NAVAL RESEARCH

REVIEWS

FEBRUARY 1976

PROFILES IN SCIENCE

Dr. Milton U. Clauser

Dr. Milton Clauser was Provost of the Naval Postgraduate School (NPS) from 1970 to 1973. He is well known for his contributions to the fields of propeller turbine installation, effects of curvature on the transition of the laminar boundary layer, and magneto hydrodynamic thermonuclear power. Dr. Clauser has served as the Head of the School of Aeronautical Engineering at Purdue University, as Director of the Physical Research Laboratories at the Ramo-Wooldridge Corp., California, and Professor of Aeronautics and Astronautics at MIT. Among the many governmental advisory boards on which Dr. Clauser has served are the President's Science Advisory Committee and the NASA Advisory Committee on Space Studies, and the Air Force Scientific Advisory Board. Dr. Clauser is the recipient of the Department of Defense Distinguished Public Service Award and the Navy Superior Civilian Service Award.

Research at the Naval Postgraduate School

***Thomas M. Houlihan**
Naval Postgraduate School

Objectives

The research goal at the Naval Postgraduate School derives 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 and to foster and encourage a program of research in order to sustain academic excellence.

Another important aspect of the NPS program is the student theses. Almost all NPS students are required to submit an acceptable thesis as part of their educational program. A substantial number of these theses are directly related to the faculty advisor's research project.

The research program is the activity by which the institution generates new knowledge and contributes directly to the Navy's 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 interests; to maintain the professional competence of the faculty through personal involvement at the dynamic horizon of their field.

Research Facilities

Today's educational and research endeavors require talented personnel and modern facilities to ensure success. With regard to the latter, the Naval Postgraduate School is endowed with a variety of modern research facilities.

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*Dr. Thomas M. Houlihan is past Chairman of the Faculty Research Committee at the Naval Postgraduate School. In 1973, he was a Visiting Scientists at ONR Pasadena.

The Dudley Knox Library, a building of 50,000 square feet dedicated in 1972, supports both the research and instructional needs of NPS. The library's collections include more than 400,000 books and bound periodicals, research reports, serial publications, and microfiches. A recently implemented RDT&E On-Line Terminal provides the capability of using the data banks of the Defense Documentation Center (Figure 1).

The W. R. Church Computer Center contains an IBM 360/67 large scale, third generation computer system which supports campus data process services ranging from local batch processing to remote-access time sharing. The Center is now preparing interface hardware for access to the ARPA Computer Network. This interface will permit expanded applications involving network optimization models, war gaming, and ASW data base compilations.

NPS operates both research vessels and test aircraft for research and educational studies. The R/V ACANIA, a 126 foot vessel operated under the auspices of the Oceanography Department, services instructional studies in oceanographic instrumentation as well as research projects involving laser propagation in the marine environment, near surface

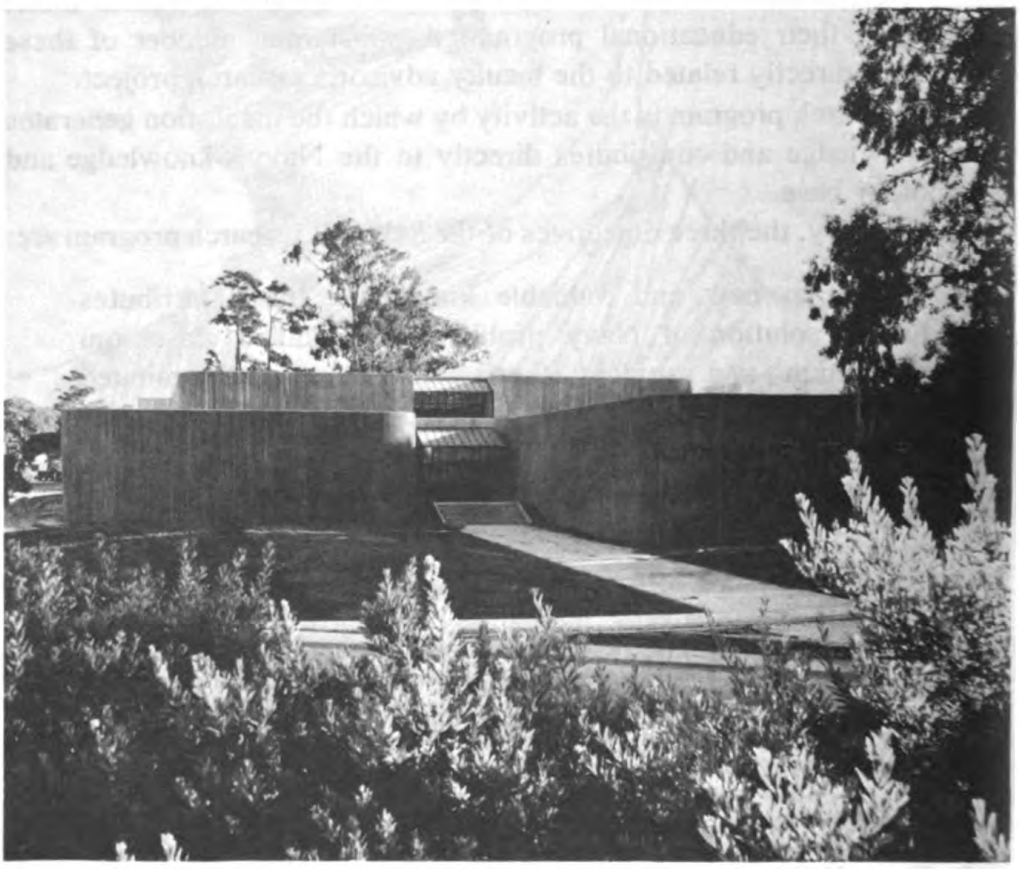

Figure 1 – Dudley Knox Library on the NPS Campus

sound transmissions, marine fog climatology, and the biodegredation of engineering materials. The Aeronautics Department utilizes a twin-engine, general aviation aircraft which features three fully instrumented test stations. Presently, this instrumentation is being supplemented with microcomputer systems to monitor and record airframe stress data. The Aeronautics Department also operates the XR-3, a three ton Surface Effect Ship Testcraft of the Captured Air Bubble type (Figure 2).

In the Electrical Engineering Department, a Navy communications satellite terminal is becoming operative. The system will be used in a study of noise and transmission problems encountered with satellite communications in a military environment. A 100MeV Electron Linear Accelerator is operated by personnel of the Physics and Chemistry Department. NPS researchers at this facility have attained international renown for their fundamental work on Giant Resonance phenomena.

In addition to these primary research facilities, a full spectrum of test installations and instrumentation is available for application to a diversity of studies. Moreover, three important research activities located on the campus, or nearby, provide mutually beneficial access to NPS faculty and students. Foremost among these is the Fleet Numerical Weather Central (FNWC) - the master computer center and comptroller of the Navy's world-wide environmental data network. FNWC provides a link to the environmental data utilized in computer-aided forecasting

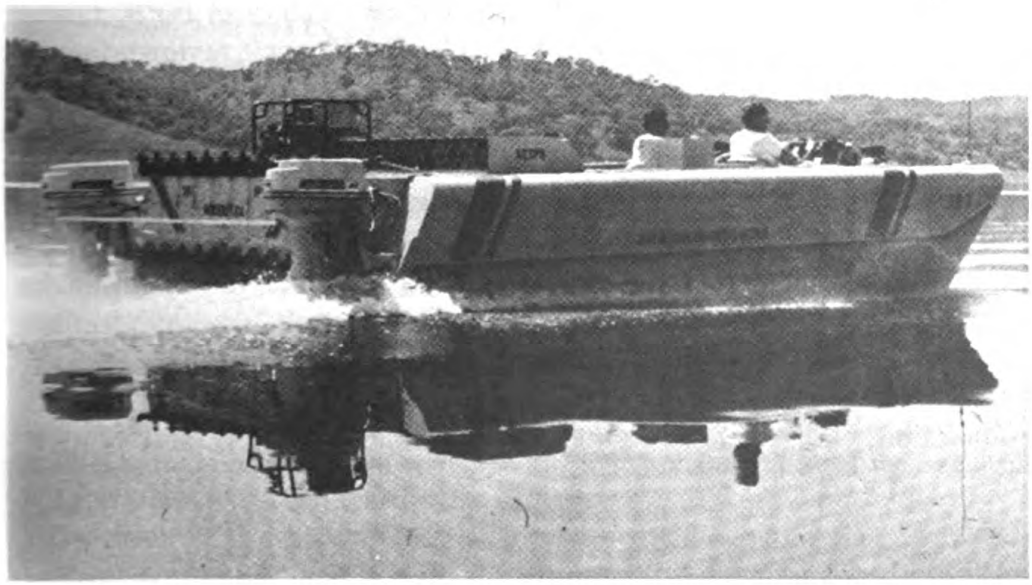

Figure 2 — The XR-3 Surface Effect Testcraft

on a global scale. Thus, daily receptions of pictures from NIMBUS, ESSA, and ATS Weather Satellites enhance synoptic analyses applied to both classroom and research environmental projects.

NPS supports through research and computer services the Manpower Research and Data Analysis Center (MARDAC) of DoD, using computer analyses of manpower data bases to assist DoD in professional management scenarios. NPS likewise supports the Navy's Environmental Prediction Research Facility (EPRF) in a wide range of studies related to the influence of environmental factors on Naval operations. Recently, this facility and NPS combined resources to develop new techniques for the forecasting of tropical cyclone movements which were subsequently installed in the global operational network of FNWC.

All in all, NPS is endowed with extensive and in many instances unique operational facilities. In conjunction with a talented faculty of pervasive Naval orientation and a student body composed of experienced Naval officers from all warfare specialities, they form a unique graduate educational and research center.

Program Management

The NPS research program is divided into two parts: the Foundation Research Program and the Sponsored Research Program. The Foundation Research Program is akin to institutional research programs in civilian universities or independent research programs in government laboratories and contractor organizations. The Foundation Research Program is funded by grants from the Chief of Naval Research and the Director of Navy Laboratories. It is administered internally by a Research Council composed of appointed members designated by the Provost and of elected members chosen by the Faculty of NPS. Under the chairmanship of the Dean of Research, this Council reviews faculty proposals, allocates funds, and evaluates the results of approved Foundation projects.

The Sponsored Research Program is similar to the contract research performed by civilian universities, government laboratories, and defense contractors. The Sponsored Research Program is administered on a contract basis between individual faculty members and individual sponsoring agencies via the Dean of Research. In FY75, sponsored research funding was received in the amount of $3.2 million at NPS. Representative sponsors, in addition to Naval agencies, included the National Science Foundation, the Air Force Office of Scientific Research, and NASA.

Summary

While the structure and logic of problem solving tends to be uniform across the professions, the specific problems vary widely. At NPS,

the research program provides numerous examples of the unique technical and management situations that the naval officer will encounter in his future career. Basic principles and skills, as they are taught at NPS, are closely related to Navy problems. Thesis work is usually part of the program which provides good experience for the officers to use their research as well as writing skills.

The following articles feature current NPS research projects. More than 130 advanced studies are presently being conducted by the faculty and officer students at NPS.

Near Surface Sound Transmission

When Professor Herman Medwin of the Department of Physics and Chemistry suggested to the visiting Director of the Royal Australian Naval Research Laboratory (RANRL) that the "Aussies" might be interested in learning more about the acoustical effects of micro-bubbles in the upper waters of the sea around Australia, he had no idea that the suggestion would blossom into a multi-dimensional experiment, involving a dozen principal investigators from Australia and the U.S. In November 1972 and February 1973, researchers from Sydney and Monash Universities of Australia, Scripps Institue of Oceanography, and the Naval Underwater Systems Center joined Medwin and LCDR James Fitzgerald in studying the air-sea interaction and acoustical characteristics of the upper ocean from an ESSO-BHP oil pumping platform set in 250 feet of water 50 miles off the coast of Victoria, Australia.

Medwin found that within several meters of the ocean surface there are enough ambient bubbles to create a distinctive microstructure with a dispersive acoustic index of refraction. In this region, the variation of *total* bubble-volume fraction produces fluctuations of the sound speed for frequencies less than about 25 kHz; the frequency spectra of these speed fluctuations are near Gaussian. However, perturbation of resonance frequencies of predominant bubble populations is the principal cause of fluctuations of the speed between 25 and 100 kHz; these fluctuations have frequency spectra that are imitations of the spectrum of the sea surface height which creates them.

The results of this research have been published in the Journal of the Acoustical Society of America **56** 1105-1109 (1974) and the Journal of Geophysical Research, **80**, 405-413 (1975).

Laser Transmissions in the Marine Environment

E. C. Crittenden and K. L. Davidson*
Naval Postgraduate School

Since the optical index of the atmosphere is primarily dependent upon temperature, fluctuations in temperature cause refractive index fluctuations that ultimately result in small scale interference effects, i.e., scintillation. The incipient temperature fluctuations are intimately related to the stability conditions of the atmosphere. Hence, both diurnal and synoptic variations in atmospheric parameters have a bearing upon laser transmissions.

In order to study the feasibility of a laser communication system, research on both small and large scale transmission effects must be accomplished. Moreover, with respect to Naval applications, such research must include the study of additional factors entering the atmospheric composition, such as water vapor and particulate matter, in order that effects peculiar to the marine environment be distinguished. In this regard, the interdisciplinary effort in electro-optics research at NPS is of note, particularly for its direct attack upon the problem of laser transmission in the oceanic environment.

Beginning in late 1972, a group of Naval Postgraduate School faculty members and students from the Departments of Physics and Chemistry, Meteorology, Oceanography, and Mechanical Engineering began an intensive interdisciplinary effort directed toward delineation of the basic characteristics of laser transmission in the marine environment. Under the auspices of this Electro-Optics/Laser Technology (EO/LT) Research Group, in early 1973, a pilot experiment was performed which consisted of the propagation of a helium-neon laser across Monterey Bay, accompanied by measurements of small scale atmospheric parameters along the transmitted beam. These measurements, consisting of hot-wire anemometer recordings of atmospheric velocity and temperature fluctuations, were conducted, utilizing facilities aboard the NPS research vessel, R/V ACANIA (Figure 1).

What was sought was a correlation of optical and meteorological measurements of the atmospheric refractive index structure function, C_N^2. From optical physics results

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Figure 1 — NPS Research Vessel, R/V ACANIA

$$C_N^2 = 2.02\ C_I^2\ k$$
$$C_N^2 = 2.02\ C_I^2\ k^{-7/6}\ L^{-11/6}$$

where C_I^2 = log intensity variance of received light

L = propagation path length

k = wavenumber of laser transmitter.

Receiver electronics produced the log intensity variance directly, thus allowing a path-wise evaluation of C_N^2 to be determined.

Simultaneously, point measurements of the refractive index structure function were produced from micro-meteorological data, viz.,

$$C_N^2 = (79.0\ (P/T^2) \times 10^{-6})^2\ C_T^2$$

where P = barometric pressure

T = atmospheric temperature

C_T^2 = temperature structure function parameter.

Again, direct measurements of C_T^2 enabled pointwise measurements of C_N^2 to be accomplished along the transmission path.

As optical considerations demonstrate, disturbances at the mid-section of a transmitted beam are the primary influences upon the

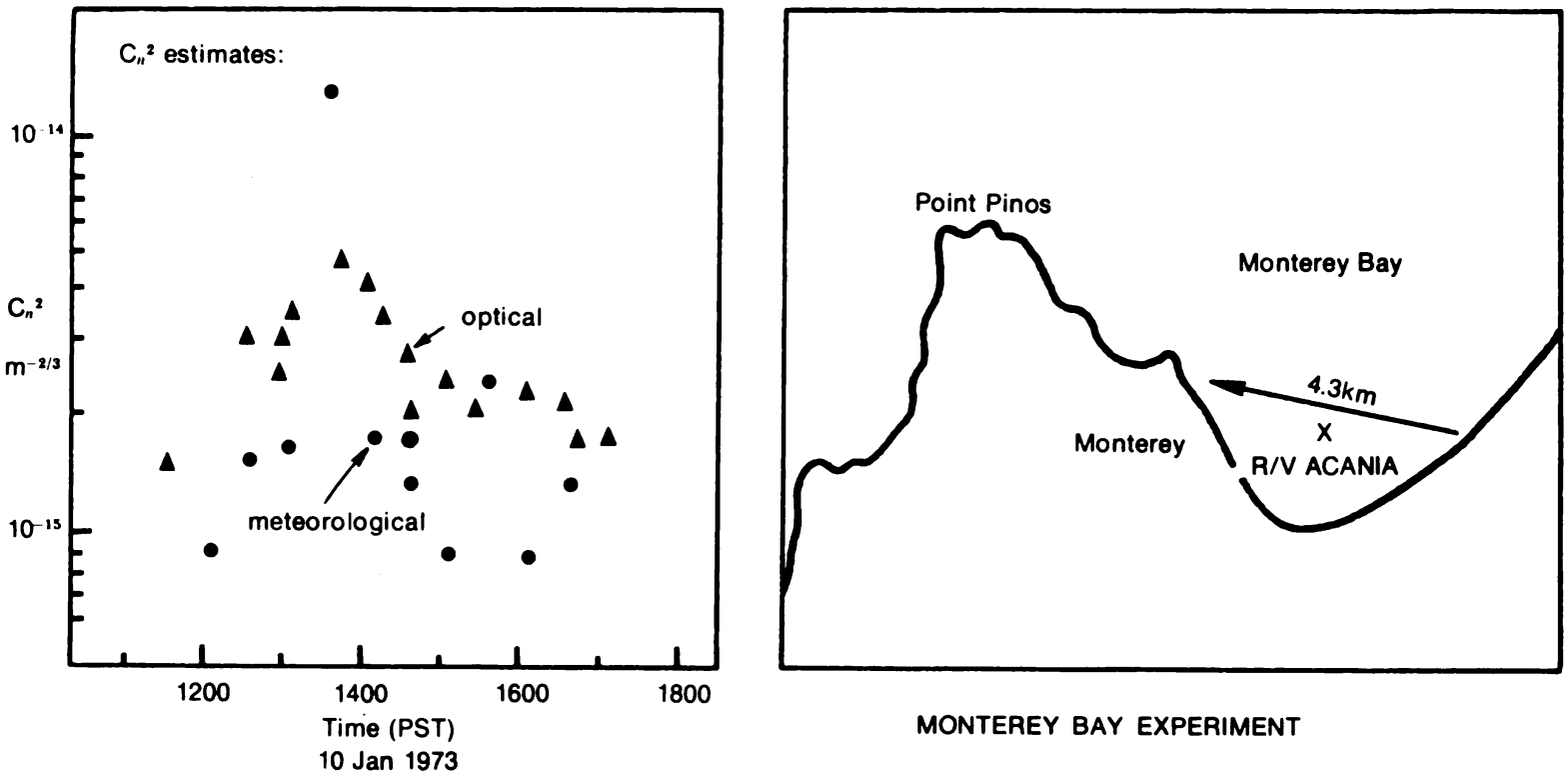

Figure 2 — Laser Transmission Results - Monterey Bay

transmission provided that the transmitter and the receiver stations are not located in atypical environs. These findings were amply reinforced when results obtained by both the optical and the meteorological groups compared to within a five percent margin (Figure 2). Surprisingly, the results of this pilot experiment were the first over-ocean laser transmission data gathered that featured the combined efforts of optical physicists and micro-meteorologists.

The interdisciplinary capabilities demonstrated in this study were expanded and applied in mid-1973 to measurements on the Pacific Missile Range. Again, very favorable data comparisons were reported by both ship and shore based personnel (Figure 3). Starting in the latter part of 1973, a series of overwater laser transmission measurements were begun. Techniques involving stabilized shipboard laser transmissions to shore based receiving stations were perfected with preliminary operations on Monterey Bay. Additionally, the optical experimental program was expanded to include beam wander, beam spread, mean transfer function (MTF), and extinction measurements.

Likewise, both the kinds and numbers of micro-meteorological measurements performed on the R/V ACANIA were increased with each cruise. Presently, four levels of mean and fluctuating temperature, velocity, and humidity measurements are being performed. As the data base grows with each operation, the sought after similarity parameters which relate the statistics of the fluctuating micro-meteorological values to the operative mean values of wind speed, temperature, and humidity

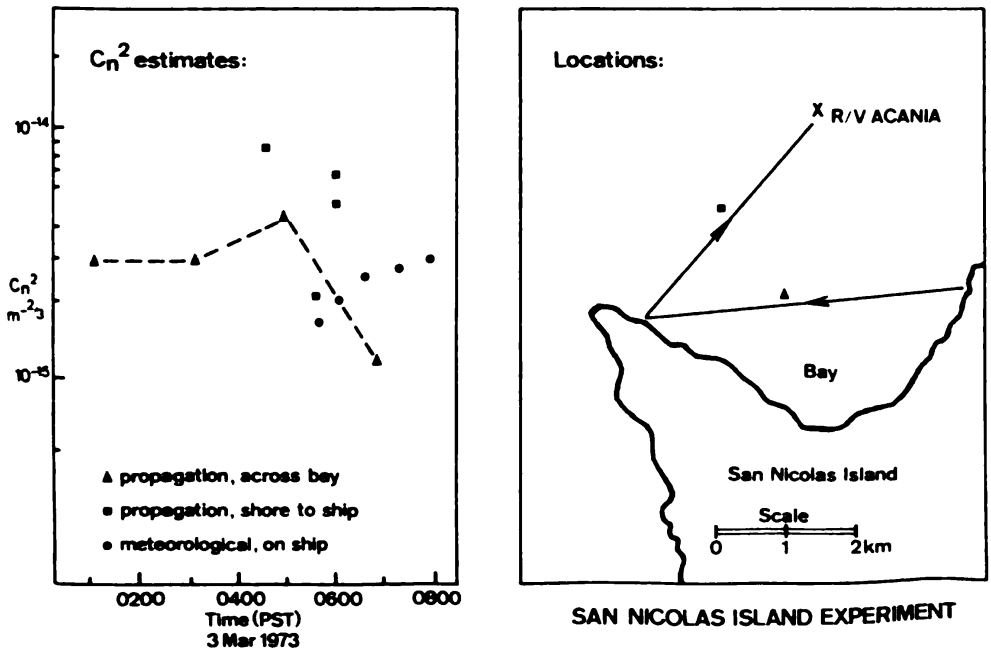

Figure 3 – Laser Transmission Results - Pacific Missile Range

are being developed and verified. Ultimately, desired operational relationships between laser transmission data (beam spread, scintillation, etc.) to onboard meteorological measurements of wind velocity, temperature, and relative humidity will be documented. In the meantime, the bounds of optical transmission theory are progressively being probed in the hostile marine environment and much important data is being gathered with consequences for both physical and meteorological models of atmospheric behavior.

Computer Simulation of Sputtering

Sputtering is the erosion of metal surfaces by ion bombardment. It is relevant to lifetime problems in high power vacuum tubes, ion implantation technology, and the containment of reactants in a thermonuclear fusion reactor. Recent work by Professor Don E. Harrison of the NPS Department of Physics and Chemistry showed that sputtering did not depend upon the Silsbee Chain mechanism which transmits momentum along the close-packed directions in the crystal. A preliminary report was published in 1966 [Applied Phys. Letters **8**, 33 (1966)] and a summary appeared in 1968 [J. Appl. Phys. **39**, 3742 (1968)]. Therein, it was established that sputtering is basically a surface effect which involves only the first two or three layers at the crystal surfaces. This conclusion, which was quite different from any existing theoretical picture of the process, generated considerable interest and perhaps even controversy. A supplementary report of additional confirming results appeared in 1969 [J. Appl. Phys. **40**, 3870 (1969)].

In the NPS simulation, positions, velocities, and a force law are stored in the computer and then ions and atoms are allowed to interact by Newtonian mechanics. Quantum mechanical effects are completely negligible with heavy particles. The particle orbits are calculated by numerical integration over several hundred small timesteps. The method is most useful as a means of determining the relative importance of various mechanisms and effects which occur in real crystals.

Laser Aerodynamics

Allen E. Fuhs and Oscar Biblarz*
Naval Postgraduate School

Internal Laser Aerodynamics

The active optical medium in gaseous lasers is compressible and the index of refraction varies linearly with the density. Density variations distort the laser beam, degrading quality. This distortion can occur within the laser cavity or external to the cavity, while the beam propagates through the optical train, out the exit aperture into the ambient atmosphere. Recently, NPS personnel identified the quantum inefficiency (which is 60% of the upper laser level in CO_2) as a significant source of density inhomogeneities, and formulated a calculation procedure for cavity density distributions.[1] In this formulation, two contributions to density variations became evident. In subsonic flow, the first contribution was analogous to a source or sink in mass addition. The second contribution was of the same form for both subsonic and supersonic flow, and represented the transport of heat by the flow velocity. The formulation accounted for the kinetic lag of heat release and for multiple wall reflections and treated any two-dimensional distribution of heat.

Density fields computed at NPS subsequently compared very well with experiments performed at the Pratt and Whitney Aircraft site in Florida.[2] Moreover, the formulation showed regions where density perturbations cascade, causing severe gradients. Previous one-dimensional (Rayleigh) flow techniques inherently averaged out the generated gradients.

External Laser Aerodynamics

In many applications, a beam from a laser may be slewed, generating a wind relative to the beam. Depending on the slew rate and distance along the beam, the wind may be subsonic, transonic, or supersonic. Absorption of energy from the beam transfers heat to the air flowing through the beam. This heat causes a density perturbation through two mechanisms. The first mechanism is obvious; it is the temperature

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perturbation of the air. One consequence is a hot wake. The second mechanism is less obvious; the temperature increase causes the streamtubes to grow as they traverse the beam. The flow is equivalent to motion over curved walls. In the supersonic case, compression waves are generated which radiate outward from the beam. A supersonically slewed laser beam generates a mild sonic boom!

As a function of Mach number, there are significant changes in the magnitude of beam density perturbations. The first mechanism discussed above varies as 1/M; this is the non-isentropic heating of gas which yields the wake. The second mechanism varies as $[M/\sqrt{|1-M^2|}]\ F(M)$; the variation of F(M) is typically weak so that $M/\sqrt{|1-M^2|}$ dominates. There are two singularities. One is at M = 0, as shown in Figure 1. The second singularity, which has been termed the transonic catastrophy, occurs at M = 1.0.

Mother nature abhors quantities marching toward infinity. The singularity at M = 0 is terminated by buoyancy. A flow of cold gas into the lower portions causes the beam to bend downward. The transonic singularity is a mathematical artifact of the linearized solutions. For a

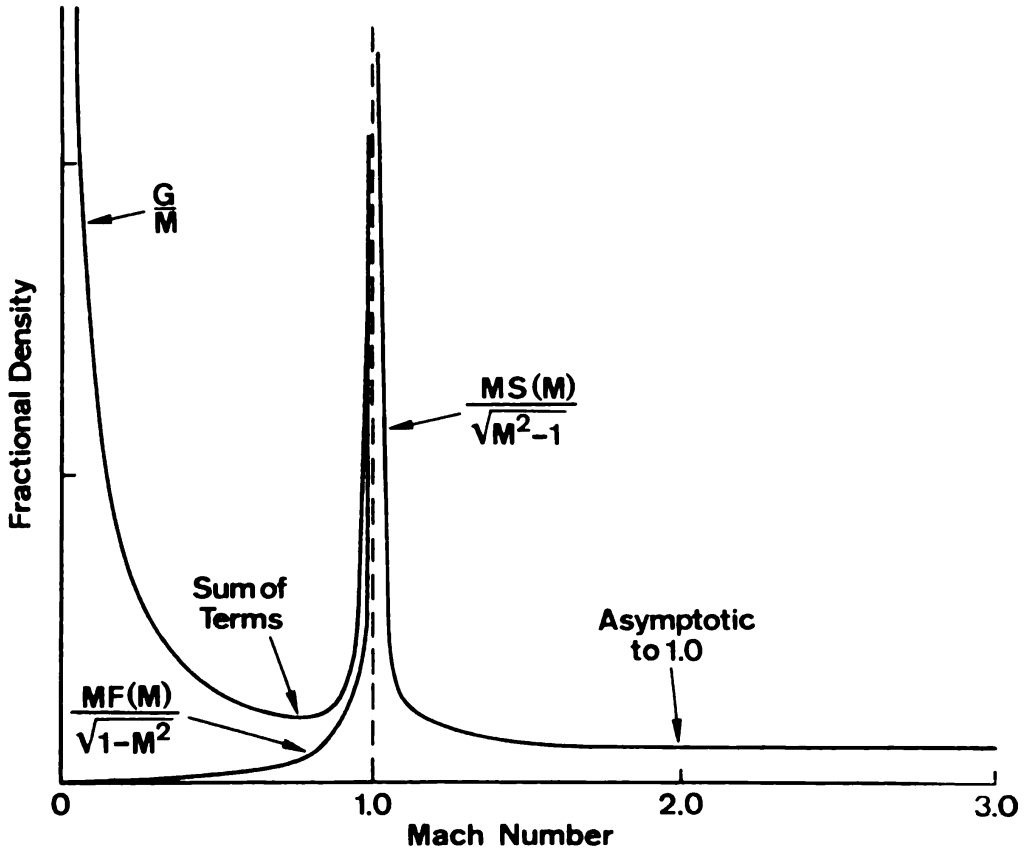

Figure 1 – Beam Density Perturbations and Singularities

narrow Mach number interval centered on Mach one, the nonlinear terms prevent the infinite perturbation.

To understand the flow beam interaction at Mach one, it is necessary to solve the nonlinear potential flow equation with distributed heat sources. At NPS, an inverse solution technique has been developed for this problem.[3] Among the significant results illustrated by this formulation is a clear definition of where the linearized equations remain valid ($0.999 < M < 1.001$). Likewise, the magnitude of density variations at $M = 1.0$ are shown to be approximately 100 times larger than those at $M = 0.9$. Finally, although convective acceleration, heat transfer and viscosity are sources of non-linear effects in the analysis, only the nonlinearity due to acceleration plays a dominant role in final results.

References

1. O. Biblarz and A. E. Fuhs, "Laser Cavity Density Changes with Kinetics of Energy Release," AIAA J. **12**, p. 1083, August 1974.
2. A. E. Fuhs, O. Biblarz, J. K. Cawthra, and J. C. Campbell, "Experimental Verification of Density Inhomogeneity Due to Lasing in a Gas Dynamic Laser," App. Phys. Letters, **24**, p. 132, February 1974.
3. A. E. Fuhs, H. Burden, and F. Carey, "An Exact Inverse Solution to Thermal Blooming in Transonic Slewing," Bulletin of American Physical Society, **19**, p. 1158, November 1974. Abstract only.

Biodeterioration of Engineering Materials in the Sea

For the past eight years, Professor E. C. Haderlie of the NPS Department of Oceanography, has engaged in an intensive study of the deterioration of engineering materials in the sea as a result of the activities of living marine organisms. This has involved determination on the biology of fouling organisms, organisms that bore into wood, stone, concrete, plastics and other materials, and the biological contribution to marine corrosion of metals. Data has been compiled on the major borers and foulers from Monterey Bay that include the identity and the distribution of each species, depth preference, substrate preference, season of settlement, rate of growth, longevity, and the ecological succession of communities. As a result of these studies, predictions of the deterioration of engineering materials placed in the seas off central California have been vastly improved with concomitant benefit to Navy operations in the area.

Acquisition Research

R. R. Judson*
Naval Postgraduate School

Acquisition Research Council

In 1974, ONR established an Acquisition Research Council which linked Navy-wide research interests in acquisition for the first time.

Under the direction of Dr. Robert Lundegard and Dr. Thomas Varley of ONR's Mathematical and Information Sciences Division, the Council includes other ONR representatives, as well as those from the Chief of Naval Material and the Naval Postgraduate School, Department of Operations Research and Administrative Sciences.

The Council is unique among the services in its emphasis on the R&D function in acquisition research and complements a number of recent studies and new functions in both the Executive and Legislative branches of government, designed to deal with acquisition on a comprehensive basis.

NPS Area Research Project

An area research project has been initiated at NPS which interrelates individual faculty and student theses projects. In addition, an "acquisition laboratory" of basic research materials has been established and creating additional "tools of research" is under consideration. More than forty student theses have been completed at NPS directly related to research in the area of procurement and weapon system acquisition. Theses work covers six principal areas:

1. Requirements determination
2. Congressional impact on acquisition management
3. Costing and pricing
4. Procurement and acquisition management
5. Test and evaluation
6. Life cycle management

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Warranties Research

A major ongoing program combining both faculty research and student theses work involves warranties research. This project, targeted for completion in December of 1976, includes:

1. analytical techniques to determine when and what type of warranties to use in appropriate situations, to enhance reliability and decrease life-cycle costs;
2. techniques to evaluate the direct and indirect cost of warranties and the effectiveness of various types of warranties; and
3. recommendations relating to warranty use in supporting design to cost objectives.

Escalation and Contractor Behavior

Recent faculty research at NPS has been focused in two areas: escalation and contractor behavior. Four major issues have been addressed in the escalation research, viz.,

1. Why are price changes of inputs a particular problem?
2. Why is escalation a good procedure for dealing with price changes?
3. What are the side effects of escalation provisions?
4. Can escalation provisions be designed to obtain a proper trade-off between administrative cost, accuracy and motivation for contractor cost minimizing behavior?

A major result of this research is the demonstration of the superiority of escalation procedures to contingency pricing in periods of uncertainty caused by inflation.

Contractor behavior work involves the development of a model of a representative defense contractor. The idea is that a contractor himself is an interrelated system consisting of activities in R&D, T&E, manufacturing, warehouse-inventory, and finance. In addition, there are various types of market structures to consider, from all but purely competitive markets for such items as nuts and bolts to bilateral monopolies for some subcontracted items and for some government customers. Finally, the contractor must make choices in the face of technological uncertainty, government budgetary constraints, and capital market fluctuations. The criteria for contractor choice must not only be profit, but also the development of a "state-of-the-art" technology. This work is to be reported in the following forthcoming papers:

A Representative Defense Contractor: Model Specification
A Representative Defense Contractor: Optimal Decision Rule
A Representative Defense Contractor: Conduct and Behavior

Future Research

Starting with FY76, under the sponsorship of ONR, a coordinated faculty research effort at NPS will address a number of additional key acquisition considerations including:

1. Enhancing management of the requirements determination process to minimize adverse cost, schedule and performance characteristics of major weapons systems.
2. Classification of system characteristics and variables to isolate and predict problem areas, thus permitting preventative actions to be taken.
3. Classification of problems related to acquisition organizations form and functioning, to develop integrative mechanisms that will assist in resolving management issues.
4. Evaluation of RDT&E manpower utilization through structural variables, to evolve standards for the management of RDT&E organizations.

These elements of the first phase of the NPS area research project are scheduled for completion during calendar year 1976.

Although modest in initial funding and available resources, NPS is taking the leadership in what is clearly emerging as an area of great research interest among DoD, GAO, Congressional Committees, and the new Office of Federal Procurement Policy.

Aircraft Fatigue Instrumentation

G. H. Lindsey*
Naval Postgraduate School

Structural fatigue of aircraft results from repreated flight loads due to gusts and maneuvers and ground loads resulting from landing, catapulting, and taxiing. It is the limiting factor in the life of an airplane, for when the airframe has reached the full extent of its fatigue life, the airplane must be retired or reworked in those areas where danger of failure exists. Because every airplane experiences a different flight and loading history, it is necessary to monitor the ongoing accumulation of fatigue damage in each airplane individually. The desirable attributes of the instrumentation system that will do this are that it be small and lightweight and, of course, dependable. It must be able to sense the loads experienced by the aircraft and to discriminate between those that are fatigue significant and those that are not and record the important data. If possible, the chronology of the fatigue loads should be preserved, for it is known that sequence of loading influences the fatigue life.

Currently, NPS, in conjunction with NAVAIR and NADC, is working on a new system of monitoring instrumentation that capitalizes upon recent developments in the field of microprocessors. Usually they are dedicated to performing a given task repeatedly and are not versatile like their maxi-computer brothers.

The proposed system, which has just completed preliminary flight test, receives analog signals from strain gages mounted near the fatigue critical points on the aircraft. The prototype currently being utilized has eight channel capacity; however, additional channels can be added without difficulty, if required. The signal passes through an analog to digital converter and multiplexer, which resolves the plus or minus five volt range of input into 2^8 different discrete digital levels. The digitized signal is then received by the microcomputer, which tests each data point to see if it is larger or smaller than the previous one. When it detects a reversal in the signal from increasing to decreasing magnitude or vice versa, it is known that a maximum or minimum has been reached and the microcomputer is instructed to store this data point and continue searching. When the 2000 word storage capacity is filled, the microcomputer transfers what is in storage in digital form to a cassette tape in the order in which it was received. In this way, the maximum and minimum points of the loading history, which are the fatigue significant events, are preserved in the sequence that they were experienced by the aircraft.

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*Gerald H. Lindsey is an Associate Professor in the NPS Department of Aeronautics. His research has been supported by NAVAIR and the Naval Air Development Center (NADC).

Furthermore, when the tape is full, which will require at least a month of flying, a new tape is inserted and the data on the tape removed is in a form readily conducive to processing with a regular computer to calculate fatigue damage. Capacity of the data acquisition system used for fatigue monitoring is 1024 words of read only memory (ROM) and 2000 words of random access memory (RAM). Thus, up to 1800 events in the fatigue history of the airplane can be experienced before it is stored on tape, which can handle a total of 180,000 events if only a single channel is used. Normally, 1800 events will exceed the number of events experienced in a single flight, but when the landing gear is cycled, a signal will be sent to the microcomputer, which will cause the memory to be transferred to tape so that is will not be lost when power is shut down.

The first prototype has been flight tested in a Cessna 310. It has been checked out and minor modifications made so that it functions very well. The first prototype had much versatility built into it which permitted interaction with it to change the program, interrogate the memory, etc. The second prototype is now being fabricated, and it is more nearly what an operational system will be like. It has eight channel capacity, which may later be changed, but it is being assembled with the thought in mind of actual flight operation. A new digital tape recorder, which is lightweight and miniature, as shown in Figure 1, is being evaluated and tested with this prototype. Savings in weight and volume of 300 percent are possible but storage capacity is also reduced. Plans are now scheduled to bring evaluation of the system by NADC by the first of the year. This will involve both laboratory testing and flight testing in a Blue Angel A-4.

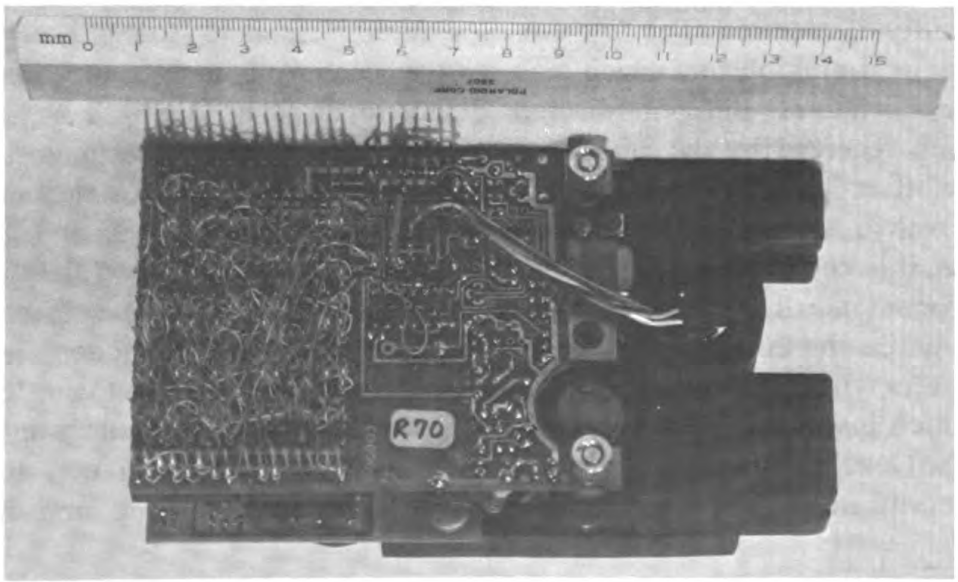

Figure 1 — Miniature Digital Tape Recorder

Charge Transport Devices

T. F. Tao*
Naval Postgraduate School

Charge Transport Devices (CTD's) are a new class of electronic devices invented in 1970, based on MOS (metal-oxide-semiconductor) technology. They differ from other electronic devices because their signal is represented by charges instead of voltages or currents. These signal charges are stored and processed in a silicon wafer under an array of MOS gates. The structure is simple and its power consumption is low, two outstanding properties which make it an important LSI (large-scale-integration) technology. The signal charges can be introduced electrically or optically. They can represent either digital or analog signals. Furthermore, the "storage and transfer" of the charges can be used to implement the delay operation in signal processing. Therefore, CTD's can be used as imaging devices, as signal processors, or as memories. Their applications to imaging, surveillance, data processing, communication, radar, sonar, control systems, and many others are indeed numerous and promising. At the NPS Electrical Engineering Department, two research projects in the CTD areas are being pursued - one in signal processing and the other in infrared imaging.

CTD Signal Processing

Both sampled analog and digital CTD signal processors are being actively developed. Primarily, NPS research has been in the sampled analog area. Researchers of sampled analog signal processors have concentrated more on transversal filters and correlators. Recursive filters have not received as much prior attention. At NPS, sampled analog recursive filters are being studied both theoretically and experimentally, using CCD as the delay elements in the canonical circuits shown in Figure 1. A theoretical analysis based essentially on digital recursive filters is developed with modifications taking into account that a CCD delay generally consists of more than one delay stage. Using the standard Z and the bilinear Z transforms, continuous filters are transformed into H(Z) forms suitable for CCD implementation. Progress up to this time is highlighted in Figures 2 and 3 which present the measured and calculated frequency responses of two recursive filters, one based on standard Z transform and one based on bilinear Z transform. Measurements

*Tien F. Tao is an Associate Professor in the NPS Electrical Engineering Department. His research has been supported by NAVELEX and the NPS Foundation Research Program.

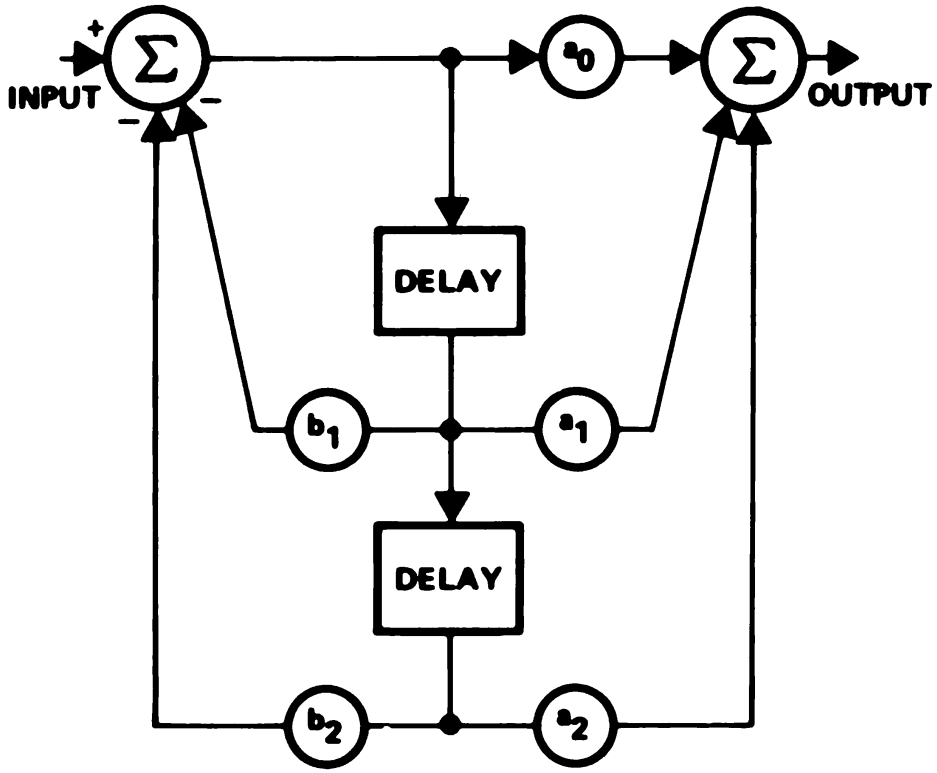

Figure 1 – Canonical Circuits

and theory agree closely at low frequency but deviate with varying degrees as the frequency is increased.[1] However, feasibility of CCD recursive filters is clearly demonstrated.

Infrared CTD Imaging

Visible imaging using CTD has been developed with considerable success. On the other hand, infrared imaging using CTD has just begun. However, the interests in using CTD's for surveillance and weapons guidance are high. Two approaches are being taken.[2] One is a hybrid approach which combines the infrared detectors with a Si CCD signal processor. The other is a monolithic approach in which both the infrared detection and the signal processing are effected in the same CTD array of a semiconductor sensitive to IR radiations. At NPS, the monolithic approach is being pursued.

First, a feasibility study using MIS (metal-insulator-semiconductor) of 4-6 semiconductors as IR charge transport imagers was performed. The highlight of the study was that high dielectric constant insulators must first be developed in order that MIS of 4-6 semiconductors can be considered for IR imaging. TiO_x and Ta_2O_5 have been chosen as the insulators and presently, two methods for their fabrications - sputtering and electrolytic anodization are being examined.

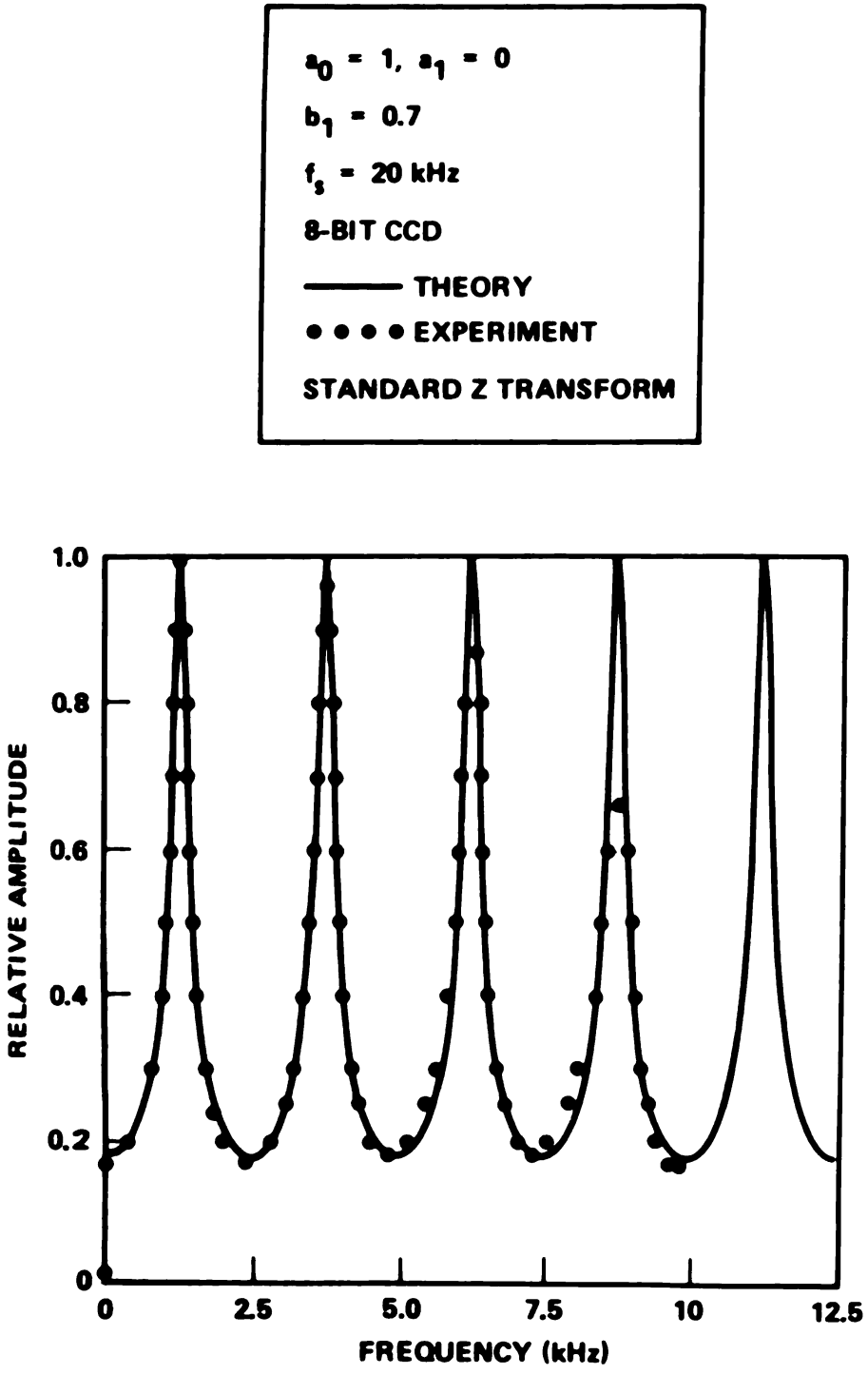

Figure 2 — Highpass Integrator Filter Characteristics

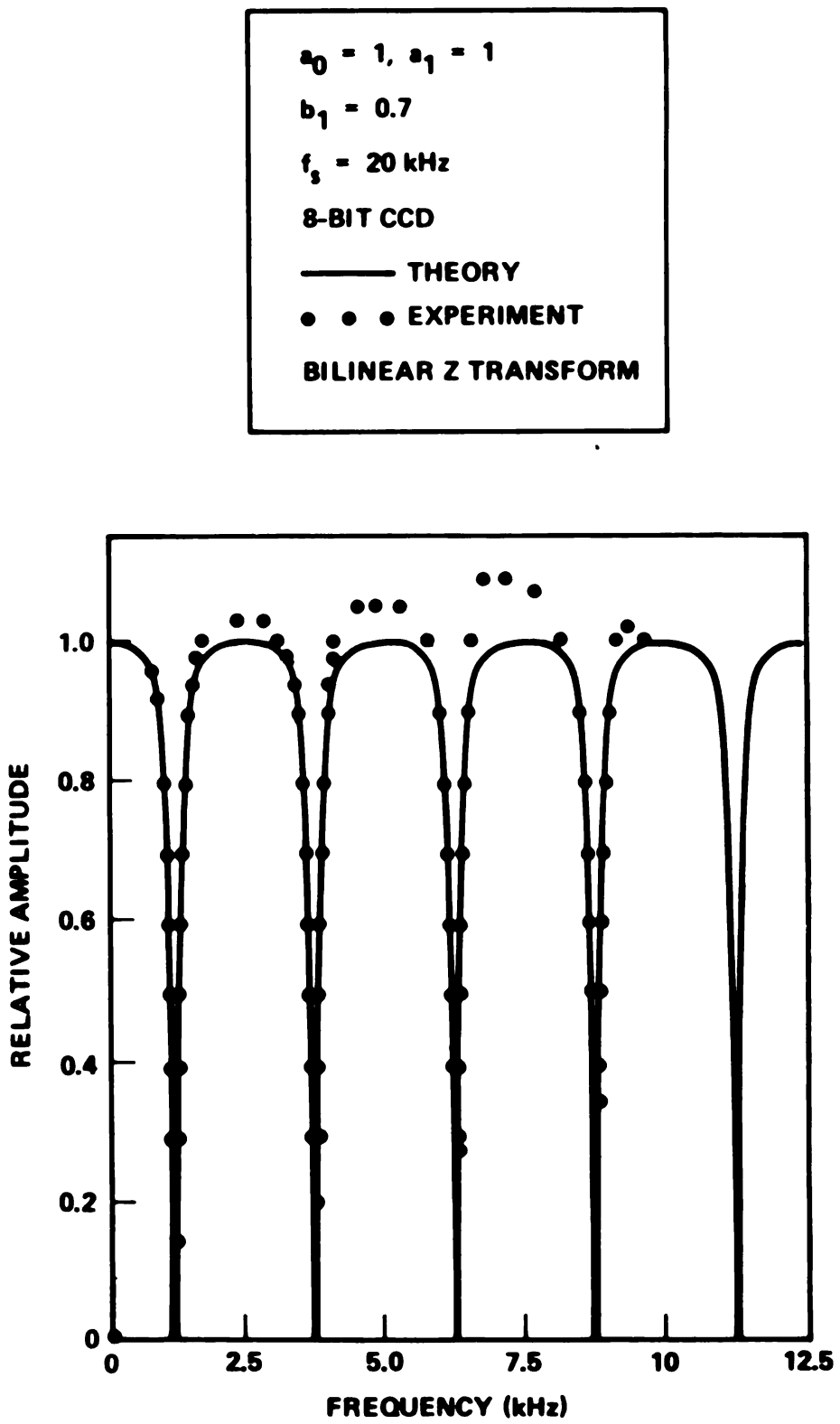

Figure 3 — Lowpass Canceller Filter Characteristics

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Computer System Testing

Increasingly, the quantitative evaluation of computer software is recognized as critically important to the effective functioning of computer systems. At NPS, the model for statistically analyzing software error detection and correction processes during software functional testing has been developed. The model provides decision aids for controlling the quality of command and control system software. The inputs to the model are error detection histories and the outputs are forecasts of the future behavior of error detection and correction processes.

A non-homogeneous Poisson process is used to model the occurrence of errors detected during functional testing of command and control software. The parameters of the detection process are estimated by using a combination of maximum likelihood and weighted least squares methods. Once parameter estimates are obtained, forecasts can be made of cumulative number of detected errors. Forecasting equations of cumulative corrected errors detected but not corrected, and the time required to detect or correct a specified number of errors, are derived from the detected error function. The various forecasts provide decision aids for managing software testing activities. Ultimately, Naval Tactical Data System software error data are used to evaluate several variations of the forecasting methodology and to test the accuracy of the forecasting equations.

The purpose of a second NPS project was to develop a methodology and tools for conducting system tests of avionics or other complex hardware/software systems.

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, 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 anlytic approaches.

Professor Norman F. Schneidewind directs this research at NPS, which is supported by ONR, the Naval Air Development Center (NADC) and the Naval Electronics Laboratory Center (NELC).

Materials Engineering Research

G. R. Edwards and J. Perkins*
Naval Postgraduate School

Materials research at NPS is closely keyed to Naval applications. Several distinct areas of interest are being pursued at present, namely, (1) zinc corrosion film studies related to cathodic protection of ships' hulls, (2) thermomechanical characterization of shape memory effect alloys related to potential Naval gunnery applications, (3) studies of high damping quiet metals in a NAVSEA sponsored ship silencing program, and (4) studies of high temperature deformation of metals.

Several of these programs were initiated when suggestions from officer students (familiar with the actual naval problems) matched faculty interests and capabilities. The output of the programs has also proved useful in bringing current naval problems into the curriculum in the form of demonstratable examples.

Corrosion Film Studies

Scanning electron microscopy is being used in an ongoing 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 alloy 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 NPS program was initiated with the aim of delineating the electrochemical and metallurgical features that are critical in this regard. The crystalography growth mechanism, and kinetics of development of such films are 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.

Shape Memory Effect Alloys

Shape memory effect (SME) behavior is defined when a material is deformed beyond an apparent "yield point," but recovers all or nearly all strain upon heating. The most widely known and developed SME

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alloys are the NiTi-based "vitroils," initially publicized by developmental work at the Naval Ordnance Laboratory in the early 1960's (therefore, NiTi NOL). Recent work at NPS has sought to characterize the significant thermomechanical parameters associated with the NiTi SME (such as reversion stress and strain). These features are of critical interest in many applications. Figure 1 exhibits typical data recently obtained, presented as a stess-strain temperature envelope, the surface of which represents an upper bound on SME reversion stress. This type of data is extremely useful to consider strain-temperature parameters that optimize thermomechanical performance in a given application. The effect of thermal cycling, and reversion stress stability with time and temperature, have also been studied.

Materials for Ships Silencing

Resistivity measurements and internal friction devices are being utilized to study the microstructural changes associated with the acoustic

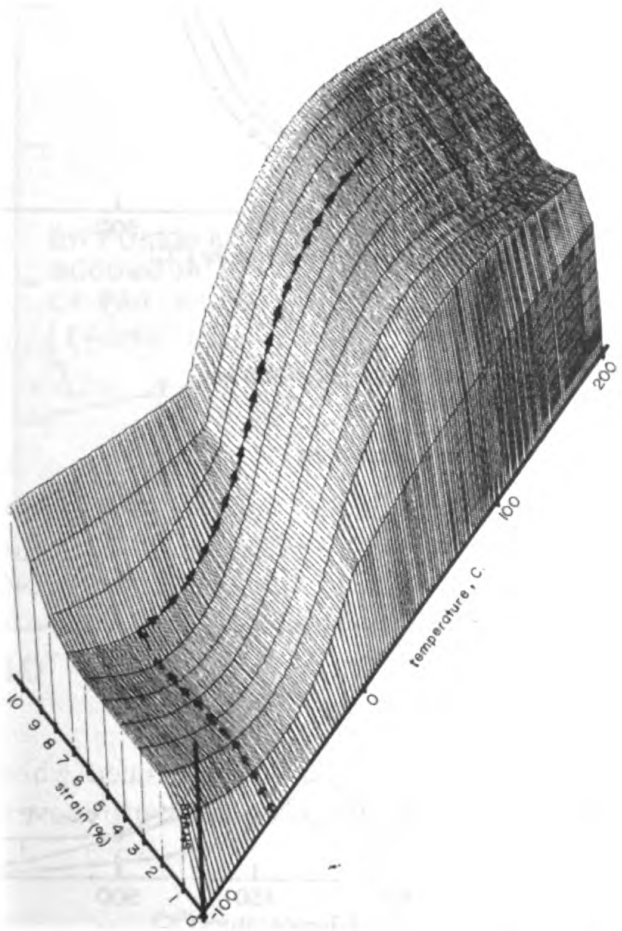

Figure 1 — Stress-Strain Temperature Envelope

damping capacity in alloys possessing unusually high specific damping capacity (SC) after careful heat treatment. Results have shown that properly heat-treated Incramute I possesses a specific damping capacity as much as four times greater than that of grey cast iron, a material commonly used in heavy industry because of its excellent damping characteristics. The achieved SDC is sensitive not only to the times and temperatures of heat treatment, but to stress, whether applied during heat treatment or during SDC measurement. Typical results are shown in Figure 2 where the excellent correlation between resistivity and

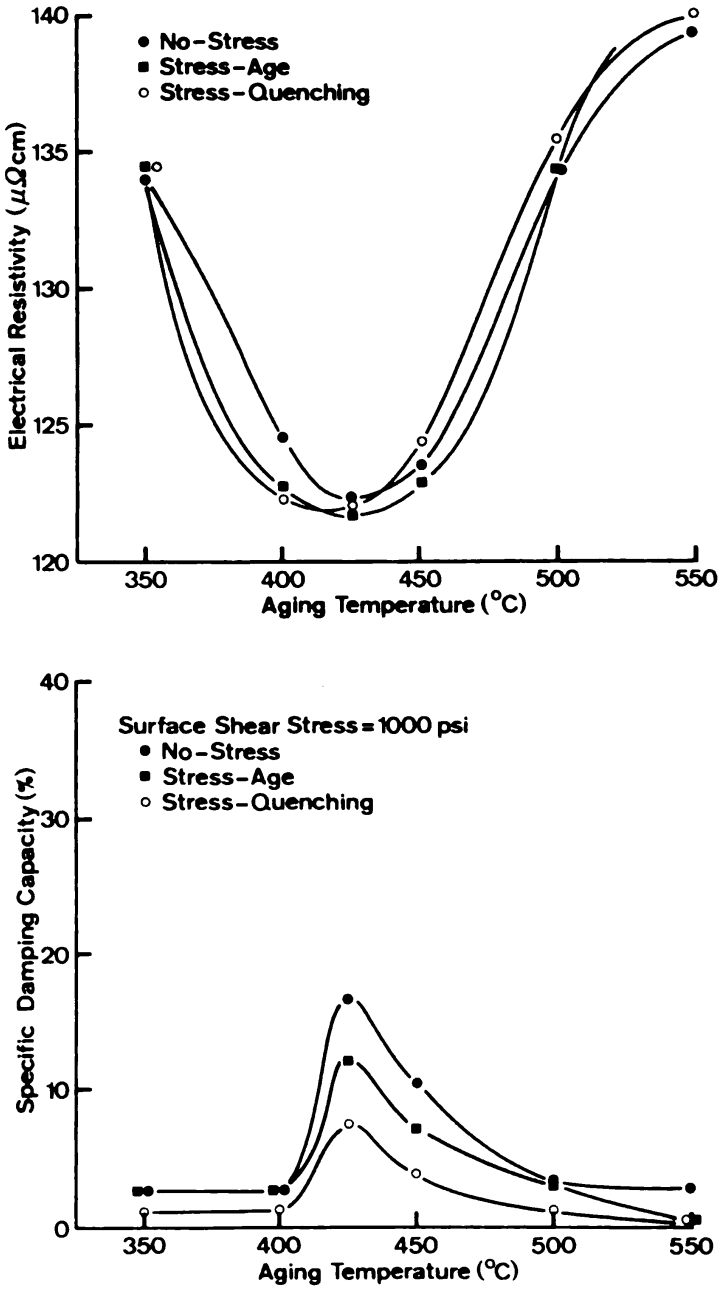

Figure 2 – Resistivity and Stress Damping Characteristics

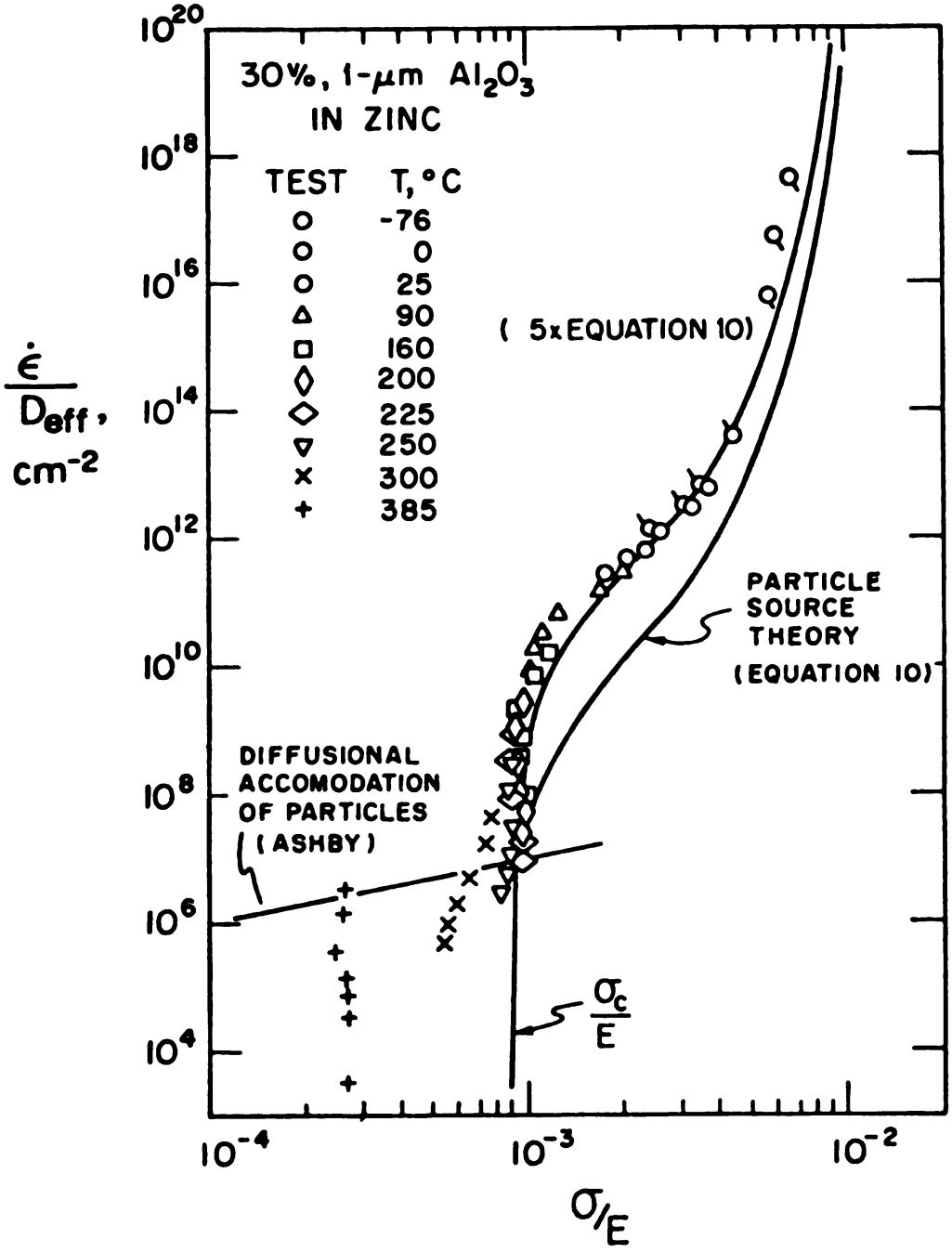

Figure 3 — Dispersion Strengthened Alloy Results

low-stress SDC is indicated. These data also show the uniaxial tensile stress, applied during either the age or the quench, interferes with the development of high SDC. Further studies, primarily microscopic, are planned to verify current hypotheses relating to microstructural damping mechanism.

High Temperature Deformation of Metals

Much of the most modern Naval machinery (e.g., the gas turbine) is limited in efficiency by the limited temperature resistance of its component metals. Several metallurgical studies, sponsored by ONR, have been conducted at NPS in recognition of the Navy's general need for temperature-resistant metals. While texture strengthening has been accepted only recently as a viable strengthening mechanism at ambient temperatures, studies at NPS make it quite clear that the concept is applicable at elevated temperatures as well. High-temperature deformation in dispersion-strengthened alloys is another example of the creep research at NPS. This work was performed in cooperation with faculty at Stanford University and at the University of Wyoming and is exemplified by Figure 3 which compares experimental data for a model system (zinc containing Al_2O_3 dispersoid) and a theoretical model derived from basic dislocation theory. This model successfully explains the high stress dependence of strain rates, which is a common feature of creep in dispersion-strengthened alloys.

Report on Atomic Spectra

Workers in any field are frequently handicapped by a lack of organization of the available information. This problem has been eased somewhat in the field of atomic spectra with the publication of a new book. It is a Naval Research Laboratory Report titled "Atomic and Ionic Emission Lines," by Professor Raymond L. Kelly (NPS) with Louis J. Palumbo (NRL). This 932-page book lists information on 35,000 spectrum lines in the vacuum ultraviolet region of the spectrum. It has been enthusiastically received by scientists around the world. The report is the latest publication from Professor Kelly's Spectroscopic Data Center.

The Oceanography of the Marginal Sea-Ice Zone

R. G. Paquette and R. H. Bourke*
Naval Postgraduate School

The Marginal Sea-Ice Zone Pacific (MIZPAC) project is a continuing program of studies directed at acoustic and related oceanographic peculiarities of the marginal sea-ice zone in the Pacific Arctic. The project is under the general direction of the Arctic Submarine Laboratory, Naval Undersea Center, San Diego. The U.S. Coast Guard has provided icebreaker facilities and ONR has provided the logistic services of the Naval Arctic Research Laboratory. The Naval Postgraduate School is one of several organizations working on MIZPAC problems. NPS efforts have been directed chiefly to understanding the oceanographic factors which cause the unusual conditions which are found.

The most striking and acoustically significant feature of the water near the margin of the ice in summer is an exaggerated microstructure in the vertical temperature profile. This phenomenon has been labelled as "mesostructure" because of the large temperature excursions involved. An example of mesostructure is shown in Figure 1b. This is to be contrasted with Figures 1a and 1c which show typical situations south of and well inside the ice margin, respectively. Acousticians will immediately recognize that a sound beam - from a submarine sonar searching to avoid ice keels, for example - will be badly dispersed if the sound source is in the depth zone of the positive-going temperature anomaly. Conversely, a beam may be trapped in a channel formed by a negative-going anomaly. In either case, the value of the sonar as a tool for "seeing" and avoiding ice keels is greatly reduced.

While the mesostructure does not always coincide with the ice margin, it does so often enough that it is believed to be formed there. It appears to be formed during the melting of ice by warm (4° − 10°C) surficial water flowing toward the ice from the south. The descent of warm water into the colder water below, with only partial mixing, is the cause of the mesostructure. It may at first seem curious that water which is anomalous in temperature may have a niche in a monotonically increasing density gradient. This comes about because the mixed water parcels contain different proportions of waters from three sources: the warm surficial

*Robert Paquette is a Professor and Robert Bourke is an Assistant Professor in the NPS Department of Oceanography. Their research has been supported by NAVMAT and the Naval Undersea Center (NUC).

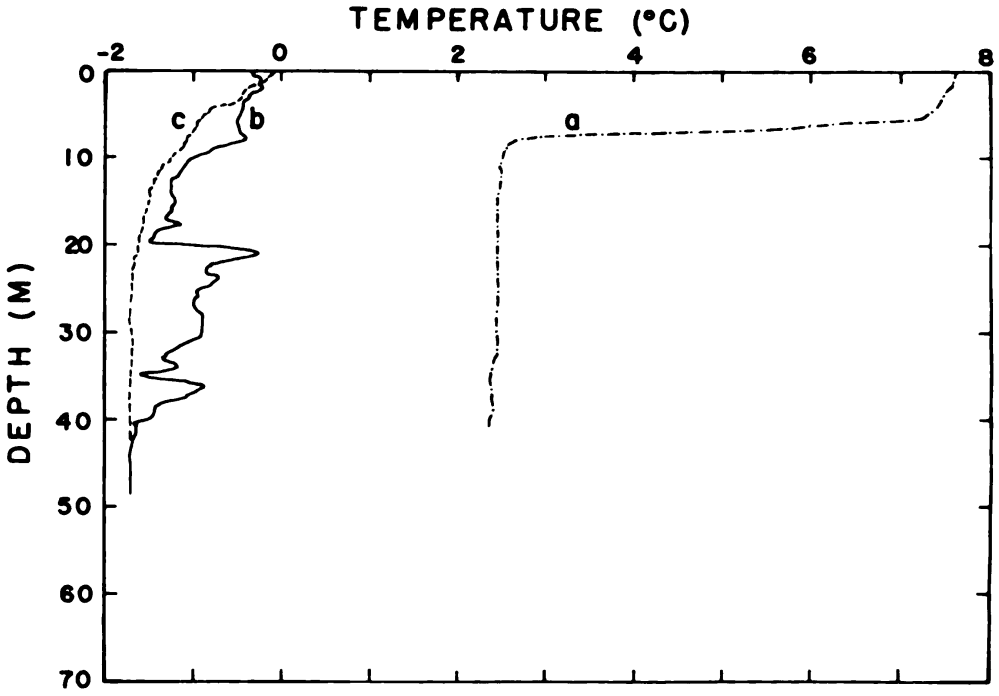

Figure 1 – Temperature "Mesostructure" in the Marginal Sea-Ice Zone

water south of the ice, the cold bottom water under the ice and the fresh water introduced by melting ice. The latter produces a different temperature-salinity-density relation than would result from mixing of the first two.

Examination of the acoustics of the marginal sea-ice zone by NPS personnel has been confined to computations of transmission loss and ray traces for the low frequencies. The wavelengths are longer than the thicknesses of most of the mesostructure elements. Under such circumstances, the propagation of sound is little affected by the mesostructure and is mainly controlled by the gross structure and by the multiple reflections from the under surface of the ice and from the shallow bottom which prevails over the entire area of our studies. As may be expected, propagation ranges are relatively short and channeling of sound in the upper and lower layers is important, particularly south of the ice. The great variability of the water columns in the marginal sea-ice zone itself and the shadowing of the sound beam by ice keels lead to propagation conditions which may be predicted in only a highly general sense.

Shipboard Satellite Communications Systems

John E. Ohlson*
Naval Postgraduate School

The U.S. Navy is currently implementing a system for satellite communications called FLTSATCOM which will involve satellites and newly developed equipment for shore communications stations and for ships of the fleet. The receiving equipment which will be placed aboard the ships of the fleet will operate in the range of approximately 240-270 Megahertz. This equipment will be much more sensitive than any other receivers which exist on the ships. As such, it will be more sensitive to interference generated by other equipment.

A project has been begun at NPS to assess quantitatively the interference environment which exists on ships of the fleet. It was felt that a comprehensive study of the interference environment is necessary to assist in the phasing in of the present implementation and also to provide quantitative information for future system development. The project consists of developing an instrumentation package which will be taken aboard several ships of the fleet while they are performing normal operational activities. The instrumentation will allow observation of the frequencies, power levels, and statistics of the various types of interfering signals which are present aboard the ships. The data will be partially processed on the ship while the measurements are being taken so that the volume of data can be reduced significantly. The partially reduced data will then be processed via computer techniques when back at the Naval Postgraduate School.

Once the data collection program is completed, which will take approximately three months, the data will be reduced to generate an overall characterization of the interference environment on ships of the fleet. There will then be two follow-on phases to complete this project. The first will be to determine if the first generation of shipboard satellite communication terminals need to be modified so as to improve performance in the shipboard environment; the second phase will be that of developing guidelines and specific techniques which should be employed in development of future systems.

*John E. Ohlson is an Associate Professor in the NPS Electrical Engineering Department. This research is supported by NAVELEX.

Man-Machine Systems Design Laboratory

G. K. Poock*
Naval Postgraduate School

The Man-Machine Systems Design Laboratory at the Naval Postgraduate School is devoted to the study of the equipment and environment in which today's modern military man works. In studying the man-machine interface, professors and officer-students working in the laboratory strive to design for maximum productivity from the system, within measurable engineering and human constraints. The medical, physiological and psychological parameters of man are design limits in most research.

Research projects in the laboratory cover a broad range of interests, some of which have included studies in the following areas:

1. The effects of breathing pure oxygen on short term memory in critical situations.
2. The effects of heat stress onset due to equipment failure and its effects on human information processing and short term memory.
3. The design of lighting parameters for underwater instrumentation. Parameters affecting readability are color, intensity, viewing distance, and turbidity conditions.
4. The design of combined accelerator and brake pedals for automobiles, trucks, etc. One such design was tested on the Laguna Seca Race Track and resulted in reducing driver reaction time to braking by over 50%.
5. The study of man's muscle responses and how one might use muscles in various parts of the body to control equipment in the surrounding environment while performing other normal routines with the visual and aural systems.
6. The study of major Navy aircraft accident rates and the associated human and equipment parameters which might cause said accidents. Preliminary results from regression and correlation studies presently indicate that out of 14 variables considered (5 human variables and 9 equipment variables), the human variables have been the only ones to show any statistical relation to accident rates. Using regression techniques, the human variables are the first entered into

*Gary K. Poock is an Associate Professor in the NPS Department of Operations Research and Administrative Sciences. Among the agencies sponsoring this research were ONR, NADC, NELC, Hq. the Marine Corps, and the Navy Safety Center (Norfolk).

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the equations with any statistical significance and they portray a correlation faction of 0.73 with accident rates by month.

7. Studies of human information processing and changes in physiological parameters have shown that overloading a person beyond his information processing capacity will lead to constriction of the pupil of the eye. Such a parameter can be used then to detect overload points in a job and indicate a redesign of the job.

These are some of the many areas which have been investigated in the Man-Machine Systems Design Laboratory using its experimental chambers, computer facilities, and specialized equipment.

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Note:

These materials have been assembled and edited by Dr. Thomas M. Houlihan, Associate Professor of Mechanical Engineering, Naval Postgraduate School, Monterey, California, 93940.

Cover Caption

NPS Administration Building-Hermann Hall - the former Del Monte Hotel