix 4014 storage display, Versatec 1200a 200 pt/in printer/plotter, Vector General data tablet, and 13 Data Media alphanumeric terminals, (6) peripheral subsystems: 3 magnetic tape units, card reader, line printer, 2 moving head disks (1.2M word), paper tape, fixed head disk (.256M word), (7) memory expansion for existing AGT-10 display systems (8K to 32K word).

In addition, development of a real-time multiprocessing control program for the laboratory is well underway. The two major subsystems not yet delivered are (1) Huges Conographic storage display, (2) AED Storage Module (100M word disk system).

Publications: None

APPLICATION OF GRAPHICAL TECHNIQUES OF ACOUSTIC SIGNAL ANALYSIS TO SEISMIC DATA

Investigator: G. A. Rahe, Professor, Computer Science Group

Support: U. S. Arms Control and Disarmament Agency

Objective:

To examine the use of computer programs and graphical techniques as a means of detecting the seismic signals of low yield underground nuclear explosions in the presence of other seismic signals and background seismic noise.

Summary:

Computer programs have been written which take full advantage of the interactive capabilities of the XDS 9300/AGT 10 Graphics System of the Naval Postgraduate School (NPS) Computer Laboratory. To display the seismic wave forms, a digitally simulated oscilloscope program, featuring a variable time base, triggering, sweeping in time, and digital documentation, has been written. Two programs were written to display Fourier transforms of the seismic data. One allows simultaneous examination of the chronological development of the frequency spectra of up to ten seismic records, while the other facilitates the study of the dynamic characteristics of signals in both the frequency and time domains.

U. S. Arms Control and Disarmament Agency (ACDA) has provided seismic data from the Large Apature Seismic Array (LASA). Through the interactive graphics display it has been possible to examine the frequency characteristics of the signals as well as to estimate their arrival times at the array. The detectibility of low amplitude transient signals appears to have been enhanced and the prospect of future gains is promising.

Publications: None

CARRIER AIRCRAFT MANAGEMENT DISTRIBUTED INFORMATION SYSTEM

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

Support: Naval Air Systems Command

Objective:

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

Summary:

The basic informational requirements for each of four command and control stations in the Air Group; the Aircraft Handling Officer (ACHO), the flight deck, the hanger deck, and the squadron maintenance stations were determined. Based on these requirements a simulation of the proposed information system was written for the XDS 9300 computer system. The simulation was designed within the constraints of a distributed computing system. Since the XDS 9300 could not be operated in a fully partitioned mode the protocol between independent stations was modeled rather than real. The simulation results demonstrated a computer based interactive graphics and information system to be a feasible solution to problems such as maintaining current and accurate data, rapid information retrieval and display, and ease of aircraft spot plan construction.

Publications: None

Theses Directed:

A. K. Johnson and K. P. Woolley, "A Simulation of a Computer Graphics-Aided Aircraft Handling System," Master's Thesis, 1975.

T. J. Giardina, "An Interactive Graphics Approach to the Flight Deck Handling Problem," Master's Thesis, 1974.

DEVELOPMENT AND EVALUATION OF THE AN/UYK-20 FOR DISPLAY CONTROLLER APPLICATIONS

Investigators: G. A. Rahe, Professor, Computer Science Group
B. E. Allen, Assistant Professor, Computer Science Group

Support: Naval Electronic Systems Command

Objective:

To develop software for the Navy's standard minicomputer the AN/UYK-20 which will permit it to act as a controller for various types of display terminals and to evaluate its performance and applicability for each.

Summary:

The Univac AN/UYK-20 has been selected as the Navy's standard tactical minicomputer. One important application for minicomputers is as controllers for display terminals. The Naval Postgraduate School (NPS) Computer Laboratory has acquired display terminals of each of the principal types as part of an Anti-Submarine Warfare (ASW) test bed. This unique capability will allow the development and performance evaluation of the AN/UYK-20 for various types of displays available.

The cost and lack of availability of the military standard peripherals required for software development on the AN/UYK-20 dictates that the laboratories DEC PDP 11-50 be employed instead. The study will begin by interfacing the AN/UYK-20 to the PDP 11 by means of a serial interface. The PDP-11 will act in lieu of the military peripherals. Development of a cross compiler hosted on the PDP-11 will allow the development of AN/UYK-20 software more efficiently through the use of software engineering aids available on the PDP-11. Loading programs will also be immeasurably improved. Finally, it is hoped that a parallel interface between the AN/UYK-20 and the PDP-11 will be obtained before the final performance evaluations.

Publications: None

PIXIE

Investigator: G. A. Rahe, Professor, Computer Science Group

Support: Naval Electronic Systems Command

Objective:

To investigate the potential use of emissions radiated by a submerged submarine as well as to determine appropriate quieting.

Summary:

Project PIXIE was initiated when it became apparent that signal processing and display techniques developed at the Naval Postgraduate School had an impact on detection ranges and probability of classification of submerged submarines. Sea tests were conducted during FY 1975 to expand the data base for further research.

Publications: None

SPOTLIGHT

Investigator: G. A. Rahe, Professor, Computer Science Group

Support: Naval Electronic Systems Command and Naval Air Systems Command

Objective:

To develop a signal processing and display system for passive sonar.

Summary:

SPOTLIGHT, as it has been conceived and developed by the investigator, is an integrated signal processing display system designed to improve target identification by the use of a time-amplitude-frequency orthogonal display. A hidden line removal technique is employed to reduce clutter and create the appearance of a relief map.

A Selected Frequency search is employed to provide high gain in frequency intervals known to provide the highest probability of initial detection. Identification is provided by amplitude correlation of signals with specific target characteristic relationships. A sliding linear amplitude scale provides the display with a dynamic range matched to the signal processor. Cursors which increase the intensity of a few resolution bins may be swept through the selected frequency groups under operator control. The frequency location of the cursors in each group is displayed to the operator in a continuous alphanumeric read out. These cursors may be moved independently or according to the relationships of the groups to aid the operator in detection and identification like a SPOTLIGHT shining on a topological surface.

The signal processor employs an ideal box-car integrator and overlapped transform methods to allow significant signal processing gains from increased integration time. The overlapped transforms provide the ability to track dynamic changes in signal frequencies which would othewise be lost during long integration intervals.

Publications: None

Thesis Directed:

R. E. Beal, "An Investigation of a Method of Obtaining a Phase Coherence Numeric," Master's Thesis, 1974.

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