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REVIEWS

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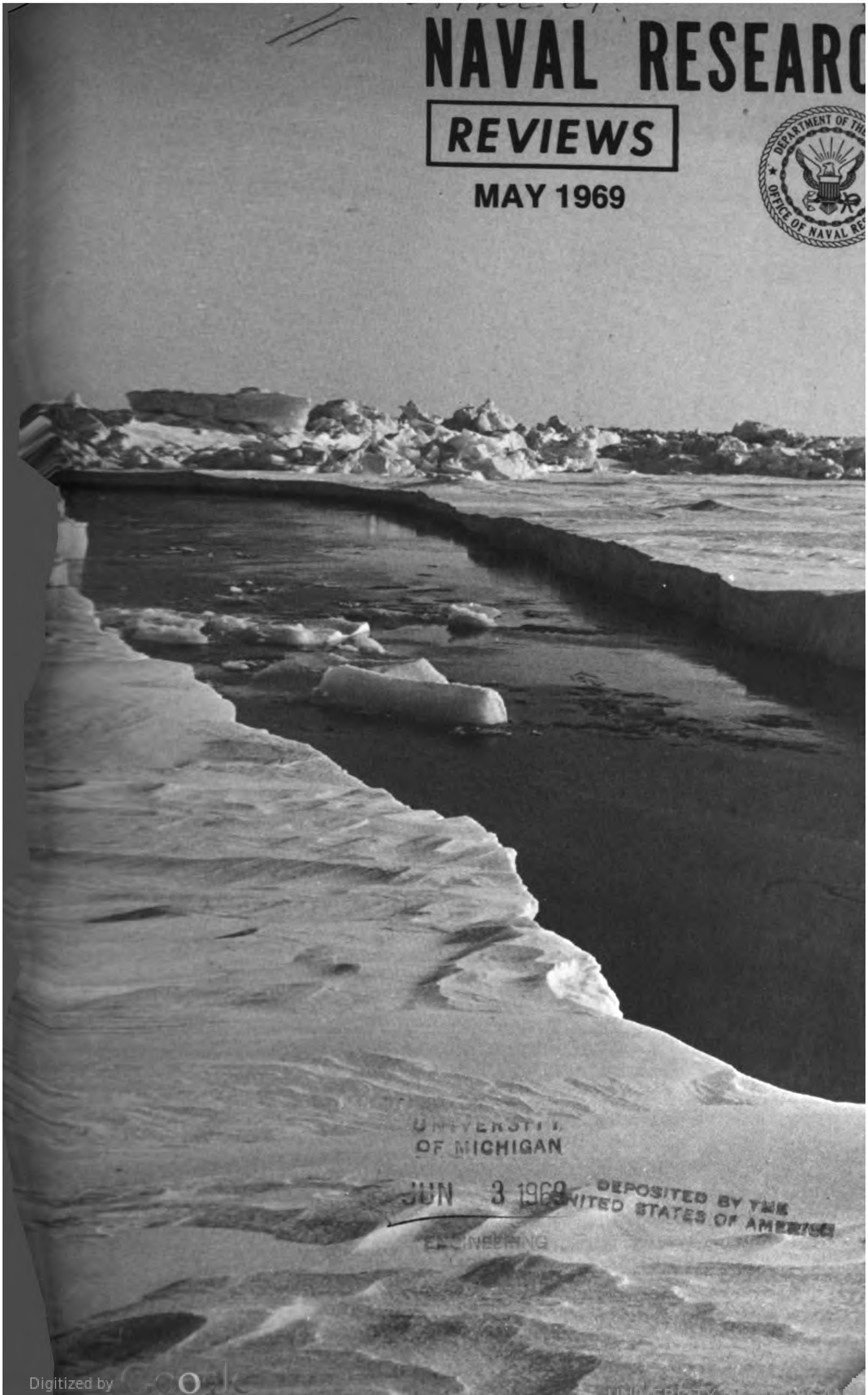

Portraits in Science

DR. ARTHUR R. VON HIPPEL CAME TO THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY IN 1936. FROM GERMANY. FOUR YEARS LATER HE FOUNDED THE LABORATORY FOR INSULATION RESEARCH AT M. I. T. WHICH HE HAS DIRECTED EVER SINCE. DR. VON HIPPEL IN A PROFESSOR OF ELECTROPHYSICS AND IS WIDELY KNOWN FOR HIS OUTSTANDING RESEARCH IN THE FIELDS OF DIELECTRICS, MOLECULAR SCIENCE, AND MOLECULAR ENGINEERING. IN 1964 VON HIPPEL BECAME A VISITING PROFESSOR AT THE NAVAL RESEARCH LABORATORY. SINCE 1966 VON HIPPEL HAS BEEN A CONSULTANT TO ONR BOSTON, SENIOR CONSULTANT TO DIRECTOR OF ONR BOSTON, AND A CONSULTANT TO THE CHIEF OF NAVAL RESEARCH IN RESEARCH MANAGEMENT.

Space and the Sea*
The New Research Horizon

RADM Thomas B. Owen
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Historical Introduction

The official birth of the United States Navy in 1798 was followed some thirty years later by the establishment of an office that included both space and the sea as its areas of interest and jurisdiction. In 1830, a Depot of Charts and Instruments was established "to store, maintain and issue charts, sailing directions, and navigational instruments for use by Navy ships." In a very broad and a very practical sense, the Navy pioneers of that era began to conduct "mission-oriented" research both in hydrography and in astronomy in order to meet their chartered responsibilities of providing such charts, sailing directions and navigational instruments. Slowly there commenced a program to gather hydrographic data for nautical charts. Of equal importance was the objective of acquiring the proper astronomical instruments to make observations of the positions and motions of the sun, moon, planets and principal stars. From these observations could come the determination of universal time and the production of a nautical almanac with its predicted positions of celestial bodies, both essential to the art of celestial navigation. The Depot's mission—to provide for the safe navigation of ships at-sea—was rather straight-forward by today's standards.

The appointment in 1842 of LT Matthew Fontaine Maury, U.S. Navy, as Officer-in-Charge of the Depot was significant in that during his 19 year tenure: he implemented a system for collecting, analyzing, recording, and disseminating world-wide hydrographic data which produced the world's first effective sailing directions and set a new standard in nautical charts, earning him the name—"Pathfinder of the Seas"; he also founded the science of oceanography in this country, thereby expanding the mission of the Depot.

In 1849, the Navy established its Nautical Almanac Office at Cambridge, Massachusetts in order to take advantage of the expert knowledge of the faculty of Harvard University, as typefied by Professor Benjamin Peirce, generally recognized as the leading mathematician in the United States of his time. This office was later moved to Washington and became part of the Naval Observatory.

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*Speech presented at the AIAA 5th Annual Meeting, Philadelphia, October, 1968

In 1854, the "Depot of Charts and Instruments" was renamed the "U.S. Naval Observatory and Hydrographic Office," which were later established as separate institutions in 1866.

Closely associated with the growth in reputation of the Naval Observatory, commencing in the 1860's, was the distinguished career of Professor Simon Newcomb, government employee of the Navy Department for over 40 years. His research in celestial mechanics—particularly his theories of motion of the moon, Uranus, and Neptune—made him one of the great scientists of his time, and was instrumental in establishing the quality and effectiveness of the U.S. Navy's Nautical Almanac as a navigational tool, still in use today. It was difficult in Newcomb's day, as is often the case today, to connect abstruse frontier research in a special science like celestial mechanics with a practical military requirement, such as Navy navigation.

For almost 80 years, this Navy organization concerned with surveys and research in hydrography and astronomy underwent little change. In the 1940's, when changes did commence, their impetus could be traced to the fantastic technical achievements in radio, electricity, aeronautics and weaponry of the early twentieth century, and their applications to naval warfare in two world wars. A part of this impetus was generated when Thomas A. Edison in 1915 suggested that the Navy have its own laboratory in which ideas or inventions could be tested and adapted to the peculiar needs of the fleet. This stimulated the founding of NRL (the Naval Research Laboratory) in Washington, D.C. in 1923.

In 1946, the Office of Naval Research (ONR), headed by the Chief of Naval Research, was established in recognition of the need to plan, encourage, and support basic research in our universities, our in-house laboratories, and the private industrial groups in those areas of knowledge that seem to be most relevant to long range Navy requirements. The experiences in scientific mobilization of World War II and the awesome strategic implications of the scientific/technological breakthrough in nuclear weapons demanded new organizational approaches to research and development for national security. NRL was made a technical field organization of ONR and has been designated as the Navy's corporate laboratory. It is a central focus of research and development in support of both the Navy and national defense efforts.

This very brief history of some of the highlights of the Navy's research efforts up to the establishment of ONR in 1946 should afford the necessary perspective to discuss the recent past of the 1950's and 1960's and the future. Excluded has been discussion of the Naval Material Support Establishment, (with its six Systems Commands and many laboratories), which is a most significant part of the Navy R&D program.

The Recent Past in Navy Research (1946-1968)

NRL emerged from World War II with a very special and well-deserved reputation for its many contributions in military R&D, in such areas as radar, communications, materials, and several fields of chemistry and physics. A new dimension in Navy research in astronomy and astrophysics commenced, when NRL pioneered solar rocket astronomy with available German V-2 rockets. In 1946, the first far ultraviolet spectrum of the sun beyond the atmospheric cut-off was obtained. From this beginning, a relatively small research group has since used radio telescopes and rocket and satellite-borne instruments to make astrophysical measurements throughout the spectrum from radio frequencies, infrared, visible, ultraviolet, to x-rays. Some of the scientific firsts of this NRL Space Sciences Division, include: the discovery of solar x-ray emission and its role in the production of the ionosphere; the detection of x-rays bursts from solar flares and the detection of x-ray bursts from solar flares and the related explanation of radio fade-out; the first short wavelength precision radar studies of the moon leading to an independently derived distance to the moon; the discovery of the non-thermal component in radiation from Jupiter, later leading to the discovery that Jupiter, like the Earth, has radiation belts; the first radio astronomy measurements to indicate that Venus has a temperature of approximately 600 degrees K; and the discovery and identification of discrete cosmic x-ray sources.

Within the NRL Space Sciences Division and also under the scientific leadership of Dr. Herbert Friedman is the *E. O. Hulburt Center for Space Research*, named for the first Director of Research at NRL. Jointly sponsored by ONR, National Science Foundation (NSF), and NASA, the Center brings together scientists and graduate students from the nation's universities for one and two year appointments. It gives them the opportunity to use the unique facilities of both NRL and NASA to conduct rocket and satellite astronomy projects.

Experiments conducted by the NRL space science and technology groups include the use of ground-based laboratory and test facilities; ground-based radio and optical telescopes; rocket payloads; special purpose research satellites; and payloads on large, multi-purpose satellites such as OGO, OSO, Gemini, and the Apollo Telescope Mount (ATM). The continuing cooperation and outstanding support of NASA in all aspects of these experiments has been the key to success in these programs.

The Naval Observatory has continued to do research in the determination of time and in astrometry. The *Simon Newcomb Laboratory* was dedicated in Washington in 1962 and is used to support astrophysical research and researchers in the determination of time.

ONR has supported many individual investigators at Universities throughout the years since 1946 with its Contract Research Program.

Included in this program has been support for several pioneer investigators in radio astronomy and for such notable individuals as Dr. James Van Allen at University of Iowa for his radiation belt work. ONR Washington is aided in such work by its alert scientific "bird dogs"—the Branch Offices in Boston, New York, Chicago, Pasadena, San Francisco and London. These branch office scientists—by monitoring research sponsored by the Army, Air Force, NASA, European governments and other agencies in universities, industry, and government laboratories—are able to help initiate and manage the various investigations in the Contract Research Program.

Navy research is "mission oriented" and responds slowly but inexorably to such outside influences as the first Sputnik in 1957 or the rise to dominance of the attack aircraft carrier to replace the battleship as the "ship of the line" during World War II. This is because such factors influence long range strategic plans for national security, that are dependent not only on our own force levels and technology forecasts but on projected enemy intentions and force levels as well.

Realization of the threat of submarine forces in future wars was another lesson of World War II. However, it was the technological achievements and system integration miracle of the 1950's that resulted in the Fleet Ballistic Missile (FBM) nuclear submarine and in other obvious military applications for the true submersible. This event has had a greater influence on Navy planning and research than any single event in our Navy's history. As is always the case in the evolution of military weapons, today's submarine is a double-edged sword in the R&D world. To design and build a better offensive undersea weapon's system and to operate it with greater skill and effectiveness is an awesome challenge to the entire naval establishment. Again, as the record shows, today's offensive breakthrough is tomorrow's defensive challenge. Tomorrow is here and Anti-Submarine Warfare (ASW) is that challenge. LT Maury's mostly two dimensional ocean of winds, shoals, currents, and waves has increased in depth during the twentieth century, and is fully three dimensional today. This means to us that the sciences of physics, geology, biology, chemistry, psychology and mathematics are shifting even more to the ocean depths in the Navy research plan. Acoustics, marine geology, marine biology, ocean chemistry, physical oceanography, undersea research vehicles, life support systems, deep moored and drifting buoys, remote sensing of the sea surface, advanced data handling, and new environmental prediction techniques—these are some of the areas of increasing interest which should present long term challenges to scientists and engineers. Instruments for detection of undersea military vehicles, data handling of raw information and its conversion to usable data for the fleet, and command and control then obviously become major challenges that grow out of these research goals and areas of interest.

The Navy and its research community began to become more involved in the ocean sciences with the creation of ONR. In addition, a long standing and continuing stimulus by the National Academy of Sciences and more recently by the National Science Foundation and other government groups has finally led to a formal planning structure for a national program. Congress passed the *Marine Resources and Engineering Development Act of 1966*. This act has set forth a "national policy to intensify study of the sea and to convert to practical reality its inherent promise for man's benefit." It also provided the President of the United States with two assisting groups: a policy planning and coordinating Marine Sciences Council, chaired by the Vice President; and an advisory Marine Sciences Commission to develop long range recommendations. Planning and coordination among 11 federal departments and agencies are required.

Several organizational changes within the Navy, starting in the late 1950's and continuing today, reflect some of the Navy's unique interests in the ocean and the increasing priority of its ocean programs. The Hydrographic Office, which had established an Oceanography Division in 1946 and had begun to operate oceanographic survey ships in 1949, was redesignated as the Navy Oceanographic Office (NAVOCEANO) in 1962. Prior to this, NAVOCEANO had established the Anti-Submarine Warfare Environmental Prediction Services (ASWEPS) for the purpose of developing an integrated system of predicting and displaying oceanographic parameters for anti-submarine warfare operations. The Navy Weather Service and its environmental data collection and processing centers have worked with ASWEPS in this area. The Fleet Numerical Weather Center at the Naval Postgraduate School, Monterey, California, started as an experiment in 1958, was commissioned in 1961. Its dual operational and R&D missions have permitted it to contribute significant advances in oceanographic data handling and environmental support. In 1960, the National Oceanographic Data Center was established as an inter-agency organization to acquire, process, perserve, and disseminate oceanographic data for educational, scientific and technical purposes. NODC is under the administrative management of NAVOCEANO and located at the Washington Navy Yard.

The most significant change thus far has been the change in charter of the Oceanographer of the Navy. In 1966, the Secretary of the Navy established the Office of the Oceanographer of the Navy, directly reporting to the Chief of Naval Operations (CNO). The Oceanographer of the Navy, RADM O. D. Waters, Jr., acts as the Naval Oceanographic Program Director for CNO, in which capacity he exercises centralized authority and control of all Navy resources to insure an integrated program in research, development and operations. He has three assistants: the Assistant Oceanographer for Research—another hat for me the Chief of Naval Research; Assistant Oceanographer for Development—another hat for RADM Goodfellow as the Chief of Naval Development; and Assistant Oceanographer for Operations—not yet filled. NAVOCEANO also reports directly to the Oceanographer of the Navy.

Another milestone of 1960's has been the creation of the Deep Submergence Systems Project. This project is responsible to the Chief of Naval Material for the following: the development of deep ocean vehicles for research, survey, search, salvage, rescue, and other military applications; advancements in the state of deep ocean technology; and the Man-in-the-Sea Program. This project office is heavily supported by the Naval Ship Systems Command, several Navy laboratories (most notably the Navy Undersea Warfare Center in San Diego) and, of course, is strongly dependent on the engineering and production know-how of industry.

In July 1967, the Maury Center for Ocean Science (named for Matthew Fontaine Maury) was established in Building 58 at the Naval Research Laboratory with Dr. John B. Hersey as Director. The Center was organized for the purpose of better coordination of the Ocean Science Program of the Navy and operates under my control, as Assistant Oceanographer for Research. The Center Brings together four groups from three different Navy organizations: (1) the Ocean Science and Technology Group of ONR; (2) the Research and Development Department (created in 1966) of the Naval Oceanographic Office; (3) the Ocean Science and Engineering Division of NRL; (4) the Undersea Surveillance Oceanographic Center (USOC—created in 1967) of the Naval Oceanographic Office. The Maury Center represents a mix of scientists, engineers, and R&D managers who combine to focus and coordinate the Navy's research and development efforts in the ocean sciences. Work is performed through individual university investigators; in-house engineers and scientists at NRL and other Navy laboratories; large institutional centers of excellence in the marine sciences—*i.e.*, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, and the Lamont Geological Observatory; and by industry investigators.

Space and the Sea

In looking at the types and scope of problems typical of ocean research and development, we are at once struck by the many similarities to our national space research programs.

- Both the ocean and space represent research environments that bring together scientists of many disciplines who are from many different types of research organizations.

- They are both relatively unknown environments, which are hostile to man, that represent extreme technological challenges in building rugged, reliable vehicles and instruments to do useful work.
- Both are on the brink of the largest survey and exploration programs that man has ever attempted; they will require capabilities in data handling systems that are far in advance of anything man has yet conceived.
- Both will probably ultimately require very sensitive advanced instrumentation for detecting and measuring phenomena throughout the spectrum from low acoustic frequencies to RF to light through x-rays.
- Both environments will call from some large-scale, high cost research facilities—particularly vehicles—that will be used for a multiplicity of scientific and technical purposes.

Some of these obvious similarities between space and the sea lie in the realm of "Big Science." The lessons we are now learning in the National Space Program, particularly APOLLO, can be well applied to the large ocean research projects.

However, it is more interesting to look at some of the smaller research projects. It is here that we can see more clearly the intimate tie-in and the frequent mutual support of research in space and the sea.

1. *Project TEKTITE*

This is an ocean bottom study, that will involve the longest continuous undersea stay of a diving team yet attempted. As the publicity release states, the project name is inspired by the combination of apparently divergent factors—space and ocean. Tektites are small mineral objects found both on land and in the ocean that have survived a flaming passage through the earth's atmosphere from space. Early in 1969 four U.S. scientists from the Interior Department will live and work for 60 straight days on the ocean floor while isolated at a depth of 50 feet. The ocean floor habitat is being constructed by General Electric Missile and Space Division. The site is in the Virgin Islands. The program will be a cooperative effort with active involvement of the Navy, NASA, Interior, and GE. The program has two objectives: (1) Extensive experimentation and study in several marine sciences on the ocean bottom; and (2) to observe and analyze the behavior of man living in an isolated, alien environment under stress. The behavioral study is applicable to both future undersea missions and extended duration space missions. ONR will provide overall management and technical direction for the program and will head up a Navy group including: Navy Facilities Engineering Command, Bureau of Medicine and Surgery, Naval Oceanographic Office, Deep Submergence Systems Project, Naval Ship Engineering Center, and Seabee units of the Atlantic Fleet.

II. *The Barbados Oceanography/Meteorology Experiment*

This is known as BOMEX, and is another planned joint project of interest to the Navy. Now scheduled for the summer of 1969, this experiment will be coordinated by the Environmental Science Services Administration (ESSA) of the Department of Commerce and will include participation by Navy, Interior, AEC, Coast Guard, NSF, and NASA. The Maury Center will coordinate the Navy's contributions. Environmental data will be collected over a limited ocean area, east of Barbados, to study the joint behavior and interaction of the atmospheric/ocean system in sub-tropical and tropical waters. Environmental sensing platforms will include moored buoys, surface ships, aircraft, and satellities of opportunity. The Navy's interest in Air-Sea Interaction has been previously discussed. Its influence on the problems of predicting undersea patterns in temperature, pressure, turbulence, current flow, and salinity is important. The obvious tie-in with acoustic detection systems and under weapons design makes this area of vital interest to the Navy in ASW, in submarine warfare and mine warfare capabilities.

III. *Spacecraft Oceanography Project (SPOC)*

The SPOC was established within NAVOCEANO in October 1965, and is now administered under the Maury Center. The project is supported by NASA as the ocean portion of its Earth Resources Survey Program. At the present time, its program is concentrating on the design. testing and ultimate space qualifications of satellite sensors for remote measurement of oceanographic parameters such conditions. Both manned and unmanned satellities using radar, visible optical systems, infrared and microwave spectrometers and radiometers are now being considered. While university investigators predominate, Dr. Friedman's radio astronomy group at NRL have been tasked to investigate certain aspects of the practicability of using microwave radiometry to survey the ocean.

IV. *Miscellaneous General Support Projects*

(1) *Navigation.* The Navy Navigation Satellite System, formerly known as Transit, was conceived and developed by the Applied Physics Laboratory (APL) of John Hopkins University under contract to the Naval Air Systems Command. First orbited in 1960 and used operationally in 1964, the technology and system facilities for this project have also contributed directly to a joint DOD program in satellite geodesy which includes Navy participation of NAVOCEANO (Hydrography Group), Navy Weapons Lab (Dahlgren), Naval Air Systems Command, and APL. The Vice President of the United States announced in 1967 that the design information of the shipboard navigation equipment

for this system was now available to U.S. industry on an unclassified basis. The importance and use of the satellite receivers for unclassified research can be most dramatically demonstrated by a description of the ONR/Scripps Institute/NSF – sponsored year-long scientific exploration by the oceanographic research ship, ARGO. This 61,000 mile historic voyage in the Pacific, Indian, and Atlantic oceans will combine on IBM 1800 sea-going computer with the satellite navigation equipment and be able to record simultaneously research data and precise location of the ship in all-weather conditions.

(2) *Satellite/Buoy Communication Experiment.* A new project now underway will participate in on-going and planned NASA programs in satellite interrogation, data relay, and position fixing of various platforms that are used to make environmental measurements. The contractor, General Electric Missiles and Space Division, will use an ocean buoy, instrumented for oceanographic/meteorological measurements. The total experiment plan will investigate the effects caused by the variation of several factors: coding techniques, satellite orbits, position-fixing schemes, frequencies, and buoy electronic packages. Basic design data, peculiar to the ocean buoy environment and applicable to many Navy problems (such as ASW), should be acquired at a reasonable cost because of the utilization of existing NASA facilities. It is hoped that this ONR/NAVOCEANO/NAVAIR project, supported by NASA facilities, will have participation by other government agencies in the future.

(3) *SOLRAD.* Dr. Friedman's NRL Space Sciences Division, supported by the Naval Air Systems Command, has conducted a series of solar x-ray and UV measurements by satellite since 1960. The 1960 satellite SOLRAD was the world's first successful astronomical observatory satellite. Real time readout of the most recent satellite, SOLRAD IX launched on 5 March 1968, is being conducted by NASA, ESSA, and the COSPAR international scientific community. While the major military application is considered to be a monitoring and warning device for communication disruption and radiation hazards to astronauts, its accumulation of insolation data for atmospheric/ocean environmental studies is an obvious and important by-product.

(4) *ESSA Weather Satellite.* A joint R&D program in weather satellites by ESSA and NASA has resulted in the successful Environmental Survey Satellite (ESSA) operational system. The Navy's interest in the products of this program has led it to develop shipboard versions of the Automatic Picture Transmission (APT) terminals. Such terminals, operating with the appropriately configured ESSA satellites, have provided 2 to 4 mile resolution pictures for synoptic cloud coverage at distances out to 2,500 miles from the ship. This information is extremely

valuable in supporting tactical fleet operations, particularly with respect to short range weather forecasts. Navy participation in satellite communications programs is of a similar nature.

The above represent a select few of many projects, involving Navy research participation, that represent a link between our research environments of space and the sea. There are additional examples of commonality and of instances wherein a technique, instrument, or capability developed in one environment has equally meaningful applications to the other: the use of acoustic wave theory to study the atmosphere; the possible use of radio astronomy radiometric techniques for an all-weather radio sextant for ocean navigation; remote underwater manipulators that have their counterparts for planetary exploration; advanced energy conversion techniques that require long-lived, unattended operation in both space and oceans.

I have attempted to describe to you today our organizations and programs in both ocean and space research, and to trace the thread that ties them together. I have tried to place it in some historical perspective, so we know from where we came and better understand where we stand on the road ahead.

To us in the Navy it is interesting to watch a cycle, started almost 140 years ago, beginning to complete its first swing. What started out as a small Depot for Charts and Instruments in 1830, with a mission to provide for safe navigation of the Navy's ships at sea, turned to a study of the oceans and the celestial bodies to help solve its problems. As we look ahead to the awesome challenge of national security in the 1970's and 1980's, the Navy research community sees many complex missions. Certainly, highly advanced sea-based weapons systems will be a part of our national strategy and military posture. Leading the way for such systems, the Navy research community sees a research horizon that begins to blend once again into a joint program of space and the sea.

As we may surmise from the projects discussed, there is a vital need in today's research for scientists and managers that can coordinate the disciplines of space and the ocean on our research problems. There is an equal need for Navy research organizations that are able to seek out and work in harmony with those good scientists and engineers of industry, our universities, and other government agencies.

As a highly appropriate example for my message to you today, let me note that the NRL Space Sciences Divison, with its E. O. Hulburt Center for Space Research, and the Maury Center for Ocean Science occupy separate buildings scarcely one-half mile apart on the grounds of the Naval Research Laboratory in Southeast Washington. They are much closer than this in the less physical realm of scientific competence, personal dedication, and interdisciplinary understanding and support. My job is made pleasurably by such outstanding groups as these.

The challenge of man's greatest adventure—the first space voyage to the moon—is upon us. The challenge of man's greatest potential for human benefit and security—the exploration and understanding of the seas and their depths—is on the horizon. We in the Navy feel proud and grateful to be alive and a part of this broadening research horizon at this most propitious moment in man's history.

Joint Cardiovascular Disease Study

Coronary arteriosclerosis and thrombosis, the great killers of middle-aged men in Western nations, are considerably less common among the Chinese in Taiwan. To determine whether coronary artery disease was increasing in Taiwan, and if so, why, Dr. Robert Bruce, head of the Department of Cardiology, University of Washington, and his colleagues, Doctors Thomas Crayston and E. Russell Alexander, both of the Department of Preventive Medicine, offered to assist the physicians of the National Defense Medical Center in Taipei. The Naval Medical Research Unit No. 2, Taipei, Taiwan, collaborated on this study and provided logistical, technical, and professional support to further study American servicemen and civilian living in Taiwan.

The original investigation was carried out by consultants from both NAMRU#2 and the University of Washington. Dr. Bruce's technique to identify coronary artery disease-prone individuals was used; it assumes that a certain easily identified electrocardiogram (ECG) abnormality will occur after maximal exercise on a tread-mill.

The data obtained are interesting from several points of view. Active men between the ages of 45 and 60 in Seattle, Washington, were tested; 17% had this abnormality, contrasting with only 6% of Chinese officers and business executives in Taipei. Although in China prevalence increased with age as expected, this "higher socioeconomic group" did not have a greater prevalence of abnormal ECG's than Chinese enlisted men. The major determinants of these ECG responses, aside from age, appear to be blood pressure and weight.

NAMRU#2 coordinated a further study of 241 American men between the ages of 40 and 60 living in Taiwan. These volunteers were examined and tested using the same techniques developed in the study of the Chinese men. These Americans, however, did not have the expected prevalence of abnormal exercise ECG's in respect to age. This probably was due to careful screening of personnel for overseas duty or employment. While cholesterol levels seemed to be of only secondary importance, those Americans with high blood pressure did evidence an increased rate of abnormality.

NAMRU#2 Aids Indonesia

Central Java, the victim of plague outbreaks every six to ten years, was again subjected to epidemic with high morbidity and mortality rates during early 1968. The Naval Medical Research Unit No. 2 was invited by the Indonesian Ministry of Health to conduct inter-epidemic studies of the ecology of plague in the Bojolali area; NAMRU#2 was to locate the reservoir of plague, define it, and explore the relationships between host, vector, pathogen, and habitas that make the perpetuation of plague possible. In September they declared the area free of plague. The appreciation of the Indonesian Government has resulted in an invitation to the U.S. Government to formally establish a detachment of NAMRU#2 in Djkarta. CNO has authorized negotiation for establishment to be initiated through the Department of State.

Arctic Sea Ice

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This paper presents the results of a thermodynamic model which describes growth and decay of sea ice. External forcing functions are incoming solar and atmospheric radiation, turbulent fluxes in the air and water boundary layers, and snow fall. Calculated are snow or ice surface temperature, internal temperatures, and thickness. Contemporary estimates of the forcing functions yield excellent agreement with empirical data. The consequences of variations in the water exchange between the Arctic Ocean and the Atlantic, and of changes in the radiation regime are discussed in the light of a possible artificial removal of the ice. As a result of the investigation sponsored by the Office of Naval Research, a projection that the Arctic Ocean may be partially ice-free by natural causes within the next few decades is considered unfounded.

Introduction

In their search for ways to improve mid-latitude weather forecasts, meteorologists for many years had hoped to find the "cradle" of weather disturbances by expanding their observations farther and farther north. Learning more about Arctic weather and climate was one of the prime purposes of the First and Second International Polar Years, 1882 and 1932. Since World War II many high-latitude weather stations have been in permanent operation. These stations serve a multitude of important purposes of a basic and applied nature, but their contribution to the improvement in mid-latitude forecasting accuracy is probably far from what the early meteorologists had hoped for. Evidently we have to view the fluid earth as an integrated thermodynamic system in which all parts are mutually dependent and interact on scales ranging from turbulence to planetary waves and from seconds to centuries. The only major, external and independent cause acting upon this system is the sun. Inside this constantly evolving system, cause and effect vacillate like the chicken and the egg (1) and, needless to say, we are far from being able to solve it in its entirety.

Most successful have been the efforts to numerically simulate the behavior of the atmosphere (2). Even though these simulations do not include an interaction with the oceans, they have been highly successful in short and medium-range weather forecasting because the major variations in the oceans proceed about two orders of magnitude more slowly than in the atmosphere. Comparable models of the oceans are being developed (3).

A feature of great practical importance in the evolution of the ocean-atmosphere system is the evolution of climate whose striking evidence in both geologic and contemporary records has been the subject of a vast number of investigations. It has been recognized for a long time that we are unlikely to find a single and unified cause for climatic variations. Among the multitude of possible causes such as volcanism, carbon dioxide, solar change, and cosmic dust the most intractable and, perhaps, most important is the auto-variation of the ocean-atmosphere system. This variation proceeds, without external forcing, by virtue of the exchange of thermal and mechanical energy of the entire layer between the top of the atmosphere and the bottom of the oceans, at a time scale of up to thousands of years (4). Obviously, the problems of numerically simulating a process of such complexity and duration are enormous because, among other difficulties, they involve variations in the total distribution of water on earth (build-up of glaciations) and variations of the terrestrial albedo and overall heat balance. Of special importance in this connection is the fraction of ocean surfaces covered by sea ice. In the following section a small contribution is reported toward an understanding of the present existence of sea ice and some features of its response to some hypothetical climatic variations.

Numerical Models

At present, about 10 percent of the surface of the World Ocean is frozen during all or part of the year. Sea ice raises the albedo of the surface from about 0.05 to 0.7, and affects the atmosphere primarily by returning most of the incident short-wave solar energy and by suppressing evaporation. The ocean not only receives less solar heating but also less momemtum from the atmosphere. Drift currents in ice-covered seas are usually weak. In addition, the convection under growing sea ice is believed to be the major mechanism leading to the formation of bottom water and the slow circulation of the deep water masses.

Sea ice is also a phenomenon of practical importance that profoundly affects the economies of the Soviet Union, Canada, Finland, and to a lesser extent Denmark (Greenland), Iceland, Sweden, Norway, Japan, and the United States (Alaska).

In order to understand sea ice we have to explain:

(a) the heat exchange between atmosphere and ocean that leads to the growth or decay of an ice cover (thermodynamics),
(b) the response of an existing ice cover to the forces exerted on it by air and ocean currents (dynamics), and
(c) The way in which the ice, in turn, affects dynamic and thermodynamic processes in the atmosphere and the ocean (feedback).

These three aspects are mutually dependent: For instance, in a region of wind divergence the ice will also diverge and expose a certain area of relatively warm water to a cold atmosphere. The results will be convection and an increase of the upward heat flux in the ocean, greatly increased evaporation into the atmosphere with its ensuing effect on the long-wave radiation balance, and the formation of additional ice. Since, as pointed out earlier, a unified treatment of the whole system water-ice-air is presently not possible, we have no choice but to approach the problem along the separate lines mentioned above.

Practically nothing is known, beyond qualitative speculation, about feedback mechanisms. This is not surprising because their understanding would have to rest on a comprehensive theory for (a) and (b).

Since Nansen introduced his fundamental studies of ice drift in 1902, its dynamic theory has been the subject of a series of investigations (5). The most recent and sophisticated model is physically complete, containing all forces acting upon the ice, but its practical application is hampered by the fact that numerical values for the internal ice stress (the force with which large, inhomogeneous sheets of ice resist deformation) are not known (6). The acquisition of the necessary data would involve elaborate and costly field observations that have yet to be made.

Our knowledge of the thermodynamics of the growth of ice on a water surface is relatively advanced. The process was mathematically formulated and solved in its most elementary form by Stefan in 1891 (7). Of the numerous later studies pertaining to Arctic sea ice those of Kolesnikov, 1946 (8) and Budyko, 1966 (9) are especially significant. The following section summarizes some results of a thermodynamic model developed at the University of Washington (10).

The model consists of two diffusion equations, one for snow and one for ice, and three boundary conditions. The diffusion equations describe the transfer of heat by conduction and contain a term representing an internal heat source due to short-wave radiation penetrating the surface. As required for sea ice, specific heat and heat conductivity are given as functions of temperature and salinity. The boundary condition at the snow-ice interface simply states an equality of both temperature and heat flux in either medium adjacent to the boundary. The boundary conditions for the top and bottom surfaces are stated as heat balance equations in the customary form. External forcing functions are:

- Incoming short and long-wave radiation.
- Turbulent fluxes in the air and water boundary layers.
- Snow fall.

Computed are:

- Surface temperature.
- Surface ablation.
- Bottom ablation or accretion.

- Internal snow and ice temperature.
- Snow and ice thickness.

The computations proceed from an arbitrary initial condition at time intervals of 12 hours and space intervals of 10 centimeters until "equilibrium thickness" is achieved which, by arbitrary definition, is reached when surface ice ablation during the summer and bottom accretion during the winter are equal within plus or minus 1 millimeter.

The method used in solving the finite difference equations was suggested by Sauliev (11). It combines the advantages of being applicable to non-linear problems and moving boundaries, with computational stability.

Some Results

A comprehensive study of the heat budget of the Arctic by Fletcher (1965) gives the best estimates for the climatological forcing functions mentioned in Table 1 (lines 1-4). A widely accepted value for the present equilibrium thickness of sea ice in the Central Arctic is about 3 meters. If, with contemporary values for the input functions, the model yields an ice thickness that is grossly different, then we must conclude that either the input functions are wrong or the model is inadequate. If the computed thickness is correct, then we can have confidence in both the input functions and the model, because the complexity of the system makes a fortuitous agreement extremely unlikely.

Figure 1 is a computer-plotted graph of the initial test of the model, computed using Fletcher's meteorological input data and a heat flux

TABLE 1
Input Data (Forcing Functions) According to Fletcher (1965) and
Calculated and Observed Mean Monthly Surface Temperatures

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
(1) Incoming Short Wave Radiation (Kcal/cm^2)	0	0	1.9	9.9	17.7	19.2	13.6	9.0	3.7	0.4	0	0	75.4
(2) Incoming Long Wave Radiation (Kcal cm^2)	10.4	10.3	10.3	11.6	15.1	18.0	19.1	18.7	16.5	13.9	11.2	10.9	166.0
(3) Flux of Sensible Heat (Kcal/cm^2)	1.18	.76	.72	.29	−.45	−.39	−.30	−.40	−.17	.10	.56	.79	2.71
(4) Flux of Latent Heat (Kcal/cm^2)	0	−.02	−.03	−.09	−.48	−.70	−.64	−.66	−.39	−.19	−.01	−.01	−3.20
(5) Calculated Surface Temperature (−°C)	30.8	32.8	31.5	22.2	9.5	0.3	0.1	1.2	10.0	20.0	28.7	30.2	18.1
(6) Observed Surface Temperature (−°C)	32.6	33.9	31.9	25.4	11.8	2.1	0.1	1.6	8.8	18.0	26.3	30.8	18.6

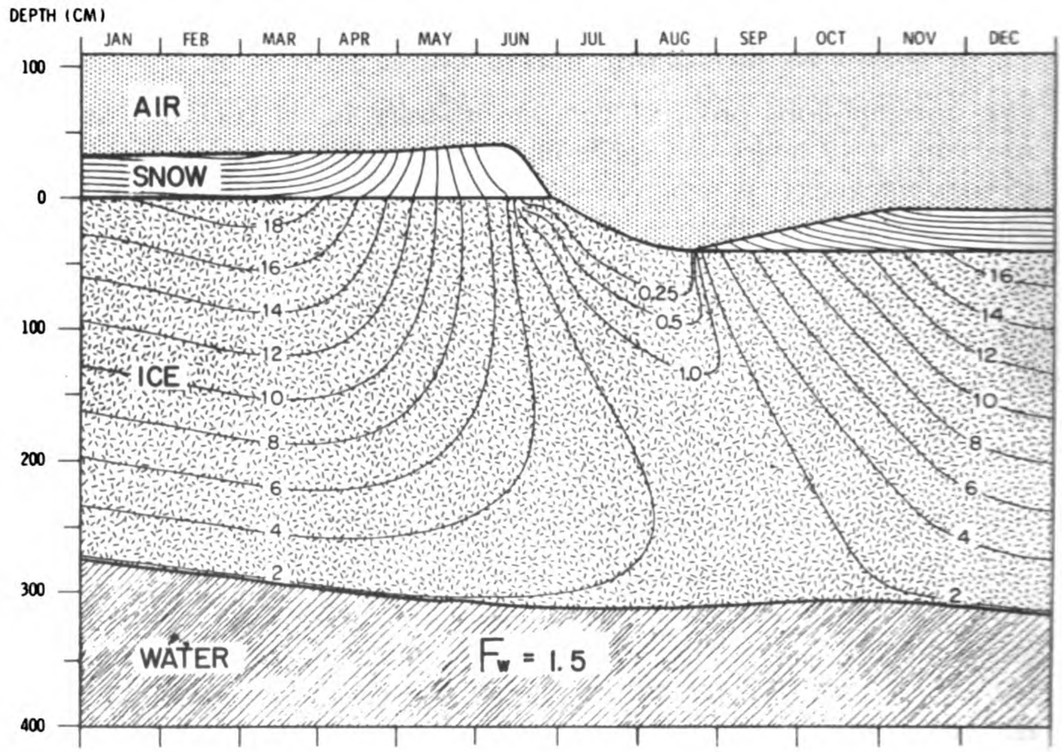


Figure 1 — Contemporary thickness and temperature of perennial arctic sea ice, computed with the input date (forcing functions) given in Table 1 (lines 1-4). The upward heat flux in the water (F_W) *is 1.5 kcal/cm²/year. Temperatures are given in negative degrees Celsius.*

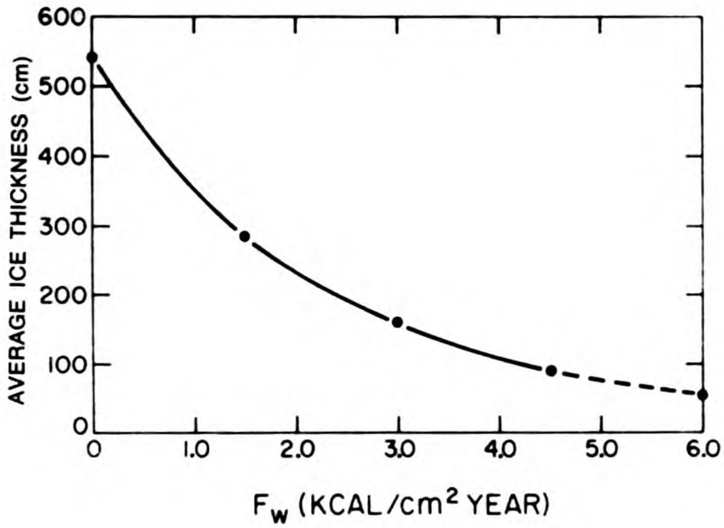
in the ocean estimated by Badgley (12). In remarkable agreement with observations, the average thickness is 288 cm, total ablation and accretion are about 40 cm, the snow begins to melt on 8 June, and freeze-up occurs on 19 August. The surface temperatures are in essential agreement with observations (Table 1, lines 5-6).

By varying one parameter at a time and keeping all others unchanged, we can now investigate how the ice responds to a change of individual parameters of its environment.

The present flux of heat reaching the bottom of the ice from below (F_w), originating from Atlantic waters at depths of about 200-800 meters, is estimated to be about 1500 cal/cm²/year. Figure 2 shows the effects of variations of this quantity upon ice thickness. If F_w were of the order of 6000 cal/cm²/year, as some authors assume (Malmgren (13) 1927, Mosby (14) 1963), the model predicts that the ice would vanish. Compared to the radiation fluxes toward and away from the ice surface, F_w is very small but the ice responds sensitively to its variations.

The next parameter investigated was the snow cover which is presently about 40 cm, with a water equivalent of about 13 cm, deposited primarily between September and November and melting completely during June (Figure 1). Figure 3 shows the result for the assumption of no snow. Surface temperatures are, of course, higher without the insulating

Figure 2 — The response of average equilibrium ice thickness to a variation of the heat supply from the ocean



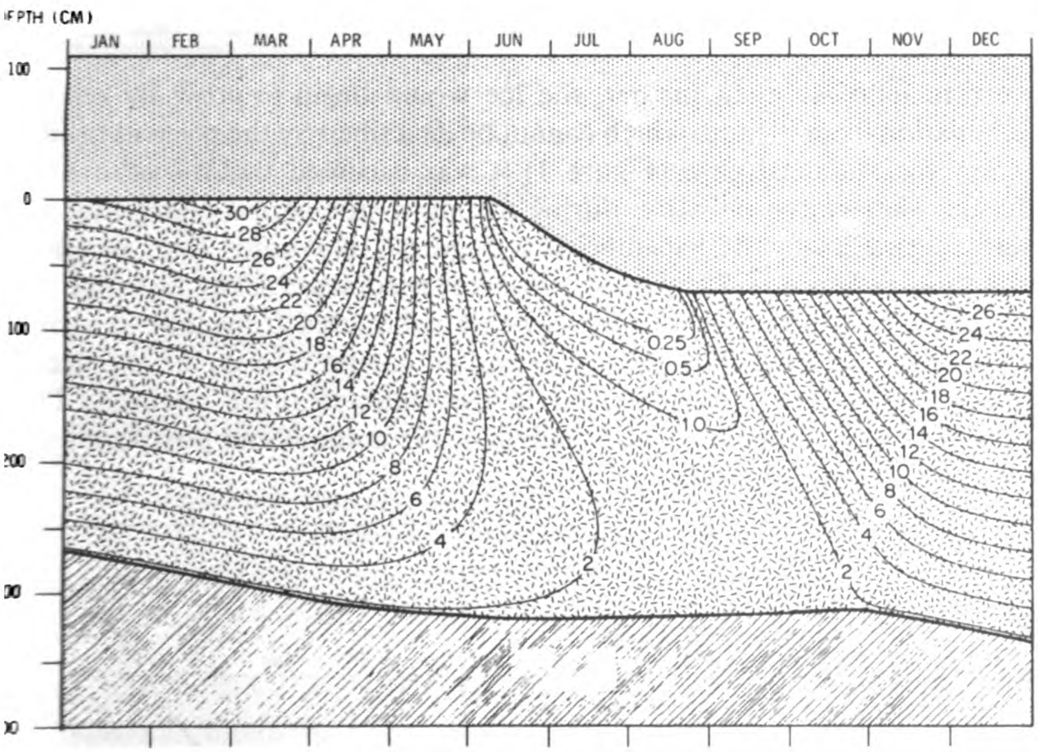


Figure 3 — Ice thickness and temperature under the assumption of complete absence of snow. All other input functions as in Figure 1.

lanket of snow, annual ablation and accretion are greatly increased, ut the average thickness is changed little. The dependence of ice iickness on the assumed snow depth is plotted in Figure 4. Up to about 0 centimeters of snow, there is no significant effect on ice thickness. 'urther increase of the snow cover leads to a rapid thickening of the :e to over 7 meters. A snow pack of that thickness barely melts away uring the summer before accumulation starts anew. If the snow cover

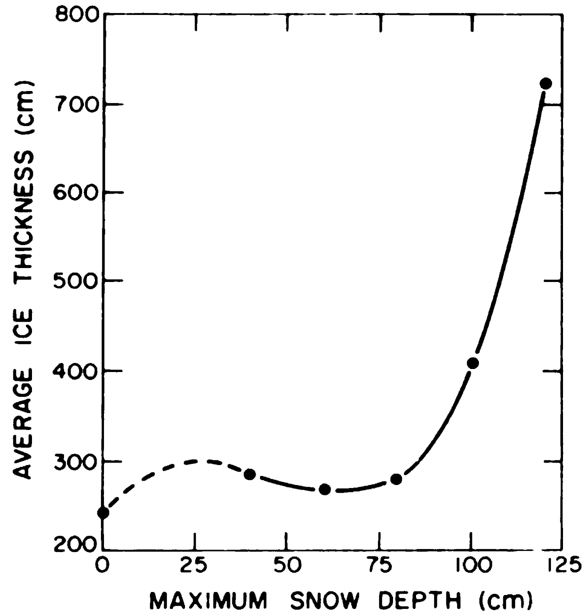
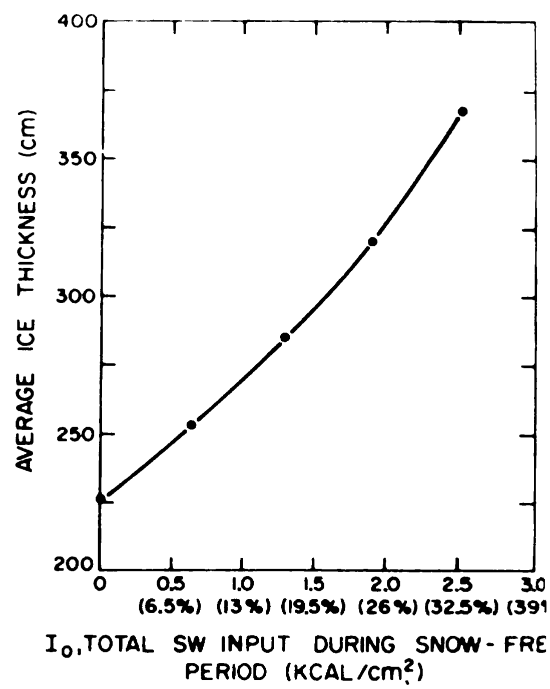


Figure 4 – The effect of snow depth on average equilibrium ice thickness

were to increase even further, the ice would begin to grow by net accumulation from the top, which cannot be described by the present model.

For the standard case (Figure 1) it was assumed that 17 percent of the net short-wave radiation during the snow-free period penetrates the surface and heats the ice internally. Figure 5 illustrates that, as more radiation penetrates the surface, the ice becomes thicker because the energy used for internal heating is being subtracted from that available for surface melting. The energy absorbed in the interior of the ice is stored in the form of latent heat in the enlarged brine pockets. This heat reserve somewhat retards cooling in the autumn and postpones the onset of bottom accretion.

Figure 5 – The effect of penetrating short-wave radiation (I_0) on average equilibrium ice thickness (percent of net short-wave radiation)



According to Table 1, by far the largest fluxes of heat reaching the ice are the short-wave radiation from the sun and the long-wave radiation from atmospheric clouds and water vapor. Any change of these fluxes can be expected to have the most drastic effects. If we assume that the average reflectivity for short-wave radiation (albedo) of both snow and ice were lowered throughout the year by only 10 percent, the model would predict conditions as shown in Figure 6. The mean ice thickness is reduced to 105 cm. A decrease of the albedo by 20 percent causes the ice to vanish in about three years. Another way in which the radiation balance could be affected would be by changing the long-wave emissivity. For natural snow and ice it has a value of very close to 1.0. If it were somehow lowered to 0.8, the loss of long-wave radiation would also be reduced and lead to the condition shown in Figure 7. From these results

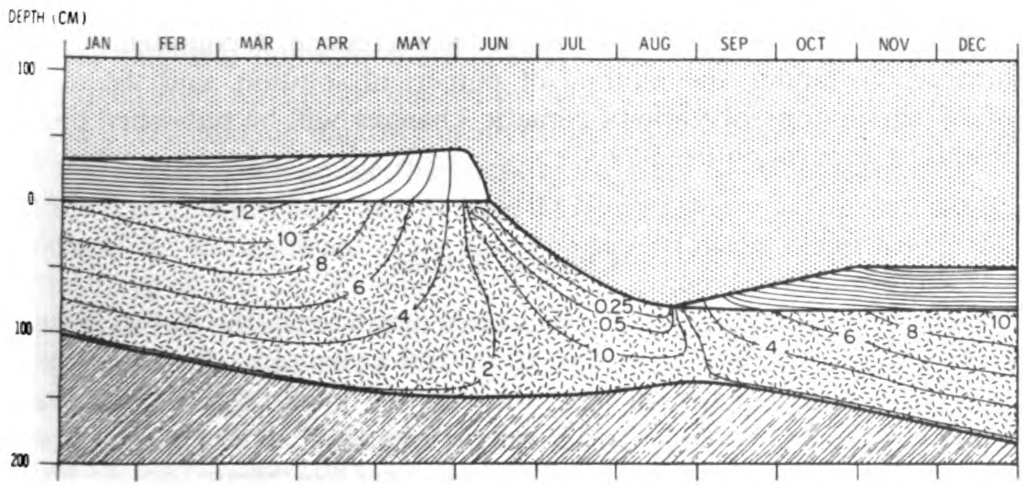


Figure 6 — Thickness and temperature patterns resulting from a 10 percent reduction of surface albedo

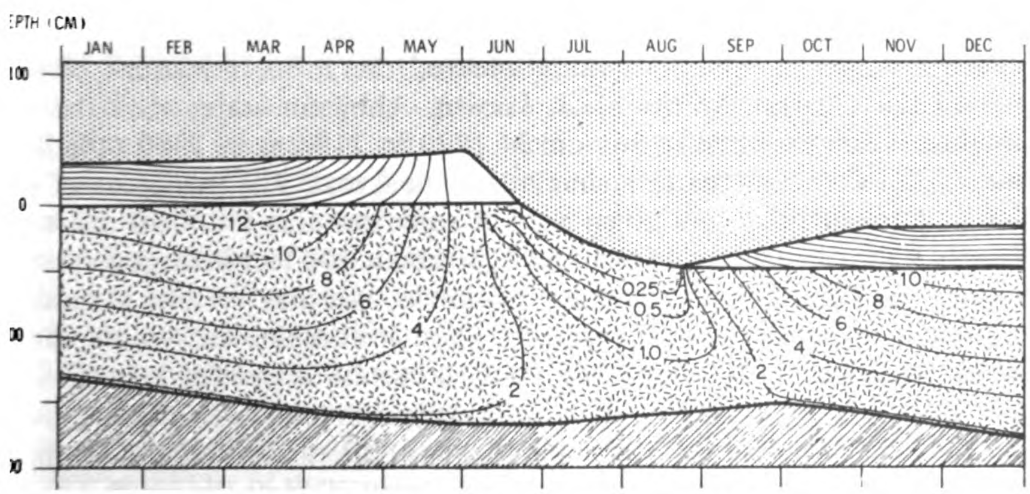


Figure 7 — Thickness and temperature patterns resulting from a 20 percent reduction of long-wave emissivity of the surface

it is evident that, if one were to contemplate the artificial removal of a sheet of sea ice, a most effective way would be to contaminate its surface with a substance that is both dark and a poor infrared radiator.

When investigating the time lag with which the ice responds to a change in its environment, it was assumed that equilibrium conditions were suddenly disturbed by an increase of the oceanic heat flux from 1.5 kcal/cm²/year to 4.5 kcal/cm²/year. The ice approaches the new equilibrium thickness along an exponential decay curve, approximately analogous to an electrical discharge, with about half of the total change occurring within three years.

One of the most serious shortcomings of the model is that no dynamic effects (ridging, formation of leads) are allowed for. Another limitation is the incomplete description of feedback mechanisms. For instance, it is doubtless incorrect to assume that the fluxes of sensible and latent heat in the air boundary layer remain constant while surface temperatures change as a result of a varying radiation regime. A complete description of the model, the method of numerical solution, and the results of 28 simulations of various climatic changes will be published by the RAND Corporation in 1969.

Climatic Trends

It is well established that the boundary of sea ice in the North Atlantic is now farther north than it was 50 or 100 years ago. It seems logical to assume that, during the same time, the ice in the Central Arctic has become thinner. However, "logical assumptions" concerning systems as complex as the atmosphere and the ocean are worthless.

The warming of the Arctic which includes water temperatures, air temperatures, and northward migration of ice boundary culminated around 1940. Since then, the trend has been reversed (15). Beginning at the same time an increasing number of mid-latitude glaciers in the northern hemisphere have experienced moderate advances.

How these climatic variations affected the mean thickness of sea ice in the Central Arctic is not known. Ahlmann states that the ice thickness decreased from 365 cm in 1890 to 218 cm in 1940 (16). Let us subject these figures to a simple statistical test: The thickness of sea ice at a given time, in a given area of sufficient size (50 × 50 miles or more), varies from zero in open leads to about 100 feet in large pressure ridges. To determine the average thickness, one has to take a random sample from an area large enough so that it contains the whole range of thicknesses. This sample will show a certain standard deviation. If we specify the probability that the average should lie within a given range of the true average, statistical theory predicts how large the sample has to be, that is, in how many randomly located spots the ice thickness has to be measured.

Not until the advent of the nuclear submarine was it possible to obtain records of the topography of the underside of sea ice. It is the underside, rather than the surface, that is indicative of ice thickness. Most of this information is still unpublished, but some preliminary information is available in the open literature. Wittmann and Schule give histograms of ice thickness for two profiles in the Canadian Basin, one taken in winter and the other in summer 1960 (17). From these histograms it can be concluded that the standard deviation of thickness is about 4 feet. They pertain to level, unbroken ice only, and exclude the 20 to 40 percent of the area covered with broken, ridged ice of greater thickness. If we now postulate that, with a probability of 90 percent, the observed average thickness should lie within plus or minus 1 foot of the true average, then the test renders a required sample of 50 measurements. Even under the above, unrealistically favourable assumptions, it is evident that, if the earlier pioneers of arctic research had done nothing but drill holes in the ice, they could not have documented a time-trend such as the one quoted by Ahlmann.

The overwhelming majority of investigators still quote a value of 9 to 12 feet for the average ice thickness in the Central Arctic (Zubov (18), Petrov (19), Wittmann and Schule (17); and there is no substantial evidence for a significant contemporary trend toward either thickening or thinning of the ice. This is not to say that such a trend cannot exist. Our model calculations have shown that the ice, because of its small vertical extent, responds readily to variations of the heat input. But if neither such variations of heat input nor the variations of the ice itself are documented, then the projection advanced that the Arctic Ocean might be ice-free by 1985 remains unfounded conjecture.

Conclusion

There are numerous reasons why it is tempting to speculate on the ossibility of removing the ice cover from the Arctic Ocean. There ould be more food from the sea for the world's growing population, pen shipping lanes between Atlantic and Pacific, free access to known nd potential sources of oil and other mineral deposits in the Arctic. o what extent will there be climatic changes in sub-arctic lands? What gency would be in a position to resolve the international aspects and e endless series of real and imagined claims of damage by individuals? ho can and will bear the burden of responsibility of predicting the outme of such an experiment, of deciding that the majority of effects ll be desirable, and of coping with the inevitable undesirable effects an experiment that, once done, may be impossible to undo?

It so happens that, from an economic point of view, an open Arctic cean would be of the greatest benefit to the two most powerful nations, e USA and USSR, and their greatest economic competitors, the

European nations and Japan. But let us remember that, in thinking about tampering with the global environment, we may be tampering with the future centuries or millennia. It is possible that removing the ice from the Arctic Ocean would cost a fraction of what it is costing to put a man on the moon. It is also possible that removing the ice from the Arctic Ocean might be a better investment of public resources. But we do not know. Crudely speaking, space travel harms no one and benefits many. For environmental control, neither an objective evaluation of the needs nor a reliable prediction of the results seems presently possible. But meanwhile we continue to degrade our physical environment, and the world's population continues to grow and, unless it can be persuaded to cease doing so, two thirds of it will continue in their present state of poverty and hunger (20). Perhaps in the next century we may find that conservation was no more than a stopgap and that we are facing the need for drastic and large-scale measures of environmental management. We may hope that such needs will not arise, but we should be prepared for them.

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Simplified Blood Preservation Process

The principal investigator on this research project has discovered a new extracellular cryoprotective agent, hydroxypropyl starch (HPS). This substance provides good protection to red blood cells and platelets when they are frozen at liquid nitrogen temperatures for long-term preservation. This substance is nontoxic, is metabolized by the body, and does not cause adverse reactions in the body after administration (nonantigenic). The preliminary results obtained with HPS indicated that it will be a very effective cryoprotective agent.

The cryoprotective agent, glycerol, which is now in use must be washed from the red blood cells prior to transfusion. This post-thaw processing requires three liters of wash solution and presents logistic problems in shipping, storing, and handling in Southeast Asia. HPS holds the possibility of eliminating the washing procedure and has the potential to reduce the processing of frozen preserved blood to a one-step thawing process prior to transfusion.

This substance is under consideration by the U.S. Army Medical R&D Command as a potential plasma expander and the research efforts of ONR and the Army are coordinated.

A Gordon Research Conference on Chemical Oceanography will be held 14-18 July 1969, at the Kimball Union Academy in Meriden, New Hampshire. The chairman for this meeting is Dr. Victor J. Linnenbom of the Naval Research Laboratory, with Dr. Noris Rakestraw of the Scripps Institution of Oceanography as vice-chairman. Requests for applications to attend should be sent to Dr. Alexander M. Cruickshank, Director, Gordon Research Conferences, Pastore Chemical Laboratory, University of Rhode Island, Kingston, Rhode Island 02881. Full details on the Gordon Conferences are contained in the 7 March 1969 issue of Science.

Applications of Interferometric Holography

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Holography is one of the relatively few technical innovations of the past decade that has stimulated the imagination of both the scientific community and the general public. Speculative literature has appeared on the application of the remarkably realistic three-dimensional imaging capability of holography to the motion-picture and television industries. Aside from these applications of considerable commercial importance and general interest, holography also lends itself to more limited, and specialized applications in technical areas. The holography activity supported by the Underwater Sound Laboratory exploits those specialized technical applications that may be adapted to the particular requirements of research and development work in underwater acoustics.

The most important characteristic of holography used in the laboratory's program is the ability to make interferometry measurements of stationary and vibrating surfaces quickly and conveniently. Interferometry has always been known as a precise optical technique requiring meticulous care both in the preparation of the specimen surface and in the execution of the actual measurements. For this reason it has been used primarily for measurements in optical research laboratories. Hologram interferometry, on the other hand, is a relatively insensitive technique requiring no preparation of the specimen surface and can be used as a production inspection tool in manufacturing processes. The potential of this new interferometry process has not yet begun to be realized.

Holography is, in essence, a photographic process carried out entirely with coherent laser illumination. It differs from conventional photography in that it records the light field produced by an object rather than its image. Although the holography process was first envisioned by Denis Gabor of the Imperial College of London, in the late 1940's he did not have available a light source of sufficient coherence to develop his idea. Interest is holography was reawakened with the advent of the laser, and the work done by Emmet T. Leith and Juris Upatnieks in the early 1960's resulted in the first holograms as we know them today. The application of holography to interferometry measurements was first achieved in 1965, and scientific interest in this technique has been growing rapidly ever since. The holography program at the Underwater Sound Laboratory began in 1967 and has already yielded tangible benefits to other current projects at the Laboratory.

Once the basic requirement of stability has been achieved, usually by placing a massive granite slab or steel casting on a soft suspension system, the actual making of a hologram is quite simple. A laser beam is split into two parts by means of a partially reflecting mirror. One part, known as the reference beam, is expanded and directed onto a high-resolution photographic plate. The other part, unkown as the object beam, is expanded and used to illuminate the object being photographed. The photographic plate records the two light fields, one of which comes from the reference beam and the other from the light reflected from the object. Since both fields are made up of coherent light, optical interference occurs in the photographic emulsion because of phase differences in the incident light waves. The storage of phase as well as amplitude information is what gives the hologram its three-dimensional properties. A typical experimental arrangement is shown in Figure 1.

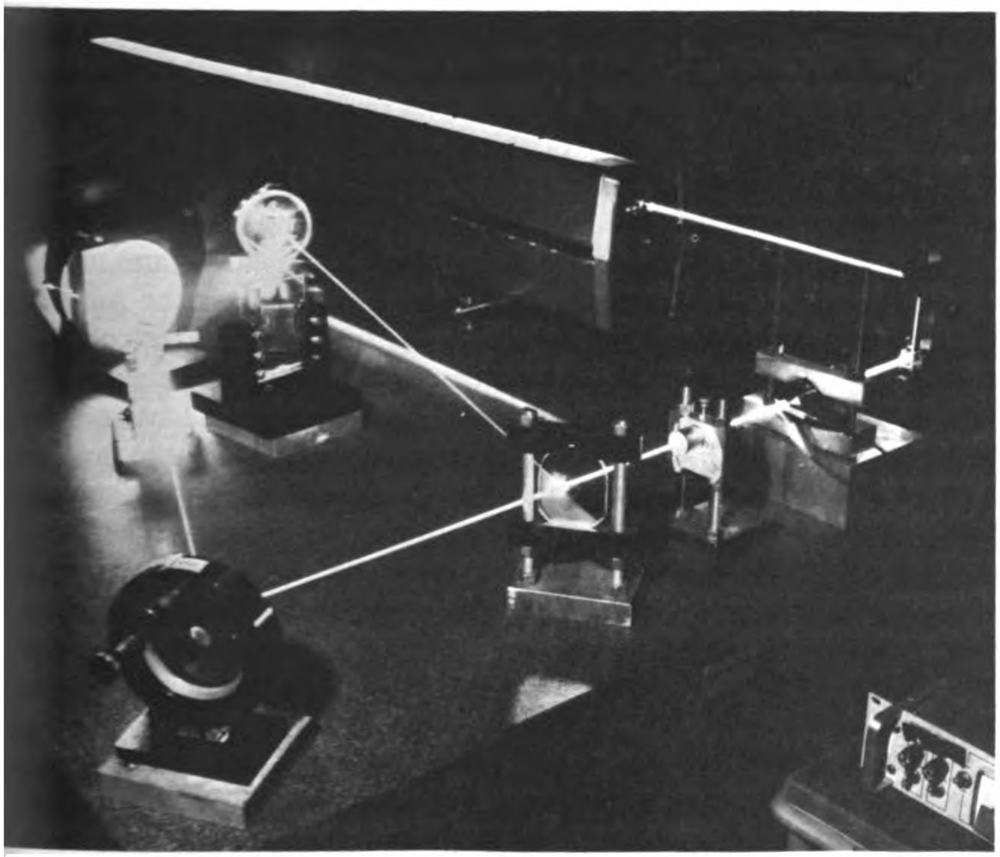

Figure 1 — Experimental setup for holography

When the photographic plate is developed, it has the physical appear-
ice of a light-struck negative. There is no apparent image when it viewed under normal room lighting conditions; in fact, it is impossible determine the subject of a hologram by observing the plate under ich conditions. If, however, the plate is viewed in coherent light the ference field is effectively canceled out, and the hologram reconstructs

the light field that was generated by the object at the time of the original exposure. The impression gained upon viewing a hologram is one of observing the original physical scene through a slightly dirty window. A logical extension of the window analogy, but one with rather startling implications, is that the scene itself will not be changed by the size of the window through which it is viewed. It is possible to break a hologram into several pieces, each of which may be used by itself to view the entire scene, though at some loss in clarity.

Hologram interferometry is accomplished in essentially the same manner as ordinary holography, except that double or multiple object positions are recorded on the same photographic plate. If the change in object position is in the form of a surface deformation, and if the magnitude of the change is approximately several wavelengths of light, optical interference will occur between the two images reconstructed upon viewing the hologram. The object will appear in its original position but will have a fringe pattern on its surface. The fringe pattern, an example of which may be seen in Figure 2, is actually a contour map of the surface deformation that occurred between exposures. The contour interval represents changes in object position that caused a net change of one wavelength in the path of the light originating in the object beam and falling on the photographic plate. The actual change in object position, then, depends on the angle at which the object beam illuminates the object and the angle at which the image is viewed, as well as the wavelength of the laser used for illumination. Note that the interference fringe pattern that we are now discussing results entirely from changes in the object beam and is fundamentally different from the microscopic fringe pattern of the object and reference beams used to record the hologram.

Since it is possible to create interference fringes simply by holographically recording a scene in which variable path-length changes have occurred, the object beam is of considerable significance in making engineering measurements. The example given above involved a simple double-exposure of an object that was given a surface deformation between exposures, but the hologram interferometry technique is far more versatile than that. Any disturbance which results in a variable path-length change in the object beam will produce similar results. Some of the more important physical disturbances that can be holographically measured are localized changes in index of refraction of a transparent medium, surface deformation, angular displacement, and periodic vibration, all of which may be measured with a common, continuously operating gas laser.

The use of a fast-acting pulsed laser that releases a large amount of energy in a few nanoseconds permits the measurement of the passage of a bullet, or of explosion phenomena, or of shock waves traveling in solid materials. A laser that can be turned to several operating frequencies may be used to generate contour lines on a stationary curved

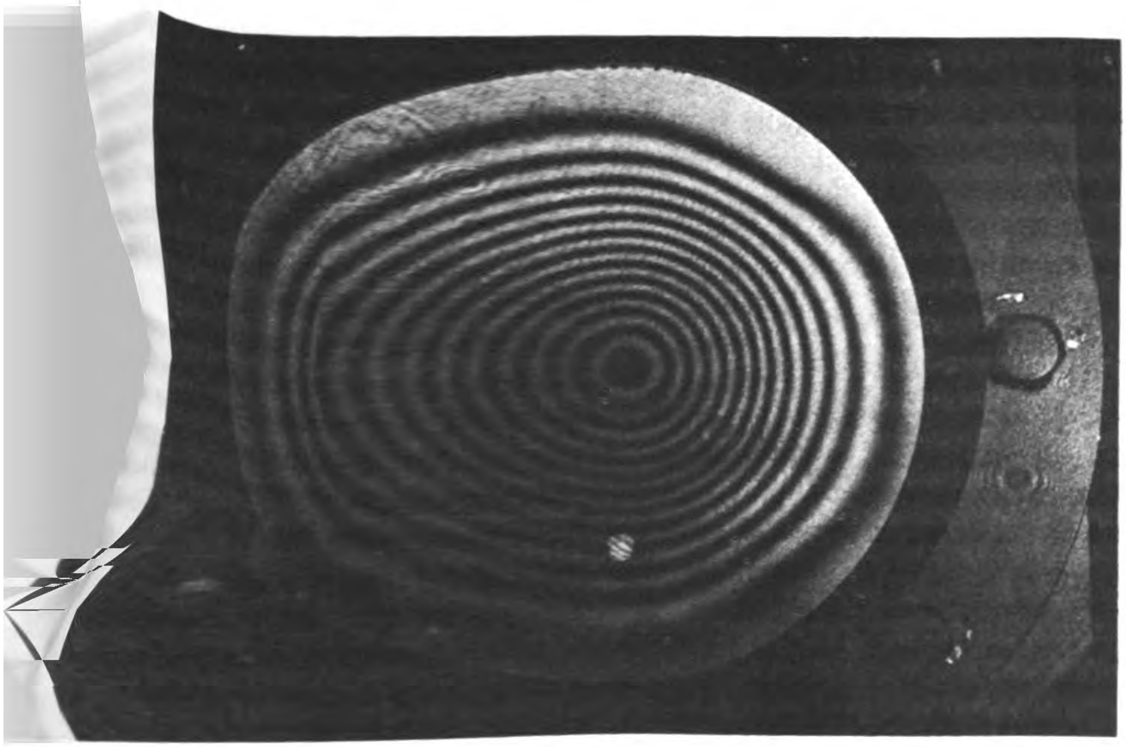

Figure 2 — *Photograph of a hologram showing static deformation*

urface, or to make holograms in full color. Interrupting the laser output with an electronic shutter produces stroboscopic holograms and opens up another field of measurements. The possibilities are virtually endless.

Certain hologram interferometry techniques are especially well-suited o measurement problems encountered in the work done at the Undervater Sound Laboratory. The identification of these techniques and heir application to current engineering projects at the Laboratory vere the basic reasons for the Laboratory's entry into the field of holoraphy.

Probably the most useful of the techniques practiced at the Laboratory s hologram interferometry of vibrating surfaces, as vibration is of undamental importance to sonar. Electroacoustic transducers depend pon vibration to put sound energy into the water and to receive sound nergy from water. Sonar dome housings are subject to vibration, and he noise generated by vibrating underwater structures limits the performance of sonar system by masking the received acoustic signals. onar transducers, sonar domes, and underwater structures, then, re prime subjects for holographic measurements.

An excellent illustration of the practical application of vibration ologram interferometry was given in a study of the vibration characteritics of thin steel plates used in hydrodynamic noise investigations in ie Laboratory's water-tunnel facility. The holography study provided uick answers to several questions of a purely practical nature. For xample, was cementing a suitable substitute for soldering in assembling the plates? Was the frame used on the plates stiff enough to approximate a fixed-boundary condition? What was the effect of residual stresses from the rolling process used in manufacturing the plates? In addition to these hardware considerations, a complete description of the mode shapes of some 36 different modes of vibration was obtained with unprecedented ease. The details provided by the holograms would require literally hundreds of point-by-point measurements to obtain comparable results with conventional vibration instrumentation. Without holography, the study would have been limited to the identification of resonant frequencies, and possibly the identification of mode locations with sand-pattern measurements. Figure 3 compares the hologram of a vibrating plate with a physical model of the plate's modal structure.

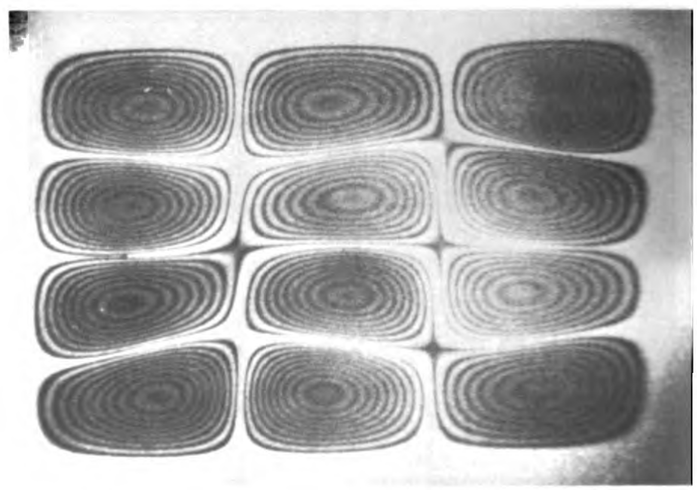

Figure 3a – Typical mode of hydrodynamic noise plate

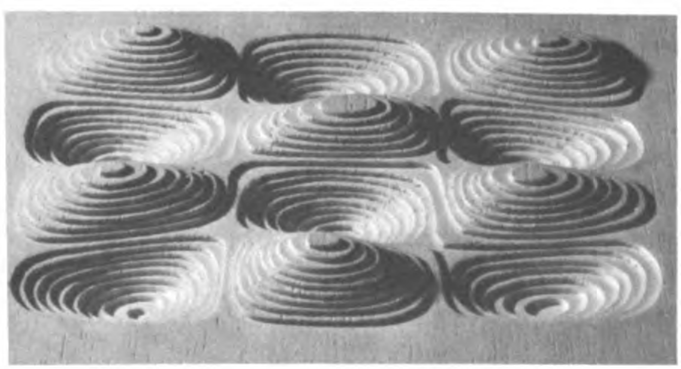

Figure 3b – Physical Re presentation of typica mode

The value of hologram interferometry in this example may be looked at in two ways. If it were truly essential to obtain data in the detai provided by holograms, hologram interferometry would be credited wit an order of magnitude savings in time, and, therefore, in cost. Assumin that a compromise would have been made if holography were no available, hologram interferometry could be credited with makin available far more detailed measurements in the same time and at th same cost.

The second most important class of hologram interferometry to the Laboratory is the static-deformation type. This type of hologram records the difference between two stationary positions of the object under investigation. The sensitivity of the measurement process is in millionths of an inch, which makes it possible to study deformations too small to be measured by conventional methods. It is a versatile inspection technique that readily detects flaws in transducer construction that are difficult or impossible to detect by other means. Cracks in fiberglass layers (Figure 4) and bonding deficiencies in rubber or plastic coatings are examples of applications of importance to sonar transducers.

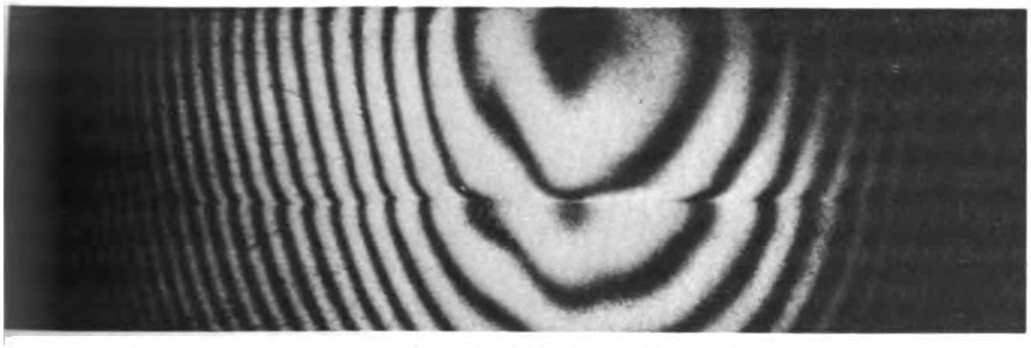

Figure 4 — Photograph of a hologram of a large ring transducer showing a crack in the fiberglass

One distinct advantage of hologram interferometry is the fact that it can be used in any transparent medium. Thus, hologram interferometry can be used to observe underwater subjects as well as those in air. The ultimate application of observing large sonar transducers operating n open water would constitute a break-through in transducer measurenent technology. The development of a holography camera capable of naking such measurements is one of the primary objectives of the Laboratory.

Underwater hologram interferometry has already been accomplished t the Laboratory by use of beam models and single sonar transducer lements as subjects. Several transducer elements, arranged in a small rray, will be studied in the near future. The graduation to open-water neasurements will take place in two stages; first, in a clear inland ake facility, and finally, in the true sonar operating environment of the pen ocean.

Holography is an exciting, new technological development with many otential applications in all fields of engineering. Several of these applicaons are especially useful for the type of measurements required in the nderwater acoustics area. The task of adapting the fundamental techology to the particular needs of the Laboratory is one that is well istified by the value of the applications and can be expected to yield oth immediate and long-range benefits to Navy programs.

WHITE HOUSE MESSAGE TO AQUANAUTS

To: Aquanauts
TEKTITE I
St. John, Virgin Islands

Your record breaking venture into inner space is another milestone in human achievements. The aquanauts joined the astronauts as space pioneers.

Congratulations!

Richard M. Nixon
President, United States

Edward Clifton and John Derwalker in the access t prior to leaving the habitat o excursion dive

Richard Waller changing an auxiliary CO_2 "scrubber" in the life support and environmental control systems

Conrad Mahnken straining a plankton sa pumped in from a standpipe assembly ou the habitat

On the Naval Research Reserve

Promotion Selections

There were five Naval Reserve officers selected for promotion to Rear Admiral by the Fiscal Year 1969 Reserve Selection Board. Three of these officers are members or former members of the Research Reserve:

	NRRC
Cronkite, Eugene P.	3-9
Weber, Alban	9-10 (Former Member)
Wiggin, Frederick A.	13-1

There were 115 Naval Reserve line officers selected for promotion to Captain by the Fiscal Year 1969 Reserve Selection Board. Four of these officers are members of the Research Reserve:

	NRRC
Clement, Marwood R., Jr.	4-12
Hill, Robert E.	1-2
Kehoe, Eleanor F.	5-8 (WAVE)
Nall, Julian C.	5-8

Seven hundred and five officers were selected for promotion to Commander. Fifteen were members of the Research Reserve Program:

	NRRC		NRRC
Briggs, Dale E.	9-3	Holway, James M.	5-4
Chapman, Robert E.	12-2	Kyser, Russell H.	5-9
Curtis, Harold B.	12-5	McMurtry, George J.	4-4
Darby, Ronald	8-3	Patterson, David A.	5-9
Fulcher, Clay W. G.	8-4	Sanders, William A.	5-8
Gentile, Vincent J.	3-8	Schickler, Edward R.	3-4
Glahn, Gerald L.	8-4	Wallenius, Kenneth T.	3-16
		Wilson, Kennedy L.	5-8

Twelve of the officers selected were from the new field and three from the old.

Seminars Planned for Fiscal Year 1970

Five Research Reserve seminars are planned by the Office of Naval Research for Fiscal Year 1970. The titles, places, and dates of the seminars are as follows:

Research Reserve Oceanography Seminar, Corvallis, Oregon	14 July 1969
Research Reserve Advanced Naval Technology, Seminar, Newport, Rhode Island	21 July 1969
Research Reserve Seminar on Electronic Computers, College Station, Texas	25 August 1969
Research Reserve Applied Research Seminar, Albuquerque, New Mexico	2 March 1970
Research Reserve Oceanography Seminar, Princeton, New Jersey	15 June 1970

NRRC 9-6

RADM Owen, Chief of Naval Research, presents the Research Reserve Award for General Excellence for FY 1968 to LCDR Molitor, Commanding Officer of the winning company, NRRC 9-6 Minneapolis, Minnesota.

The 1969 Gordon Conference on Photonuclear Reactions to be held at Tilton School, Tilton, New Hampshire, 4-8 August. Additional information may be obtained from Professor H. S. Valk, University of Nebraska, Department of Physics, Lincoln, Nebraska 68508. Phone: Area Code 402, 472-2770. Co-sponsored by Gordon Research Conference, University of Rhode Island; National Science Foundation; Air Force Office of Scientific Research, and the Office of Naval Research.

Neisseria Repository Established

The Navy has established a Neisseria Repository at the Naval Medical Research Unit No. 1, at Berkely, California in an attempt to learn more about meningitis. Sponsored by the Bureau of Medicine and Surgery, the repository is a collaborative effort which includes the Navy Biological Laboratory and the University of California's School of Public Health.

The repository will receive from Navy laboratories and treatment facilities cultures and sera taken from patients with meningitis. Specimens received will be identified and typed. Listings of the specimens and other experimental data will then be distributed to Navy medical activities and other interested investigators. Typing sera and lyophilized cultures will be provided on special request.

The repository will also produce and type anti-sera for BuMed laboratories, preventive medicine units, and contractors. High-quality sera produced to date have been used to supplement supplies of other military labs and contractors.

Research at Berkely will continue toward developing the best methods for shipping specimens to insure maximum recovery of viable cells. Studies are also slated to find the best means of preserving *Neisseriae* for storage and lyophilization.

To develop broad-spectrum classifications of Neisseria isolates from scattered geographical areas, the repository will establish exchange procedures with the World Health Organization repository in Marseilles, France, and the National Communicable Disease Center in Atlanta, Georgia.

One of the biggest blocks to research in meningitis in the past has been the lack of suitable isolates from healthy carriers and patients with the disease. Information acquired at the Navy repository is expected to aid researchers in future studies of meningitis epidemiology, pathogenicity, immunity, serology, and genetics.

1969 Government Microcircuit Applications Conference (GOMAC) to be held in Washington, D.C., 16-18 September. Additional information may be obtained from Mr. Ancel E. Cook, Office of Naval Research (Code 400B4), Washington, D.C. 20360. Phone: Area Code 202, 696-7782. Co-sponsored by the Department of Defense (Army, Navy, Air Force), National Aeronautics and Space Administration, Environmental Science Services Administration (ESSA), National Bureau of Standards and the Post Office Department.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important Naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Washington, D.C., 20360. The magazine is listed for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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IN THIS ISSUE

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Arlis IV (Arctic Research Laboratory Ice Station) was subdivided by a lead only 300 feet from camp. Predictions of the location of such a cleavage line or the time of the opening of the lead cannot be made with assurance. *See page 12.*

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OFFICE OF NAVAL RESEARCH
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