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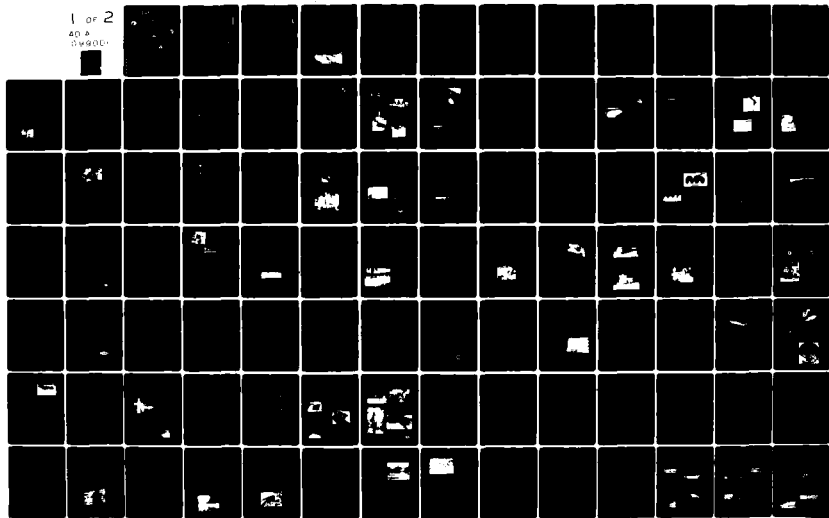
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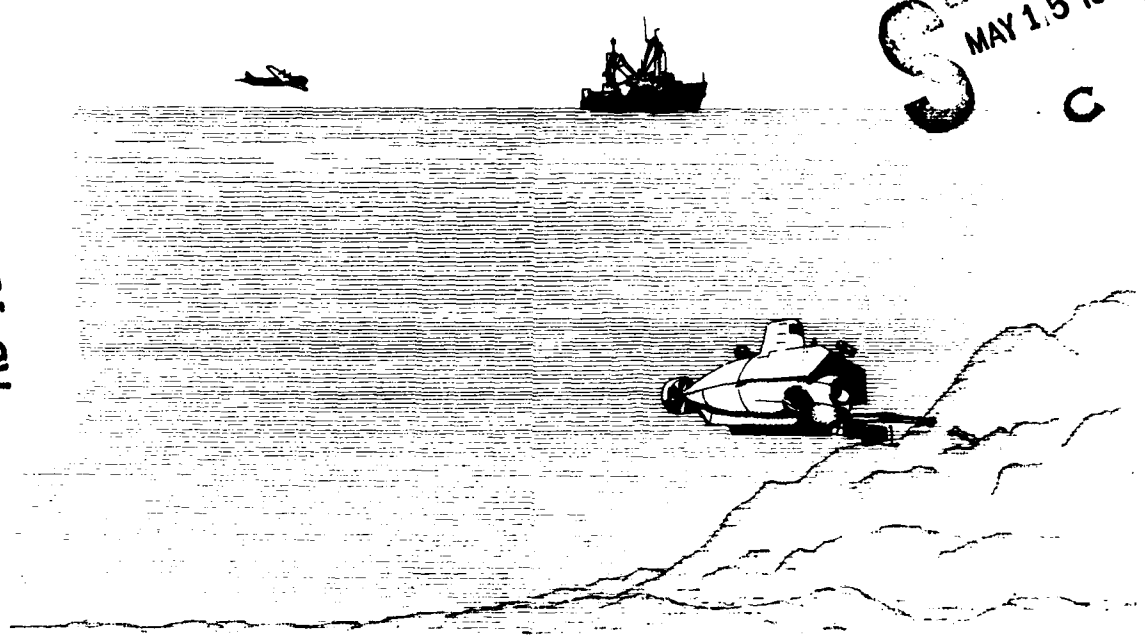


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(6) **The Ocean Science Program  
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20. can access. In addition to a Glossary, the Appendices include Directories of Participant Organizations within the Navy and Academia, and a listing (with photographs) of the principal U. S. oceanographic ships used for the Program.

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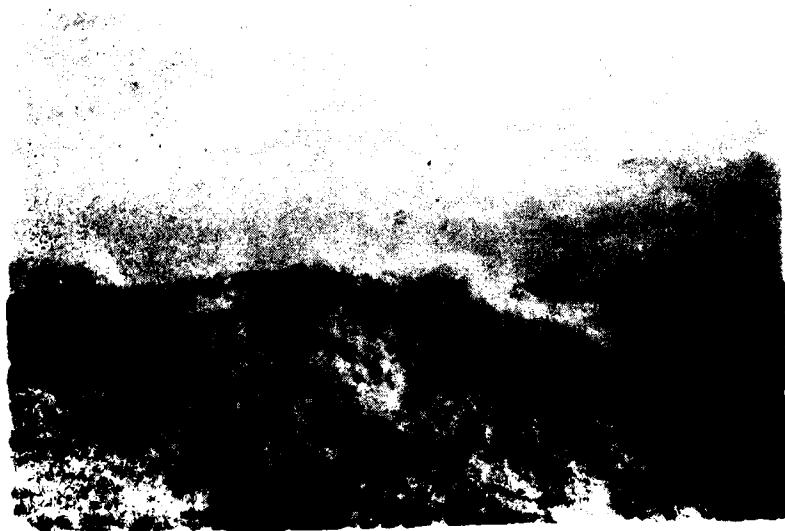
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FOREWORD

The Navy Ocean Science Program comprises research and development in all the scientific disciplines that oceanography embraces: physics, geology, biology, chemistry, hydrography, and meteorology as it involves atmospheric interaction with the sea. All of the effort is directed to one end - to build a base of knowledge and technology related to ocean phenomena and effects that will satisfy the future needs of the Fleet. Some of these future needs can be predicted, others will be generated by events and pressures that are not predictable and, in some cases, may be beyond our control. The task of the Ocean Science Program is to try to be ready for whatever may be asked of it.

Success of the Navy Ocean Science Program depends on many things: good management, adequate funds, new ideas, hard work, and even luck, but most of all it depends on the scientists whose accomplishments fill the content of these pages. This report is dedicated, with appreciation, to them.

PHOTO



*THE RESTLESS SEA*

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## CHAPTER 1

### OCEAN SCIENCE SUPPORT TO NAVAL WARFARE

#### OBJECTIVE OF THE NAVY OCEAN SCIENCE PROGRAM

The objective of the Navy Ocean Science Program is to provide information about the ocean and its boundaries for the design, deployment and operation of Naval Warfare Systems.

Naval forces are hardware and technology oriented, requiring large capital investments and 5 to 15 years' leadtime from new concept approval to Fleet introduction. Major weapons and support systems have an operational lifespan of 10 to 20 years, although improvements are commonly backfitted. An important concern in all new developments is to exploit the opportunities and minimize the constraints imposed by the operating medium - the ocean - on any particular system or platform. The Ocean Science Program provides the technology base from which the Navy engineers, strategists and tacticians can draw to insure that the Navy carries out its mission responsibilities for the national military strategy in the most effective manner.

#### NAVY MISSION AREAS

The essence of the Navy responsibility to national military strategy is defined by the mission areas:

- Strategic Deterrence
- Sea Control
- Power Projection
- Support

Sea control is the Navy's fundamental function. The Strategic Deterrence, Power Projection, and Support missions are shared with the other services.

#### STRATEGIC DETERRENCE

As a principle of military strategy, deterrence is only effective as long as a potential aggressor sees the risk to himself

as unacceptable. Ballistic missile submarines, capable of remaining submerged at sea for extended periods, are in the forefront of the defense arsenal that restrains would-be aggressors. The Navy is responsible for maintaining the capability and security of the SSBN force.

#### SEA CONTROL

The Navy's principal programs for mastery of the sea control mission are in the areas of ocean surveillance and anti-submarine warfare (ASW). Both employ systems and techniques acutely sensitive to environmental effects. These areas place the most difficult and extensive requirements on ocean science and technology.

Sea denial, or preventing the enemy use of the sea for his own military or economic purposes, is another facet of sea control. Sea denial is accomplished most often by means of barriers or blockades set up to deny enemy naval forces access to the open sea, taking advantage of geographic "choke points" wherever possible. Offensive mining, a principal tactic employed in barrier/blockade operations, is another warfare area heavily dependent on ocean science and technology. By extension, mine countermeasures -- responding to enemy attempts to interdict shipping and naval movements by mining harbor entrances and strategic choke points -- is also a sea control function requiring environmental support.

#### POWER PROJECTION

Power projection by Naval forces covers a broad spectrum of offensive operations: strategic nuclear missile firing; tactical employment of carrier based aircraft against land targets; bombardment of enemy targets ashore; amphibious assaults carried out by Marines or by Army units



transported in Navy ships; and in peacetime, showing the flag as a psychological ploy to alleviate tension, evince support, or demonstrate capability.

#### SUPPORT

Support comprises the command, intelligence and logistic functions necessary to effect the deterrent, sea control and power projection objectives successfully, and maintain the Fleet in a state of operational readiness.

#### REQUIREMENT FOR THE NAVY OCEAN SCIENCE PROGRAM

Navy leaders have the responsibility to look ahead, forecast future requirements and set in motion programs that will shape the Fleet of the future and ensure its readiness. An integral element of such planning is a broad, strong base of ocean science. Developing that base is the purpose of the Navy research and development program in ocean science. The program is conducted at several levels leading to operational capability at Navy laboratories and contractor facilities to meet specific requirements of emergent systems and provide a fund of basic technical information and support.

Provision of required environmental information, or environmental support, has many ramifications. Questions of systems designers about constraints the ocean medium imposes on new concept weapons systems must be answered. Requirements of Fleet operations for system performance predictions and operational doctrines must be anticipated and satisfied. In all, Navy ocean science seeks understanding of the processes that govern ocean and coastal dynamics and by which oceanic properties are distributed in time and space. Boundary interactions and the associated process are an important part. Navy responsibilities extend to operations above, on, and in the sea, on the sea floor, in the coastal zone, and in the Arctic. If any of these operations has a better chance of success by employing particular data or knowledge about

the ocean environment, the Ocean Science Program has an obligation to ensure that the needed data or knowledge can be obtained with adequate quality.

Clearly, every need cannot be anticipated, or even if anticipated, met. Priorities are established within the Defense Department and the Navy that impact on the research program and provide direction. Consequently, it is important that close ties be maintained with the oceanographic programs sponsored by other Federal departments so as to derive maximum benefit from these efforts. The ultimate responsibility is to ensure that information generated by the Ocean Science Program is properly interfaced with more advanced levels of development so that research results are exploited expeditiously and the program is continually aware of potential problem areas for which new forms of environmental support are needed.

#### REPORT STRUCTURE

There are four sections to this report. The first discusses requirements for a Navy Ocean Science Program and the organizational makeup of the program. The second describes the current Program in the context of the Navy's mission responsibilities to national military strategy. Major international, multidisciplinary research programs in which the Ocean Science Program participates are summarized in Section III, together with a discussion of some of the unique facilities and instrumentation developed. The last section comprises Appendices listing major program participants and principal research platforms.

Owing to the sensitive nature of activities relating to the Strategic Deterrence mission, a separate account of Ocean Science Program support in this area has been omitted from Section II. It will be clear to the reader, however, that many of the research and development objectives of the Program address more than one of the mission categories. This is especially true of ocean modelling and instrumentation system developments, which have important application to all four mission areas.

## ORGANIZATION OF THE OCEAN SCIENCE PROGRAM

The Navy Ocean Science Program spans three levels of research and development and is grouped in ten broad task areas whose titles generally indicate the type of work being done and its purpose.

- Research
  - very broad technology base for concepts
  - Oceanography (deep sea and ocean floor)
  - Terrestrial Sciences (coastal and polar)
- Exploratory Development
  - directed technology base for optional system designs and proposed operating doctrine:
  - Ocean Environmental Support
  - Ocean Acoustics
  - Environmental Remote Sensing
  - Polar Environmental Support
  - Environmental Protection
- Advanced Development
  - specific technology system developments to meet Fleet operational requirements:
  - Oceanographic Instrumentation Development
  - Long Range Acoustic Propagation - Surveillance
  - Long Range Acoustic Propagation - Tactics

The Chief of Naval Research is the principal sponsor for the Ocean Science Program. Other sponsors include the Director of Navy Laboratories and the Naval Air, Sea, Electronics, and Facilities Engineering Commands, all reporting to the Chief of Naval Material through the Deputy Chief of Acquisition. The Chief of Naval Operations, OP-095 (Director, Antisubmarine Warfare and Ocean Surveillance Programs), sponsors the advanced development tasks.

There are two other programs that, with the Ocean Science Program, comprise the total Navy Oceanographic Program (NOP). One is the Ocean Engineering Program, which is primarily developmental and is sponsored

and managed (for the most part) by the Naval Material Command. The other is the Operations Program supporting current Fleet operations and sponsored by the Chief of Naval Operations, OP-095. The Operations Program is managed and conducted by the Naval Oceanography Command, which encompasses the Naval Oceanographic Office (NAVOCEANO) and the former Naval Weather Service Command. Although the Engineering and Operations Programs are addressed only peripherally in this report, readers should be aware of the extent and composition of the Navy's total oceanographic effort and know that the parts are strongly linked.

## MANAGEMENT AND COORDINATION

Management of the Navy research and development programs in oceanography is coordinated at the Secretariat level by the Assistant Secretary of the Navy for Research, Engineering, and Systems. For budgetary purposes, the Navy's total Research, Development, Test and Evaluation (RDT&E) Program, which includes oceanography, is Program 6, and is structured in six levels (6.1 through 6.6) of ascending operational readiness.

Level 6.1, Research in Ocean Sciences, provides the fundamental scientific knowledge and understanding required for conceiving future weapon and defense systems for optimum design and efficient at-sea operation. This essential scientific and technological base is accumulated through studies and experiments conducted by academic and non-profit institutions, Navy in-house laboratories and industry. The scope encompasses physical oceanography, air-sea interaction, biological and chemical oceanography, marine geology and geophysics, underwater acoustics, coastal geography, polar research, biomedical research and instrument development.

The major thrust at the Research level, and the great majority of funds, are devoted to expanding and refining knowledge and theories of the environment and processes that bear on known or forecasted naval

requirements. One small fraction of the effort is speculative: to explore and exploit any possibility, however remote, of a "breakthrough" with significant payoff. The 6.1 Program is directed and managed by the Chief of Naval Research through ONR, NRL and NORDA. Program management in ONR resides in the Ocean Science and Technology and Arctic and Terrestrial Sciences Divisions, which are staffed with experts in the principal oceanographic and earth sciences sub-disciplines. The research is accomplished primarily by non-profit and academic institutions with strong oceanography departments on a contract basis, and the efforts are seldom identified with particular weapon systems or warfare areas. At NRL and NORDA most of the research programs are carried out by the staff of the respective laboratories and are remotely related to systems.

Level 6.2, Exploratory Development (ED), draws upon the 6.1 technology base for more operationally oriented objectives in support of Navy systems: torpedoes, sonars, mines, etc., or warfare areas: amphibious antisubmarine, antisurface, et al.

The goal of 6.2 is to provide a technological base from which options can be selected for improving present undersea warfare systems and developing new ones. Engineering aspects are directed toward enabling the Navy to operate within the oceans at any depth, location, and time. More selective in approach, 6.2 work includes research and development on materials; search, rescue and recovery systems; environmental prediction, and weapon system support. The 6.2 RDT&E Program in toto is the responsibility of the Assistant Deputy Chief of Naval Material (ADCNM) for Technology and Laboratories. Work is performed principally by Navy in-house laboratories and industry. The Director of Navy Laboratories (DNL) manages and administers "independent" research and exploratory development funds which are dispensed to investigate intriguing new concepts or provide answers that can fulfill a limited need. The bulk of 6.2 funding is managed by the Director

of Navy Technology. Ocean science or engineering that supports specific weapons and defense systems, or classes thereof, is controlled by Program Managers in the appropriate Systems Commands, whose functional responsibilities are defined by the names, Air, Sea, Electronics Systems and Facilities Engineering Commands.

Biomedical research and development is managed by the Bureau of Medicine; deep ocean search, rescue and recovery is sponsored by the Deputy Chief of Naval Operations for Submarine Warfare (Deep Submergence Systems) and is managed by the Naval Sea Systems Command.

Level 6.3 Advanced Development, is the highest level at which ocean science research and development retains a unique identity. At this stage, options have been limited to a few, usually single-system concepts for which additional information is needed for design, criteria and preliminary operating doctrine. Current oceanographic R&D in this category supports surveillance, tactical employment of sensors, and acoustic measurement systems, and is managed by the Chief of Naval Research for the Director, ASW Systems and Ocean Surveillance Programs and the Naval Electronic Systems Command (NAVELEX). NAVELEX directly funds and manages underwater acoustic research pertinent to the engineering and data processing aspects of surveillance systems.

Major system developments requiring multidisciplinary technology bases are common throughout the Navy acquisition process. In the early R&D stages one or another of the Program Managers generally is designated to take the lead. In an equally common situation, where essentially the same technology base can satisfy requirements of several system developments, the concept of "Block Funding" is being practiced. In such cases, a single 6.2 Program Manager (who may be in a Systems Command Headquarters or at one of the Navy Laboratories) administers the effort for a variety of users.

The Naval Oceanography Division (CNO OP-952) is the focal point for general information about the Navy's total program in oceanography. The Division Director, as Oceanographer of the Navy, interfaces with the National Ocean and Atmospheric Administration (NOAA), NASA and other Federal Agencies sponsoring mission-oriented oceanographic programs; represents the Defense Department on interagency oceanographic matters and the United States at certain international functions. Under Op-952 direction the Commander, Naval Oceanography Command, commands the Naval Oceanographic Office (NAVOCEANO), the Fleet Numerical Oceanography (formerly Weather) Central (FNOC), and the global organization of Fleet components responsible for operational weather and ocean forecasting.

The Navy in-house laboratories are organized for specialization in various classes of weapons and defense systems -- surveillance, anti-air, surface, undersea, coastal -- with one major center primarily devoted to ship design and another to civil engineering problems of structures and installations. Since many system developments require similar oceanographic inputs from the biological, acoustics or geophysics bases, and so on, it is not uncommon to find two or more Systems Commands sponsoring an integrated R&D program at the laboratory where that particular area of needed expertise resides.

The Director of Research, Development, Test and Evaluation (RDT&E) of the Chief of Naval Operations provides policy and development planning guidance for the naval research community, indicating where new thrusts are needed, the geographic areas of priority and force structure rationale. When system developments reach a stage at which they are ready for test and evaluation under simulated war-time, "real-life" conditions, the Director of RDT&E validates the readiness of the system for operational testing. The Director manages and administers the funding for such evaluations and plays a prominent role in deciding the ultimate fate of a system -- go ahead, more R&D, or terminate.

## PARTICIPANTS

Of seventeen Navy laboratories, centers and facilities that perform research and development in science, technology and engineering, twelve are involved to some extent with the ocean sciences. Major programs are conducted at the Naval Ocean Systems Center (NOSC), San Diego, California; Naval Underwater Systems Center (NUSC), Newport, Rhode Island; Naval Research Laboratory (NRL), Washington, DC; and the Naval Ocean Research and Development Activity (NORDA), near Bay St. Louis, Mississippi. Appendix B lists the Navy activities engaged in ocean science research and development, together with the organizational mission and special area(s) of expertise, where applicable. Most of this effort is at the Exploratory Development or higher levels of direct system or Fleet support.

The Ocean Sciences Research Program of ONR is contracted to seventy private and academic institutions of which the Universities of California, Hawaii, Miami, Rhode Island and Washington; Columbia, Louisiana State, Oregon State and Texas A&M Universities; the Massachusetts Institute of Technology; and the Woods Hole Oceanographic Institution are the principal performers. A more inclusive listing can be found in Appendix C.

Continual interaction exists among the universities, private institutions, and the Navy laboratories, as well as between many of these and the Fleet. This is especially true of the working scientists, engineers and the growing cadre of naval officers who hold advanced degrees in oceanography and related fields.

Many of the Navy laboratories have established Support Offices or Teams to interact with Fleet commands, respond to special problems with "quick fixes" insofar as possible, and maintain a constant awareness of Fleet requirements in the operational milieu. Additionally the Navy Science Assistance Program (NSAP) provides senior technical personnel from the laboratories

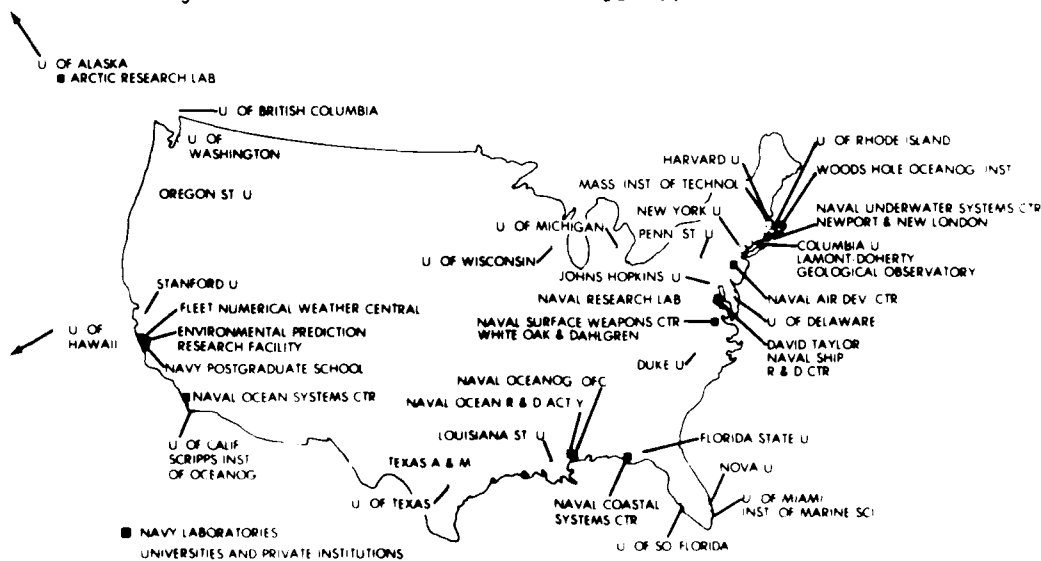
system to major command headquarters in order to develop an appreciation of Fleet needs and refer these to the appropriate laboratory for resolution. While both the Fleet Support Groups and NSAP cover the entire spectrum of Navy science and technology, oceanographically related problems are not uncommon. One on-going project is a multi-lab analysis of the tactical significance of oceanic fronts and mesoscale eddies, responding to a request by Commander-in-Chief, Atlantic Fleet. The Naval Ocean Systems Center, Naval Underwater Systems Center, ONR contractors, and the Naval Oceanographic Office are cooperating in this effort, under the overall direction of Op-952.

### INTERNATIONAL COOPERATION

The Ocean Science Program sponsors and engages in various types of international activity: experimental projects, data exchange agreements, scientist exchange programs, workshops and symposia. The Navy has been a party to data exchange agreements with over forty countries in Europe, Asia and South America individually or through such channels as the National Oceanographic Data Center and International Hydrographic Bureau (which currently includes a retired

Navy oceanographic officer among its Directors). The Office of Naval Research branch offices in London and Tokyo assist in the international exchange of information and explore new areas for cooperative research; the staffs include special competence in ocean science.

Cooperation is also extended through liaison with the Anti-Submarine Warfare Research Center in La Spezia, Italy, which is operated by the Supreme Allied Commander, Atlantic, as a support arm for the North Atlantic Treaty Organization, NATO. Research at the SACLANT Center pertains primarily to enhancing the overall ASW posture of NATO in the seas adjacent to the member nations. The Center has a small permanent staff; however, most of the personnel rotates for 2 to 3 year assignments from the research organizations of the countries. Currently the Deputy Director is a civilian scientist who has long been an ONR contractor. Every two years (approximately), the SACLANT Center coordinates a NATO Military Oceanographic field program (MILOC) which is conducted by member representatives to investigate a particular naval oceanographic problem. Planning is now underway for MILOC 80.



Locations of major Navy laboratories, universities and private institutions supporting Navy ocean research and development

## CHAPTER 2

### SEA CONTROL

Sea Control is the sole responsibility of the Navy and its fundamental mission. Sea Control does not imply complete control of all the seas all the time, but rather, the capability to find and neutralize the enemy wherever and whenever necessary. Enemy submarines, fast, quiet and deep, are the principal threat to Sea Control. The Navy spends a substantial share of its R&D dollars to improve its antisubmarine warfare (ASW) capabilities, which are highly dependent on the effectiveness of the acoustic systems used for submarine surveillance and localization, and for weapon guidance.

Sound travels fast and far in the ocean; under some conditions a detectable signal can propagate for thousands of miles. The behavior of sound in the sea, however, is governed by the properties of the water and their distributions, and by the characteristics of the ocean boundaries - the sea surface and the bottom. Thus, a significant part of the Ocean Science Program is devoted to understanding these environmentally caused effects and the dynamic processes that determine their occurrence.

#### SURVEILLANCE AND TACTICAL ASW SYSTEMS

The primary objective of ocean science undersea surveillance support is to under-

stand the acoustic properties of the ocean well enough to be able to specify the acoustic environment in which surveillance systems must operate. The success of long range passive systems is dictated by opportunities and constraints imposed by the environment, and such systems require reliable assessment of the resulting environmental acoustic factors. Short-range passive systems depend upon direct path propagation but are also affected by bottom reflection and transmission. Systems operating in shallow water are sensitive to bottom interactions and require extensive measurements of bottom loss, sound speeds and ocean bottom topography.

#### MINE WARFARE AND MINE COUNTERMEASURES SYSTEMS

Mines are designed to meet three principal operational objectives: blockage of enemy ports and coastal sea lanes; defense of our ports, coastal sea lanes and near-shore operating areas; and control of open ocean and strategic passages. Mining in very shallow water requires knowledge of the environment which is obtained by detailed surveys not requiring R&D. Mines operating in the open ocean and strategic water passages are sensitive to the environment and receive environmental science support. The requirement for

*Destroyer - bird dog of the seas*

OFFICIAL U. S. NAVY PHOTOGRAPH



*Aircraft Carrier - forward base afloat*

OFFICIAL U. S. NAVY PHOTOGRAPH



PROTECTORS OF THE SEA LANES AND PARTNERS IN ANTISUBMARINE WARFARE

widespread pressure fluctuation measurements in deep water is expected to induce cooperative efforts with other governments and agencies to share the survey burden. Engineering development of a pressure mine mechanism for deep ocean exposure seems feasible and will permit the use of long endurance, remotely implanted instruments.

Mine countermeasures is the other face of the mine warfare coin. Mine-hunting sonars are highly directional sensors whose design and operation use a spectrum of environmental input: the density and nature of false targets, e.g., fish schools, wrecks and echoes due to various types of bottom roughness any of which may obscure the wanted target. The strong salinity and temperature gradients common in shallow water may seriously alter the propagation paths of the mine-hunting sonar thus altering its coverage, and suspended particles that cause high turbidity in coastal areas scatter sound and cause reverberation that can mask a true target return. Sea and swell changes affect mine pressure mechanisms. Mine burial and under ice location present other countermeasure difficulties.

#### SOUND PROPAGATION IN OCEAN WATERS

For the Navy to optimize the design and operation of sonar systems, the effects of the ocean environment and its boundaries on sound transmission and noise must be understood well enough to predict the behavior of a particular sonar at a specific location for a given time. Acoustic propagation research is concerned with the identification, efficiency, and distortion of the many paths by which sound may travel from a source to a receiver in the ocean. Acoustic energy does not travel along straight paths but is refracted by variations in sound speed of the water and the underlying sediments and reflected by the ocean surface and sea floor to produce a complex pattern of sound intensity variation both in space and time.

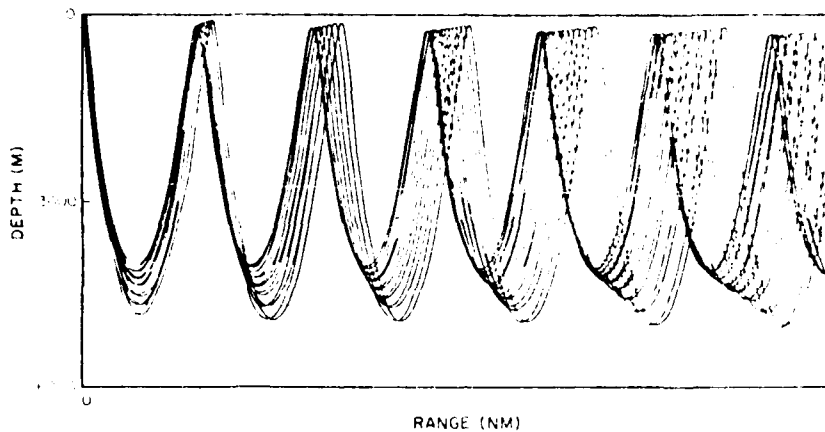
Reliable prediction of ocean acoustic processes will not be completely in hand for another decade or more because of the serious gaps in environmental data needed as model inputs. Significant advances have

been made in computer-assisted modeling. Normal mode theory, ray theory, parabolic equation and other approximations to the familiar wave equation have been developed to provide rapid sound propagation modeling. FACT (Fast Asymptotic Coherent Transmission), a ray theory model with caustic corrections, has been certified as a standard model for general use. Computed ray paths of sound and sound propagation losses are shown for illustration.

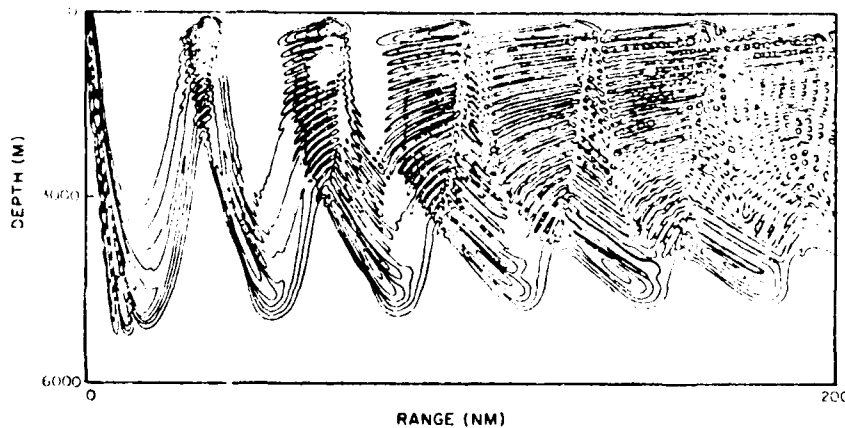
#### ABSORPTION

Early experiments thirty years ago established that the absorption of sound in sea water was higher than in pure water. Further experiments attributed this increased absorption to the interaction of the sound wave and dissolved salts in water. Continuing investigations have confirmed that three distinct attenuation mechanisms exist for the frequencies of interest to Navy underwater systems. From 10 to 200 kHz absorption is due mainly to a magnesium sulfate ( $MgSO_4$ ) chemical relaxation process. Temperature and pressure dependency exists but the exact relationship has not been determined. Below 10 kHz it has recently been confirmed by laboratory measurements that absorption is due to a boron chemical relaxation process. This process appears to be a buffering reaction and hence is sensitive to pH. Measured pH at the sound channel axis can explain variations of a factor of two or more in the boron absorption throughout the world's oceans. At low frequencies, scattering due to ocean inhomogeneities and sound channel diffraction may introduce additional attenuation. This is a very difficult region to isolate attenuation due solely to absorption but the bulk of data does indicate a frequency independent component.

A new equation for sound absorption in sea water has been developed, based on earlier acoustic absorption work on boric acid and magnesium sulfate. A reanalysis of the pressure dependence of absorption in  $MgSO_4$  solutions and pure water provides a closer fit to the observed pressure dependence of absorption in the ocean than earlier predicted. On the basis of this analysis, there appears to be some evidence



RAYS TRACED FROM A DIGITAL COMPUTATION OF RAY GEOMETRY FOR PROPAGATION IN THE OUTER PART OF THE SOFAR CHANNEL. NOTE THE CLOSE CROWDING OF RAYS AT REGULAR INTERVALS AT THE EDGE OF THE BUNDLE OF RAYS. THESE ARE NOW KNOWN AS CONVERGENCE ZONES. MANY RAYS THAT REFLECT FROM THE SURFACE AND THE BOTTOM OF THE OCEAN ARE NOT SHOWN.



THE SAME FIELD AS ILLUSTRATED ABOVE IS COMPUTED HERE, USING A DIFFERENT APPROXIMATION THEORY--KNOWN AS THE PARABOLIC EQUATION--AS THE BASIS FOR DRAWING CONTOURS OF EQUAL SOUND INTENSITY. THE PARABOLIC EQUATION, UNLIKE RAY THEORY, ACCOUNTS FOR THE DIFFRACTION OF SOUND THAT IS OF LITTLE SIGNIFICANCE AT HIGH FREQUENCIES, BUT RESULTS IN A SMEARING OF THE SOUND FIELD AT LOW FREQUENCIES.





for the existence of another chemical relaxation process in the ocean near 5 KHz.

Attenuation of sound in ocean sediments has been a difficult determination to make. Vertical reflection methods have been used for at-sea attenuation measurements. Recent methods employing deep sources and receivers measure the attenuation coefficient in sediments using refracted wave paths that travel nearly horizontally in the sediment. Such methods produce values closer to the intrinsic attenuation values than those that can be obtained using the vertical-reflection technique. Special deep bottom hydrophone systems have been developed for the studies. These microprocessor-controlled recording instruments use an automatic event-detector scheme to trigger the data recording.

#### Underwater Acoustics

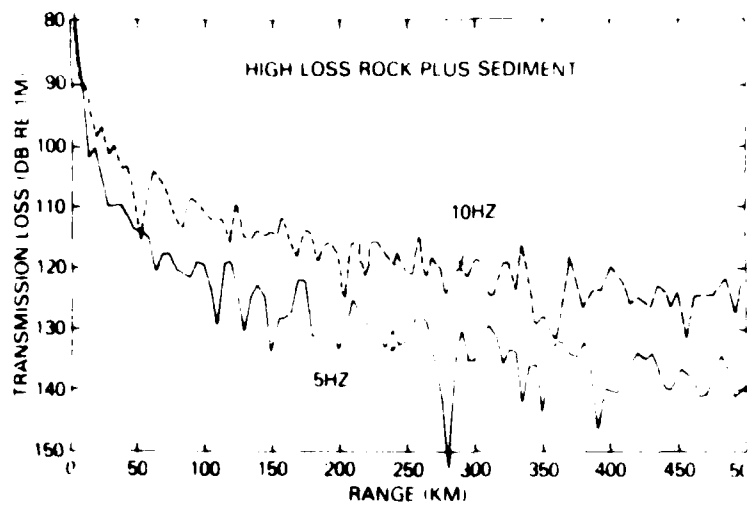
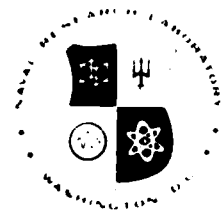
In order to develop an understanding of underwater acoustic propagation for tactical and strategic purposes, the interaction of acoustic energy with the ocean floor has been studied by the Navy for many years. Until recently simplicity has dictated that the practical predictive model of ocean floor interaction has been an infinite horizontal plane reflector forming the interface between the ocean water and flat lying sediment, both flats. Sound approaching the ocean floor downward through the water is partly reflected back into the water and partly transmitted into the sediment where it is eventually absorbed. The fraction of sound energy reflected back into the water was regarded as propagating outward from the source by successive reflections from the bottom and the surface of the ocean, each bottom reflection attenuating the propagating energy by the fraction lost into the bottom with each reflection, (very little energy is lost on surface reflection.)

This oversimplified concept neglects reflection and refraction of sound in the sediment and also neglects the effect of hard rock underlying the sediment. The principal of these latter effects for Navy purposes are the refraction or reflection of sound energy that entered the sediment back into the water where it may be received by

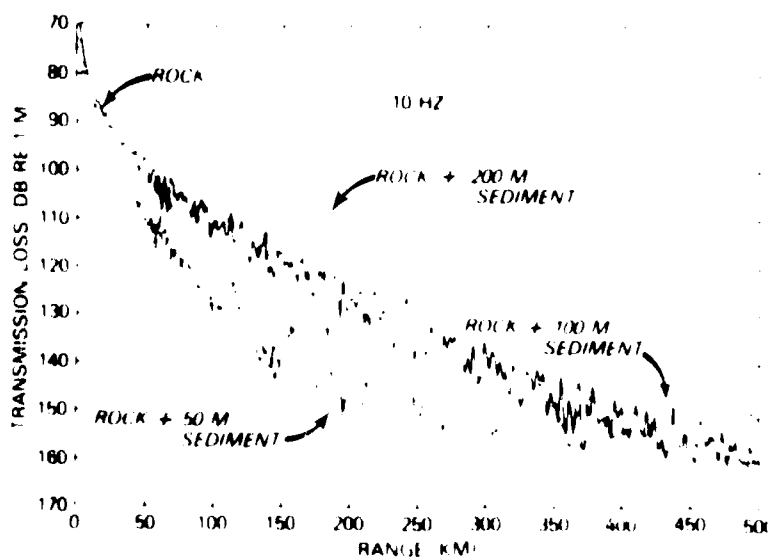
Navy systems. The interaction of sound energy of these frequencies with the ocean floor has been a difficult determination to make. Recent methods employing deep sources and receivers measure the attenuation coefficient in sediments using refracted wave paths that travel nearly horizontally in the sediment. Such methods produce values closer to the intrinsic attenuation values than those that can be obtained using the vertical-reflection technique. Special deep bottom hydrophone systems have been developed for the studies. These microprocessor-controlled recording instruments use an automatic event-detector scheme to trigger the data recording.

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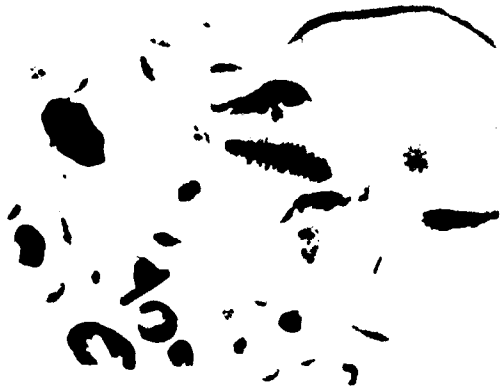
The ocean floor is a complex structure formed of many layers of sediment, sand, silt, clay, and shells. The sound energy that enters the ocean floor is partly reflected back into the water and partly transmitted into the sediment where it is eventually absorbed. The fraction of sound energy reflected back into the water was regarded as propagating outward from the source by successive reflections from the bottom and the surface of the ocean, each bottom reflection attenuating the propagating energy by the fraction lost into the bottom with each reflection, (very little energy is lost on surface reflection.)



TRANSMISSION LOSSES FOR A COMBINED ROCK-SEDIMENT BOTTOM ARE COMPARED AT FREQUENCIES OF 5 HZ AND 10 HZ TO A RANGE OF 500 KM. THESE FREQUENCIES FALL IN THE TRANSITIONAL REGION OF AN ENHANCEMENT EFFECT THAT IS ZERO AT LOW FREQUENCIES, RISES RAPIDLY AT 7.5 HZ AND LEVELS OFF AT HIGH FREQUENCIES. AT FREQUENCIES ABOVE 7.5 HZ, THE WAVELENGTH IS LESS THAN THE SEDIMENT LAYER THICKNESS, AND IT IS PRESUMED THAT PROPAGATION OCCURS VIA UPWARD REFRACTING RAYS WITHIN THE SEDIMENT LAYER. THESE RAYS SUFFER LITTLE ATTENUATION FROM THE SEDIMENT.

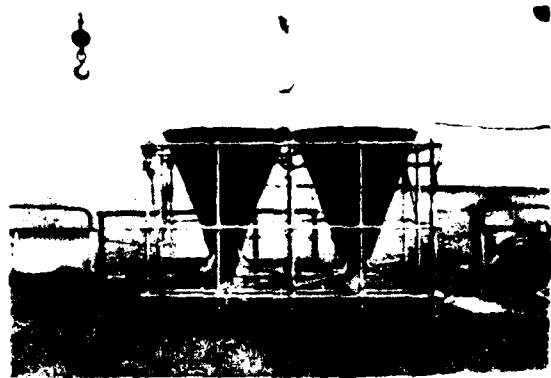


WHEN THE ROCK IS OF THE HIGH ATTENUATION TYPE AS USED HERE, THE PRESENCE AND THICKNESS OF SEDIMENTS IS CRITICAL. TRANSMISSION LOSS FOR A FREE ROCK CASE IS COMPARED WITH CASES FOR A ROCK WITH SEDIMENT LAYER OF 50 METERS, 100 METERS AND 200 METERS. TRANSMISSION LOSS IS FIRST AN INCREASING, THEN DECREASING FUNCTION OF LAYER THICKNESS.



COLLECTION OF TINY ORGANISMS THAT INHABIT BOTTOM SEDIMENTS SHOWS THE WIDE DIVERSITY OF THEIR DEVELOPMENT.

WHOI



WHOI

LARGE-PARTICLE SEDIMENT TRAPS BEING PREPARED FOR LAUNCHING FOR 3 MONTHS MOOR. PUMPS CIRCULATE WATER VERY SLOWLY IN EXPERIMENTAL CHAMBERS TO MEASURE RATE OF DISSOLUTION OF BIOGENIC MINERALS AT DIFFERENT DEPTHS.



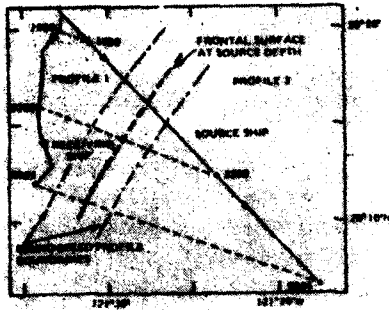
WHOI

BOX CORER PROVIDES A LARGE SAMPLE OF LITTLE DISTURBED OCEAN SEDIMENTS.



WHOI

WHIMP (WOODS HOLE INTERSTITIAL MUD PROBE) EXAMINES BOTH THE SEDIMENT MATERIAL AND INTERSTITIAL WATERS AND PHOTOGRAPHS THE SAMPLING OPERATION WITH CAMERA MOUNTED IN TRIPOD.



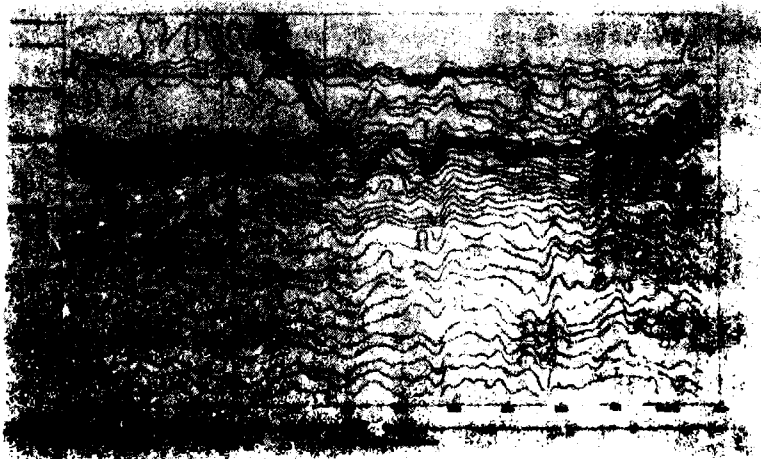
NOSC

AN INTERESTING SET OF PROPAGATION LOSS MEASUREMENTS WERE MADE IN THE PRESENCE OF A MARKED TEMPERATURE FRONTAL SURFACE DURING SUDS (SURFACE DUCT SONAR) MEASUREMENTS. THE HEAVY DASHED LINE SHOWS THE LOCATION OF THE FRONTAL SURFACE AT THE SOURCE DEPTH OF 38 METERS IN THIS PLAN VIEW OF THE EXPERIMENT. THE LIGHT DASHED LINES SHOW PROPAGATION PATHS AT THE INDICATED TIMES DURING THE RUN.



NOSC

THERMISTOR CHAIN AND HOIST (TOTAL WEIGHT 20 TONS) USED IN SUDS EXPERIMENT TO OBTAIN TEMPERATURE MEASUREMENTS FOR SOUND VELOCITY PROFILES.



NOSC

TEMPERATURE CROSS SECTION DELINEATING THE SUDS FRONTAL SURFACE. THE HEAVY SOLID LINES INDICATE THE THREE DISTINCT WATER MASSES.

The determination of the sound velocity structure of deep ocean sediments for accurate modeling of low frequency, long-range transmission of sound through the sediment is essential for predictive models. Since mapping the entire ocean floor is infeasible, detailed studies must be made in key locations. These can be used to develop predictive models applicable to other areas with the use of limited local information obtained by in situ measurements, cores, and historical data. Geoacoustic models are important to the study of sound interactions with the ocean floor. At higher sound frequencies, sound will penetrate usefully no more than several tens of meters. At lower frequencies, information is needed on the whole sediment column and on properties of the underlying rock.

As part of a program to measure in situ properties of sediments, transducers capable of measuring shear-wave speed and attenuation in laboratory measurements have been designed and fabricated. Transducers consisting of an array of ceramic benders have been found to be the most useful in measuring shear-waves in high-porosity laboratory sediments. To use the bender element to generate shear waves, the propagation medium is placed in contact with one of the elements. As the element bends back and forth in response to an electrical driving signal, the transverse motion of the end of the element generates shear waves in the portion of the medium in contact with the moving end. Shear and compressional wave attenuation data can be taken at the same time as the shear wave speeds are measured by recording the amplitude of the received pulse.

#### AMBIENT NOISE

Ambient noise is defined as noise other than that associated with the sensor platform, that interferes with detection of a target signal. Noise from breaking surface waves, sounds of a wide variety of marine animals, earthquakes, and ships at sea have been regarded as the principal sounds comprising ambient noise. There are, however, many others and the sounds of off-shore oil exploration (seismic exploration and drilling) have emerged as

very important sources of ocean noise in recent years.

Naval systems performance is degraded by ambient noise and it is important to have good estimates of how loud the noise is and its directional characteristics so that in-water systems design and signal processing may minimize its effect.

Sonar array design requires a model capable of predicting the spatial and temporal coherence, spectral characteristics, depth dependence, and directionality of the noise field. A Research Ambient Noise Directionality Model (RANDM) and Fast Ambient Noise Model (FANM) have been developed for use in the design of ambient noise experiments and system analysis studies.

A variety of measurements are required in order to measure these directional, depth, location, and temporal dependencies of ambient noise so as to provide basic data for developing and testing the ambient noise models. The special features of the principal instruments now in use are reviewed below.

For many years understanding of ambient noise advanced very slowly because the quite formidable instrumentation and arrangements for the monitoring of noise-making ships, storm centers and the like were beyond reach. The decade of the '70's has seen the gradual development of the necessary instrumentation. During this development instruments have been used to acquire data on omnidirectional and directional noise properties. From these data acquisition operations and their analysis we now know much more of their depth and location than prior to 1970. We know that shipping has a marked effect on noise over a broad spectrum of low frequencies. In places where shipping is especially heavy, as in the Mediterranean Sea and along the coast of western Europe shipping noise dominates the low frequency noise. Sonar systems deployed without regard for these facts will probably perform very poorly.

Our present knowledge and understanding of ambient noise is a good start, but it remains most incomplete and experiments continue on its depth and directional dependence, the effect of ocean floor relief and so on.

Developments in underwater moored acoustic sensor systems such as Acoustic Data Capsule (ACODAC), Moored Acoustic Buoy (MABS) and Ambient Noise Buoy (ANB) as well as the vertical array on FLIP are increasing our knowledge of ambient noise depth dependence and vertical directionality in the deep open ocean.

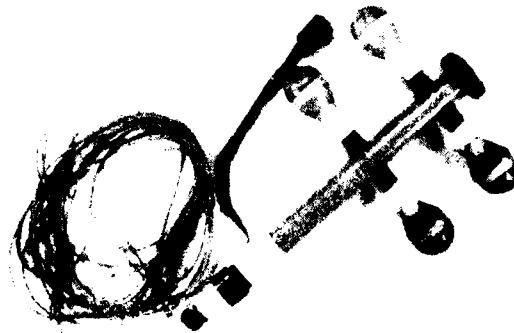
A deep ocean data acquisition system, Directional AUTOBUOY, is unique in that it is completely decoupled from the ocean boundaries. Because it moves with the water mass, and unaffected by surface wave motion the array is unperturbed so that sources of self noise may be greatly reduced. A weight carries the nearly buoyant system to a selected depth where it is released (as deep as 6000 meters). A depth sensor provides signals to control the valving of light and heavy fluids to achieve neutral buoyancy at the depth at which data recording commences. Subsequent depths are achieved by valving heavy fluids to permit ascent and then ballasting about the next programmed depth. The Directional AUTOBUOY has been tested and recently deployed in joint U.S./New Zealand 1978 exercises in the Fiji basin area of the South Pacific.

The Programmable Acoustic Recorder (PAR) is a midwater vertical measurement system capable of long-term unattended operation in both shallow and deep regions of the world oceans. This multichannel system operates to depths of 6000 meters and can be used to record throughout the water column acoustic parameters such as ambient noise, bottom loss, propagation, and vertical directionality. The PAR system evolved from the ACODAC which was first used in 1971. The major second generation developments that have been incorporated into PAR are microprocessor control, modular hydrophone array construction, and modular payloads.

The VEKA (Versatile Experimental Kevlar Array) light-weight hydrophone arrays can be easily deployed in various configurations from non-dedicated ships. The arrays use light weight Kevlar cables, miniaturized low power electronics, and special hydrophones suspended either in the vertical or horizontal mode which are individually wired directly or transmitted by multiplex telemetry back to the ship.

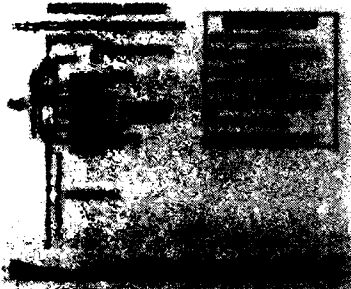
## MARINE BIOACOUSTICS

Another phenomenon important to surveillance (and tactical) sonars is the scattering of sound energy by some animals and plants of the ocean. Some larger marine animals (whales, sharks, and others) and schools of smaller fish may produce echoes that resemble submarines or torpedoes. These have long been a difficult problem because of their occasional appearance and highly variable nature. Some of the smaller animals of the ocean that are diffused through the upper 1000 meters of the ocean also scatter sound, a phenomenon known as volume scattering. This scattered sound limits active sonar performance, and under some circumstances can obscure submarine echoes completely. From past research we know that some of these animals, particularly those who have some sort of gas-filled sacks as part of their depth control apparatus, congregate at nearly the same depth by species to form layers that are readily distinguishable on echo sounding records. These are the so-called deep scattering layers. These animals seem to prefer depths dictated by some combination of light intensity, temperature, and pressure. Thus they migrate toward the surface at sunset and at sunrise go down to a depth that appears quite the same from day to day when viewed over a period of several days. Several years ago a decision was made to monitor the behavior of the layers over several years. This study, called Ocean Acre, was one of the most comprehensive ever undertaken. It was completed in 1977. The Program characterized volume scattering profiles measured acoustically and successfully predicted scattering strength profiles from net trawl data on 55 species of air bladdered midwater fish collected during different years and seasons within a defined area near Bermuda. Volume scattering strength was measured at selected frequencies from 3.95 to 15.5 kHz to determine diurnal, day-to-day variability as a function of frequency. Variations among profiles from different seasons or years were significantly greater than those among the day-to-day profiles. A simple prediction model using air-bladdered fish abundance correlated well with measured



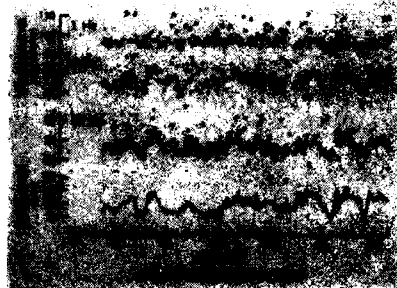
VIEW OF RESEARCH PLATFORM ORB BEING TOWED TO SEA FOR OCEAN NOISE STUDIES WITH THE SUBMERSIBLE ACOUSTIC ARRAY ADA (ADVANCED DETECTION ARRAY) IN TOW. SEA GOING OPERATIONS CALL FOR ARRAY TO BE TOWED TO ITS WORK STATION IN UP-SIDE DOWN POSITION. ON STATION, BARGE IS SUBMERGED, ROTATED THROUGH 90°, AND SUSPENDED FROM MOORING LINE BETWEEN ORB AND THE OCEAN BOTTOM. ARRAY UTILIZES SIGNAL PROCESSING AND BEAMFORMING CONCEPTS TO MAKE ADVANCED MEASUREMENTS OF STATISTICAL DIRECTIONAL PROPERTIES OF BACKGROUND NOISE FIELD IN THE OCEAN. ADA MEASURES 21x8.8x6 METERS AND WEIGHS 60 TONS. ADA AND A HYDROPHONE "TREE", ONE OF 720 IN ARRAY, ARE SHOWN.





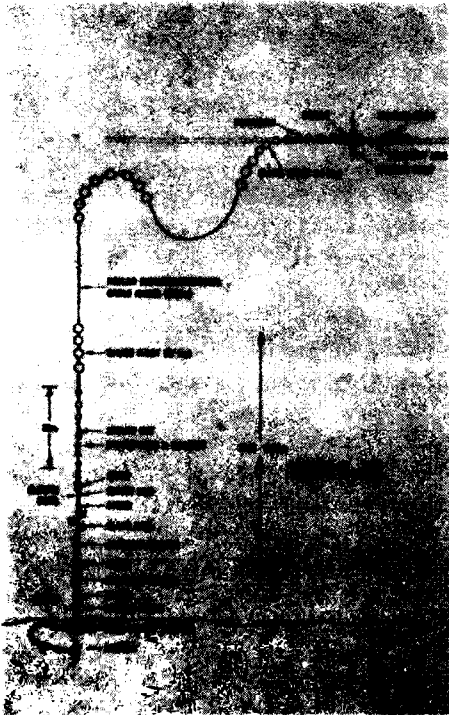
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DIRECTIONAL AUTOBUOY CHARACTERISTICS.



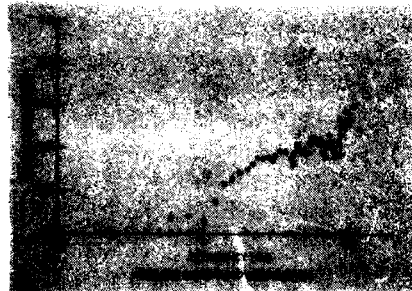
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THE BOTTOM CURVE REPRESENTS WIND SPEED VARIATIONS RECORDED SIMULTANEOUSLY WITH THE AMBIENT NOISE AT 1, 5, AND 10 HZ FREQUENCIES IN THE BURMUDA AREA DURING WINTER CONDITIONS. THE GENERAL SHAPE OF THE AMBIENT NOISE LEVELS RESEMBLES THE WIND SPEED FLUCTUATIONS, PARTICULARLY FOR THE 5 AND 10 HZ BANDS.

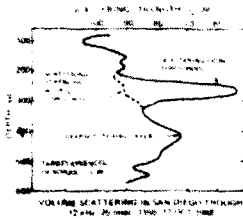


NORDA

VEKA II-22, ONE IN A SERIES OF VEKA ACOUSTIC ARRAYS, USED FOR AMBIENT NOISE MEASUREMENTS AS WELL AS OTHER ACOUSTIC MEASUREMENTS.

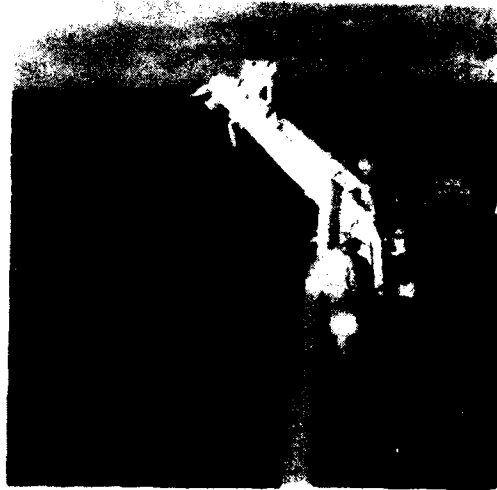


COMPUTED CROSS-CORRELATION COEFFICIENT SHOWS THE STRONG RELATIONSHIP BETWEEN THE WIND SPEED AND THE AMBIENT NOISE LEVELS SHOWN ABOVE. THE DECREASING VALUE FOR FREQUENCIES BELOW 2 HZ IS THE RESULT OF SYSTEM NOISE CONTAMINATION.

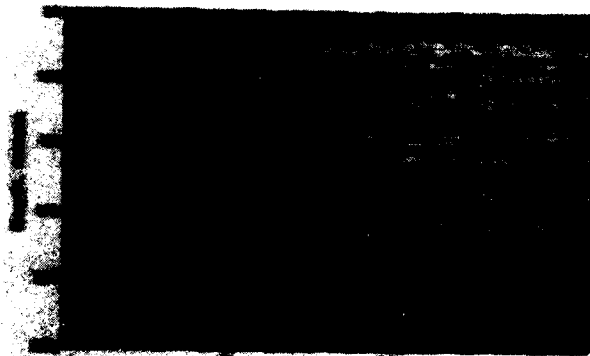


NOSC

SOUND SCATTERING OF BIOLOGICAL ORIGIN HAS BEEN OBSERVED IN VIRTUALLY ALL OCEANS MAINLY WITHIN 1000 METERS OF THE SEA SURFACE. SHOWN HERE IS VOLUME SCATTERING IN THE SAN DIEGO TROUGH.

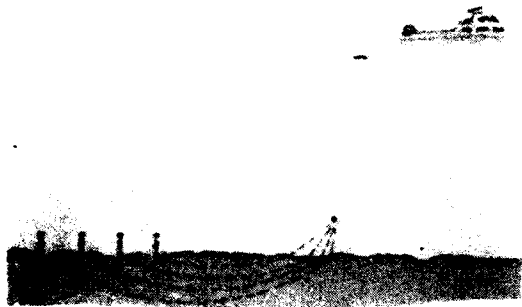


NET TRAWL COLLECTED 55 SPECIES OF AIR BLADDERED FISH DURING THE OCEAN ACRE RESEARCH PROGRAM



MFL

DISTRIBUTION OF BIOLOGICAL LAYERING AS OBSERVED ACOUSTICALLY WITH AN 87.5 KHZ SONAR SYSTEM. LAYERS APPEAR TO OSCILLATE AT TYPICAL, INTERNAL WAVE PERIOD. MAJOR PORTION OF DEEP SCATTERING LAYER IS AT 240 METERS AT THIS LOCATION.

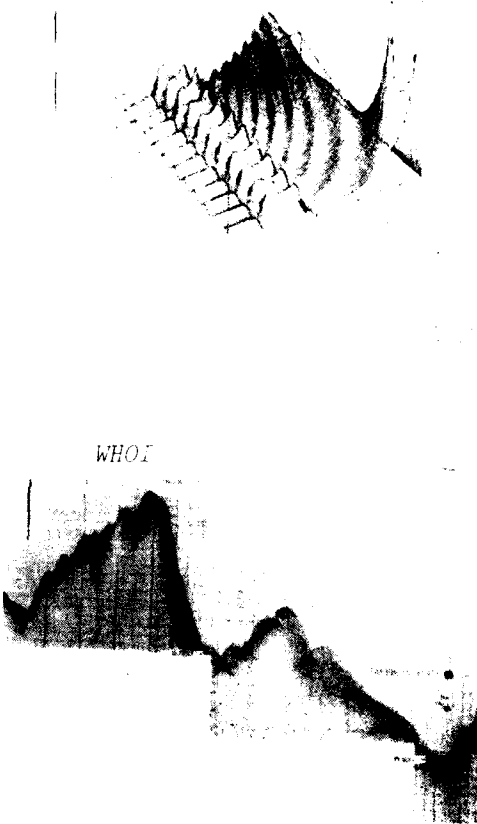


DEEP SOURCES AND RECEIVERS  
PLACED ON THE SEA FLOOR  
MEASURE SEDIMENT ATTENUATION



THE DEPLOYMENT OF THE DIRECTIONAL  
AUTOBUOY WHICH HAS A 12-ELEMENT  
ARRAY AND A CORRESPONDING  
PROCESSING ALGORITHM

THE HIGH LOSS AT LOW FREQUENCIES  
SHOWN HERE AT SMALL GRAZING  
ANGLES IS DUE TO COUPLING OF  
ACOUSTIC ENERGY INTO A STONELEY  
WAVE. THIS HIGH LOSS CAN EF-  
FECTIVELY BLOCK OUT LONG RANGE  
SHIPPING NOISE



COMPOSITE OF ECHO-SOUNDING PROFILES  
SHOW CONTOUR OF FAULT SCARP ON ONE  
SIDE OF THE CAYMAN TROUGH. EXAMPLE  
OF BOTTOM ROUGHNESS THAT AFFECTS  
BOTTOM INTERACTION.

acoustic profile data. The success of the model is attributed to the observation that 50 species of fish appear to serve as a reliable index to the total population of potential scatterers within the insonified volume.

The Ocean Acre Experiment was carried out in but one geographic area. Other programs indicate that there are significant contrasts among different water masses, changes of latitude, and probably several scales of oceanic phenomena. We know little about geographic contrasts of this sort compared, for example, with our knowledge of depths of the ocean.

Sounds generated by submarines or ships detectable by passive sonars may also be obscured by sounds generated by marine organisms. This complex subject has received considerable attention in the past, and various of its phenomena remain a highly effective constraint on sonar performance in particular situations. Like the false submarine echoes from whales, sharks and fish schools, it appears highly variable and not predictable to the sonar community. As examples, all cetaceans (whales and porpoises or dolphins) produce sound, some at very high levels. Certain shrimp and nektonic fish also make sound that can cause local or short term problems for sonars. For these reasons a significant effort continues on the acoustical properties and behavior of marine organisms which actively or passively alter the operational efficiency of the Navy's underwater acoustic surveillance, guidance and communications systems.

#### NON-ACOUSTIC ASW SYSTEMS

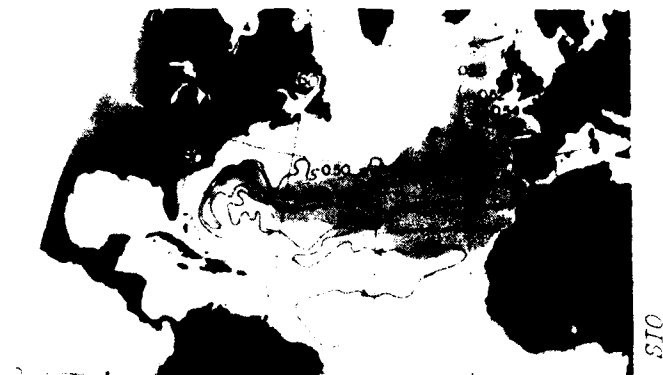
The competitive pressure among potential adversaries in our world and a gradually more polluted environment (acoustic noise pollution in this instance) may well seriously impair the efficiency of sonar systems of the sort that are reasonably successful today. Hence there is always pressure on ASW specialists to be sure that they are not disregarding other potentially useful ways of detecting and tracking submarines. Especially the U.S. Navy does not want to be second in such a development race! The list of candidate influence

fields is long, and only a few will be cited: the internal wave generated by the passage of a submarine, its magnetic field, its electrical field, its response to low frequency electromagnetic fields, to light, to radar pulses, various chemical possibilities, and so on.

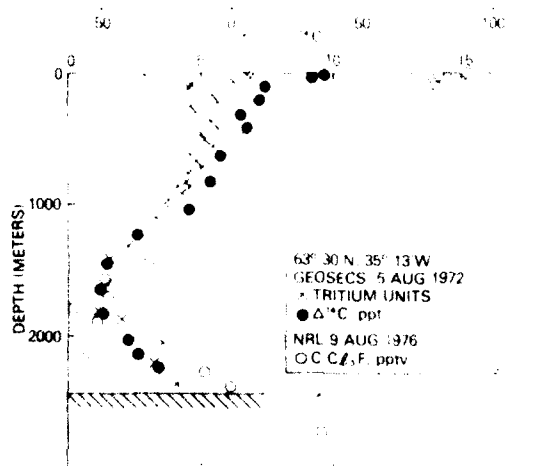
Many of the implied methods have been used to find submarines in staged exercises, but regardless of the outcome a principal obstacle to success has been the natural noise field, and our general lack of knowledge about it. All of these noise fields are proper objects of study to ocean science. Together their understanding forms an important research objective for the Navy. The answers to many if not all of the questions about these noise fields are to be found in understanding physics and chemistry of the waters of the ocean. In what follows, these matters are reviewed indicating the general aspects receiving emphasis at present and probably in the near future. Most of these research objectives are significant both to acoustic and non-acoustic methods of submarine detection.

#### WATER MASSES

Water masses throughout the oceans are characterized by various physical and chemical properties such as oxygen, salinity, temperature, sound velocity, etc. The geographic distribution of specific water masses, their formation, and circulation within the world oceans have long been studied using various ocean water properties such as oxygen content, temperature-salinity relationships, and more recently trace materials such as carbon fourteen ( $C^{14}$ ), tritium, fluorine, etc. Such water masses, which are formed and driven by winds and by heating, cooling, evaporation, and precipitation, circulate on various time and space scales, among which are the great gyres of middle latitudes, the west-wind drifts of high latitudes, and the deeper flows carrying denser waters of high latitudes into the central oceans, from ocean to ocean and from basin to basin. From a better understanding of the nature and magnitude of the general circulation, estimations of the balance of exchange of water, heat, salt and nutrients within the



CIRCULATION IN THE NORTH ATLANTIC OCEAN AT A DEPTH OF 1000 METERS SHOWING THE DIRECTION OF FLOW OF AN ANTICYCLONIC GYRE (SOLID LINES WITH ARROWS) WHICH INFLUENCES THE WESTWARD AND NORTHWARD SPREADING OF THE WARM, SALINE WATER FLOWING OUT OF THE MEDITERRANEAN (SHADED AREA).



A SIMPLE, RAPID, INEXPENSIVE SHIPBOARD METHOD FOR TRACING WATER MASSES USES MAN-MADE FREON-11. THE RESULTS ARE STRIKINGLY SIMILAR TO THOSE OBTAINED BY MORE ELABORATE AND EXPENSIVE METHODS WHICH DEPEND ON SHORE-BASED MEASUREMENTS OF TRITIUM AND CARBON-14.

great ocean systems can be realized. Such realization can provide a proper background against which theoretical examinations and detailed numerical models can be developed more efficiently and more effectively to improve the Navy's understanding of the world oceans, its circulation patterns, and its environmental effects on Navy systems and operations.

Oceanographic surveys of the chemical and physical parameters of salinity, temperature, pressure and/or depth provide information concerning the density distribution and physical characteristics of various water masses in the ocean. The movement of water masses in the deep ocean can be estimated or inferred from a knowledge of the water's density structure in the earth's gravitational field and the effects of the earth's rotation. The direction of flow, and the volume of water transported in a determined direction, and in many cases the origin of such water masses can be estimated. Such information for the world ocean allows the determination of general circulation patterns of the major currents, exchange rates of various water masses, deep circulation characteristics, and seasonal and long-period variations of major current regimes. Oceanic regimes in which fronts (discontinuities in water mass characteristics) and/or eddies having a potential to impact the Navy's surveillance and ASW missions are also located and studied by these methods. Several cooperative oceanographic programs are discussed in Chapter 5 which include studies of large-, small- and micro-scale water structures that have received considerable emphasis during the past few years.

#### FRONTS AND EDDIES

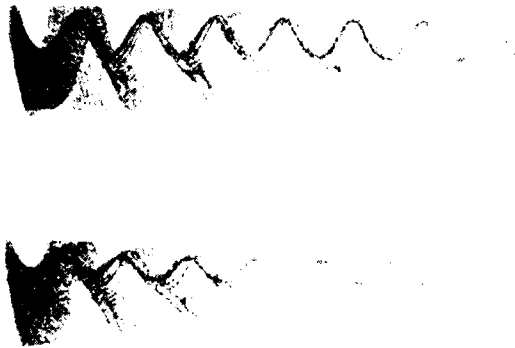
The Navy is investigating the characteristics of fronts and eddies in the ocean to determine how and under what conditions they are formed and their impact on present ASW systems. Environmental satellite imagery provides the Navy with a capability to view the ocean surface synoptically at frequent intervals. This capability is particularly useful with temporal and spatial mesoscale variabilities of water mass boundaries (such as fronts)

and eddies have been difficult and expensive to monitor using standard shipboard measurements. Satellite sensors monitor ocean surface features in the electromagnetic spectrum and therefore sense to maximum depths as little as a millimeter below the surface or at most penetrate to tens of meters.

In the past, atmospheric interferences, i.e., moisture, clouds, and aerosols, have been limiting factors in time-series observations of the relatively subtle ocean surface temperature gradients. In 1978 SEASAT-A was instrumented with microwave sensors, which are capable of viewing the ocean surface through clouds. While the SEASAT-A results were encouraging during its short life much more research will be required to establish the scope of usefulness of microwave surveillance of the ocean.

With respect to its application to tactical ASW this relatively new technology has not yet been adequately evaluated. How reliable is this information for input to acoustic prediction determinations? Surface values must correlate adequately with temperature and density structures in the water column to define changes in acoustic regimes. These correlations will vary seasonally and locally in some geographic areas. The next step is to assimilate this satellite derived information into the environmental data base for acoustic predictions. With established correlations, the satellite data can be used to complement and render more efficient, low density in situ sampling in deriving acoustic forecasts. The availability of these data will then permit assessments of range dependent acoustic prediction models and determinations of the feasibility of operational shipboard utilization in areas where fronts and eddies exist.

Spatial temperature changes are small over a large portion of the ocean but there are localized areas where extreme variability in the thermal profile down to 300 meters is found. These areas are in the vicinity of ocean fronts where perturbations moving along the front may break off to form eddies of warm or cold water that drift slowly in an alien water mass. These eddies may last from a few weeks to more than a



THE ACOUSTIC FIELD COMPUTED WITH AND WITHOUT AN EDDY PRESENT IN AN ACOUSTIC CHANNEL. THE STRONGEST (DARKEST) SIGNAL FOLLOWS A SINUSOIDAL PATTERN. THE EDDIES CAUSE THE VERTICAL EXTENT OF THE PATTERN TO DECREASE 30%. IN ADDITION THE PEAKS AND TROUGHS ARE 180° OUT-OF-PHASE IN ONE PLOT RELATIVE TO THE OTHER.

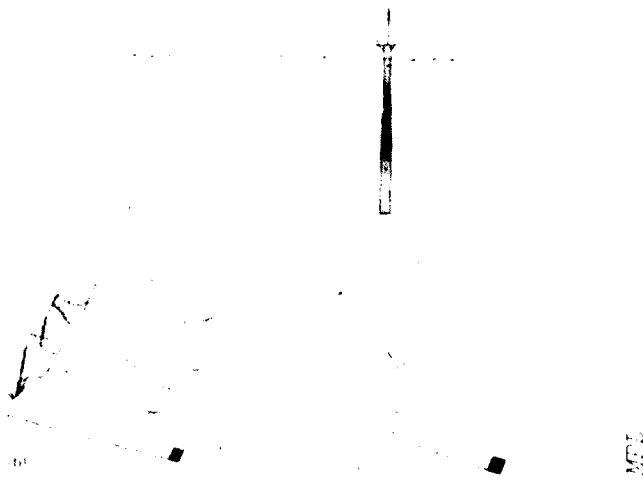


FIGURE (a). INITIAL TESTS OF THE DOPPLER SONAR CONCEPT USING A NARROW BEAM SONAR MOUNTED ON FLIP. FIGURE (b). CURRENT VELOCITY AS A FUNCTION OF TIME FOR VARIOUS RANGE CELLS IS SHOWN. NOTE THE NEAR INERTIAL MOTIONS WITH PERIODS OF 24 HR WHICH DOMINATE THE CURRENT FIELD. FIGURE (c). THE DERIVATIVE OF VELOCITY WITH RESPECT TO RANGE, WHICH IS EFFECTIVELY THE DERIVATIVE WITH RESPECT TO DEPTH FOR LOW FREQUENCY MOTIONS, PROVIDES AN ESTIMATE OF THE CURRENT VELOCITY SHEAR.

year. work in progress is directed at evaluating, both analytically and numerically with the aid of computers, the effects produced by these disturbances on single acoustic receivers and arrays of hydrophones. When a reliable model is developed it will be possible to predict to what extent the ASW forces will encounter problems from the eddy phenomena.

#### INTERNAL WAVES

Wave motion on a smaller space scale such as internal waves is thought to affect the coherence of sound waves in the sea. Specific objectives are to develop techniques for measuring internal motions and to determine the oceanwide distribution of their energy spectra.

A particularly challenging aspect of physical oceanography is that many of the phenomena of interest can only be adequately observed by multidimensional arrays of sensors which are difficult to field in the open ocean. The several difficulties that confront a reliable observation program require further development, possibly a complete departure from moored buoys. One such alternative to moored instrumentation, is Doppler sonar which can provide remote velocity information. In one approach, high intensity sound is transmitted in a narrow beam which scatters from the plankton and nekton in the upper ocean. From the Doppler shift of the back scattered reverberation, the component of velocity parallel to the sonar beam can be deduced at many ranges.

Initial tests of the Doppler sonar concept have been conducted using a 37.5 kHz narrow beam sonar mounted on FLIP. The slanting sonar beam provides a quasi horizontal array for observing high frequency (1 cph) internal wave motions.

#### THE ARCTIC

The Soviets have expended a very large effort and many resources to establish naval supremacy in the Arctic region. To counter this commitment the U.S. Navy maintains the capability of operating in the Arctic, countering military threats in that region, and maintaining freedom of the seas. Naval Arctic environmental exploratory development

relates directly to three warfare areas, Surveillance, Antisubmarine warfare, and Coastal Mine warfare.

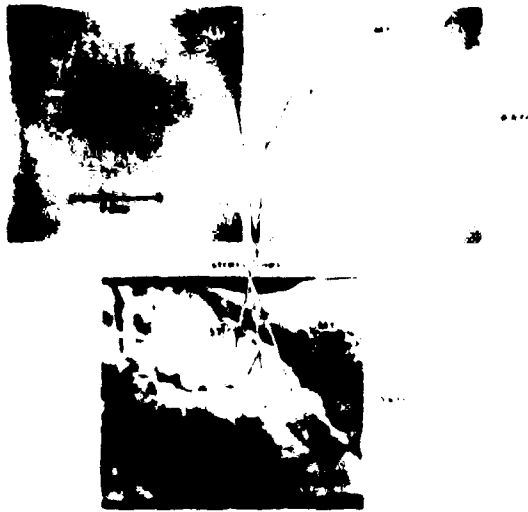
Arctic research studies require special approaches to accommodate ice behavior and the extremes of high latitudes. For example, ambient noise in the Arctic is unique. The ice canopy is constantly under deformational activity such as fracturing, pressure ridge formation, floe interaction, and overturning. Within many of the shallow marginal ice zone areas, sea ice and icebergs scouring produce unusual ambient noise and an abundance of sound producing marine life adds to this already complex problem. The petroleum-related industrial boom on the North Slope of Alaska and Canada also contributes to the ambient noise problem.

The Naval Arctic Research Laboratory (NARL) located on the shore of the Arctic Ocean at the northernmost limit of the United States (about four miles north of Barrow, Alaska) presents unique opportunities to support arctic research objectives. From NARL the Navy operates several field stations, including research stations on ice islands. These programs have been supplemented by airborne studies of the distribution and dynamics of pack ice. An ice surveillance program, BIRDSEYE, uses airborne infrared scanners and laser altimeters to collect statistical data concerning the distribution of various ice features and conditions. In addition, acoustic studies of the marginal sea ice zones of the Arctic Basin are being conducted using the BIRDSEYE aircraft to launch sonobuoys, SUS charges, and expendable bathythermograph (XBT) systems.

Underice operations have made important contributions to knowledge of the physics of sea ice. The profiling of many miles of the underside of the Arctic pack ice canopy by submarines has provided invaluable data concerning distribution and size of ice ridges and underice features. The Arctic investigations have developed many practical applications including ice forecasting and bathymetric charts of the Arctic Ocean.

Sea ice penetration/perforation performance of air-dropped projectiles, particularly mines, is assessed by analytical, scaled models and field studies. Hardness, salinity, moisture content,





AIRBORNE PASSIVE MICROWAVE IMAGERY OF SEA ICE  
SHOWING FEATURES TENTATIVELY IDENTIFIED AS  
STRESS LINES, VARIATIONS IN TONE, REFLECTING  
RADIOMETRIC TEMPERATURE DIFFERENCES, DISTINGUISH  
NEW, SINGLE YEAR (SY) FROM MULTIYEAR (MY) ICE.



SCIENTISTS MEASURING THICKNESS OF THE ICE COVER AND  
DEPTH OF PENETRATION OF AN-AIR DROPPED PROJECTILE.

temperature and temperature gradient, thickness, and snow cover are the ice properties important in these assessments. Projectile characteristics include weight, dimensions, shape, nose configuration, and material. The conditions of impact, velocity, and angle, are all important variables for investigation. In addition to evaluating the through-ice capability of attackable hardware, the program is developing new design and design certification criteria and techniques for predicting penetration performance.

Satellite imagery has proven especially useful in Arctic research. The wide-area synoptic observations of surface characteristics, repeated sequentially, permit calculations of drift vectors and estimates of the consequences of drift: drift opening, and closing or intensified drifting, for example.

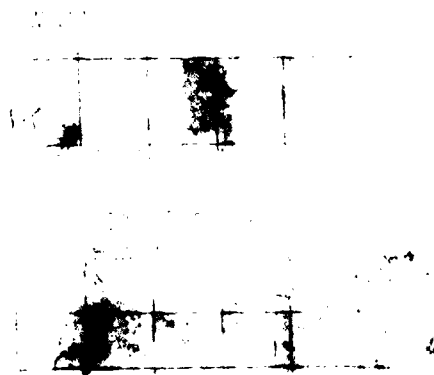
Improvements to remote sensors, satellite and airborne, are continually sought as refinements to imagery interpretation emerge. The ability of passive microwave techniques to provide useful information

under weather conditions (especially in the visual sensing field) has been demonstrated in the Arctic) is of increasing importance to Arctic researchers. The program is developing a passive microwave remote sensing capability for terrain applications. This capability will into the relationships between the spatial distributions of terrain features and the characteristics of many different types of terrain. The program is varying wind, temperature, and humidity of formation, and other factors, and weather. Lowest radiation temperatures were recorded over the ice. The program is developing new ice with a high degree of accuracy, and over some land areas. The program is developing forms which will permit the use of a considerable number of different types of radiometric temperature measurements. Areas of thin hard ice, new ice, and ice with frozen melt ponds, and other unique features, may be identified tentatively as a function of the program. If the information is available, further investigation is being conducted on forecasting.



SATELLITES - DMS, 6 JULY '76  
NOAA - VHRR, 19 AUGUST '77

PROJECT HUELVA INVESTIGATED THE OCEANOGRAPHIC AND ACOLUSTIC PROPERTIES OF A PERSISTENT SURFACE DISCONTINUITY IN THE WESTERN MEDITERRANEAN. SHOWN IS NOAA VERY HIGH RESOLUTION RADIOMETER (VHRR) INFRARED IMAGE OF THE COOL WATER INTRUSION



TRACK OF A BUOY IN THE MEDITERRANEAN. BUIRY CORRECTED FOR THE INFRARED IMAGE OF THE WATER IN THE MEDITERRANEAN.



## CHAPTER 3

### PROJECTION OF POWER ASHORE

In wartime, Projection of Naval Power Ashore implies the ability to carry the fight to the enemy, penetrate defenses and subdue. Power Projection rests on the correlative ability to maintain supply lines throughout and after a specific engagement. This function is integral to the Sea Control Mission. The Navy's role in Power Projection is implemented primarily by the Fleet Ballistic Submarine Force, by the tactical aircraft operated from aircraft carriers and by amphibious assault forces. Previous chapters have treated the ocean environmental research and development to support the first of these operations. In this chapter the coastal marine research in support of amphibious operations is presented.

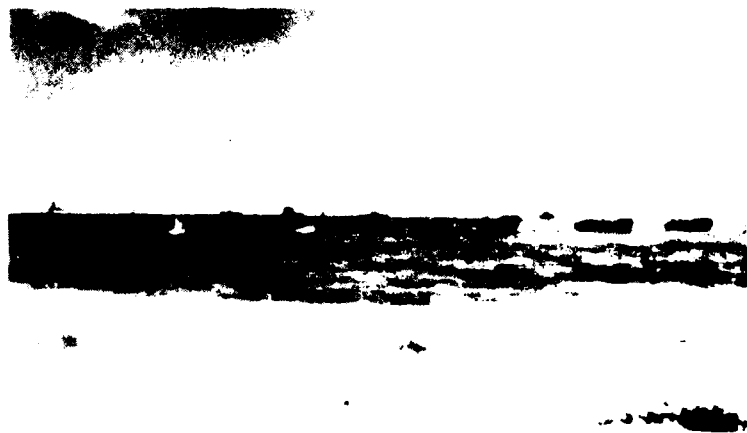
#### AMPHIBIOUS ASSAULT

Coastal features and processes most important to amphibious assaults are tides, shore currents, surf, beach topography and trafficability, and the sediment characteristics of the seafloor.

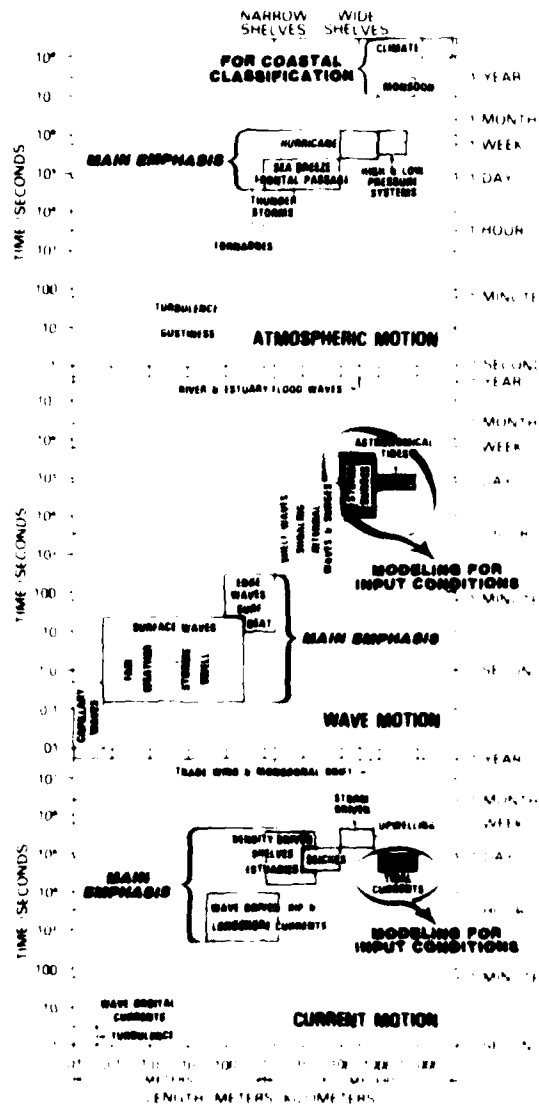
All of these properties are dynamic variables; all are interactive. To achieve a capability to make reasonably short range predictions of changes in these parameters anywhere in the world, the Ocean Science Program expends considerable effort in trying to unravel the mix of mechanisms that modify coastal environments for the purpose of quantifying the critical processes. The research includes theoretical, laboratory measurement programs, instrumentation development with special attention to remote sensing, and the associated analyses that may yield useful empirical correlations and support new theory.

#### TIDES

Of all the processes that affect the coastal zone, the theory of tides is best understood. The variations in the depth and shape of the ocean basins and the interference of land masses cause the tides to assume very complex patterns.



AMPHIBIOUS ASSAULT OPERATION



SPATIAL AND TEMPORAL SCALES of atmospheric, wave, and current motions of significance to coastal dynamics - To achieve a worldwide capability for predicting coastal conditions, the Navy Ocean Science Program supports research in spatial scales that would affect the nearshore and inner shelf regions over the duration of a military operation -- several hours to several days. Shaded areas denote primary research; unshaded research.



Other studies are investigating the stability of longshore currents, prediction of rip currents on plane and barred beaches, and currents in the transition zone between areas dominated by inlet and beach processes.

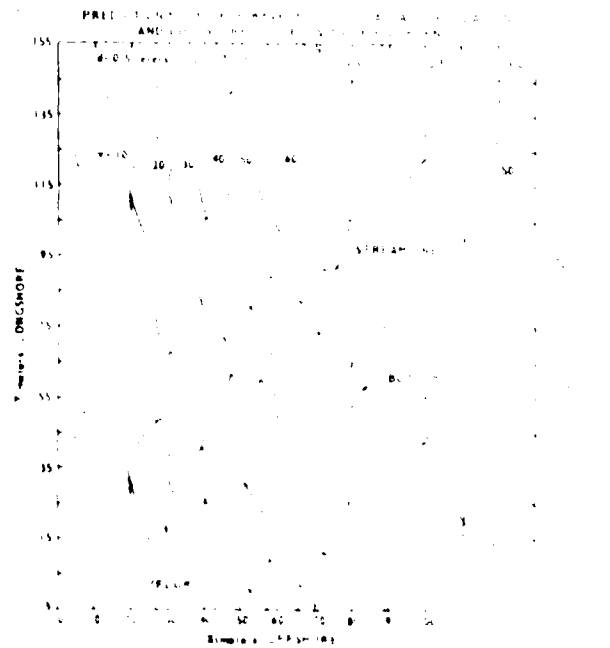
Associated improvements in measurement capabilities include an innovative application of over-the-horizon (OTH) radar techniques using a ground wave mode to locate, track, and interrogate expendable drogoue-type buoys on demand. The small, low-cost drogues are fitted with traps that can be adjusted to provide real-time information on current velocities and temperatures as functions of depth over the continental shelf.

### SURF AND SEDIMENT TRANSPORT

The characteristics of surf depend on many factors, e.g., local winds, stage of tide, swell generated by storms at sea, etc. The fundamental cause, however, is the refraction that takes place in the shapes of waves as they move shoreward over a shoaling bottom. Surf determines the ability to land on beaches and may exert destructive force on any object in its path. In addition to such important but obvious effects, surf contributes to the genesis of longshore currents and plays an active role in redistributing sediments, changing the beachline, and other littoral configurations, all of which substantially contribute to the changes required for better definition and understanding of the longshore sediment transport. Most of the surf-related measurements of the sea-surface topography are limited to these two variable areas.

Improvement in the measurement of sediment transport and the related measurements require knowledge of the surf-related processes and characteristics of the surf zone and the sediment. The present state of knowledge regarding surf-related processes is limited to the water depth and period that define the surf zone and the sediment transport. The present state of knowledge regarding surf-related processes is limited to the water depth and period that define the surf zone and the sediment transport.

joined forces in a field program to obtain detailed and coordinated time series data on waves and currents along transects normal to the coastline in a variety of open ocean nearshore conditions. Measurements in surf zones characterized by plunging, spilling, collapsing, and surging breakers and data on the interaction of offshore currents with surf zone processes are being examined for answers to questions of sediment exchange between the offshore and surf zones and the nature of wave, current, and turbulence spectra under varying surf conditions. It appears that when the surf is formed of breaking waves, the longshore sand transport due to this action is confined to the



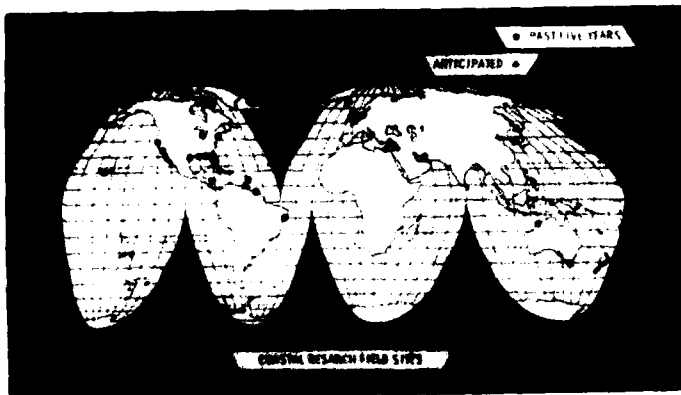
The present state of knowledge regarding surf-related processes is limited to the water depth and period that define the surf zone and the sediment transport. The present state of knowledge regarding surf-related processes is limited to the water depth and period that define the surf zone and the sediment transport.

narrow, swash zone just inshore of the breakers. Slightly farther offshore, sediment transport is caused by the combined action of wave orbital currents and the average currents that result both from winds in the local area and those occurring elsewhere.

Measurement programs are underway along California, Gulf Coast, New England, Florida, and some foreign coastal sites to obtain data representative of different kinds of beaches. Exposure, coastal configuration, bottom topography, beach gradient, and the sediment characteristics

are all significant properties to be considered. Models being developed can be evaluated against actual conditions for various combinations of the significant parameters. Certain consistent principles have emerged that augur well for successful modeling. When waves are of the surging or collapsing type, for example, it is possible to use well-known wave theory to predict the fluid stresses that result from wave orbital motion. This is not true, however, for spilling and plunging waves and new theory is being formulated and evaluated for these cases.

CNR Code 462



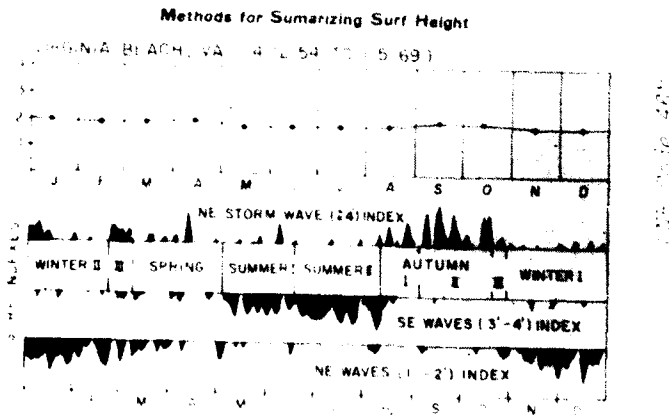
MARKERS: ENVIRONMENTAL CONDITIONS CHANGE rapidly as major frontal systems pass through coastal regions, illustrating why one of the ultimate objectives of the Navy's coastal dynamics research program is to be able to provide near real-time observations and real-time tactical predictions of such factors as longshore and cross-shore currents, wind and breaker direction and intensity, wave height, and visibility. Numerals on the figures refer to wind speed in knots.

The transformation that waves undergo as they move into shallow water (before breaking) must also be considered in predictions of surf and sediment transport. Dissipative mechanisms include friction, percolation, and bottom motion, as occurs in soft clays. Model concepts compared with experimental results of field programs indicate that the dominant dissipative mechanism appears to correlate with sediment type: bottom motion is the primary agent where soft muds and clays are abundant; percolation, where the bottom is coarse sand.

The ultimate objective of this research, a dynamic coastal classification and prediction system, will be only as effective as the models it employs and the methods that are used to handle the input data. Promising new approaches to the latter are also being studied; one of the more interesting is recognition that there are recurring events in the coastal climate that appear to follow a "natural" calendar. Coastal wave conditions, for example, appear to conform to such a pattern, a phenomenon that is masked when wave data are averaged on a monthly basis -- the standard practice.

A new approach being developed, the Natural Wave Climate Calendar, reflects a natural atmospheric calendar that defines the beginning and end of seasons for each year. Distinct subseasons of each season can also be defined. Since waves are a direct result of atmospheric processes, it may be possible to construct wave climate calendars for the various coastal regions of the world. Certain key dates are being examined for such correspondence. One of the dates is October 16. Around this date, the North American Polar front moves southward to its mean winter position. Since migratory extratropical storms move along this front, one might expect pronounced changes in storm wave climates.

Plots of hindcasted data around this date for Cape Hatteras show that this is indeed the case: the probability of storm waves is about half again as great for the 15 to 20 days after 16 October than at any other time. Additional analysis has shown this same behavior repeated at five other stations along the eastern seaboard.



WAVE CLIMATE CALENDAR COMPILATION FOR VIRGINIA BEACH, VA., DISPLAYS DISTINCT PATTERNS AND SUBSEASONS THAT ARE NOT REFLECTED IN THE MONTHLY AVERAGES COMMONLY USED FOR DATA ANALYSIS.





IN ADDITION TO ENERGY ATTENUATION, waves moving onshore over mud bottoms may be drastically deformed. Although wave height would no longer be cause for concern, the saw-toothed character of the resultant wave train could wreak havoc with small craft and surface effects vehicles meeting them head-on, the marine equivalent of "running into a stone wall."

#### REMOTE SENSING APPLICATIONS

The Ocean Science Program conducts an aggressive program in remote sensing applications to coastal and shallow water problems. Remote sensing offers three advantages--it promises a capability for timely and secure reconnaissance of enemy-held landing areas, provides a method to obtain experimental data on dynamic processes over a wide area in real time, and offers a rapid safe means for hydrographic surveys of coastal areas.

Remote sensors are carried on helicopters, aircraft, and satellites or are mounted on shore stations. Techniques and hardware are in a state of constant, rapid evolution, and the last five years have seen

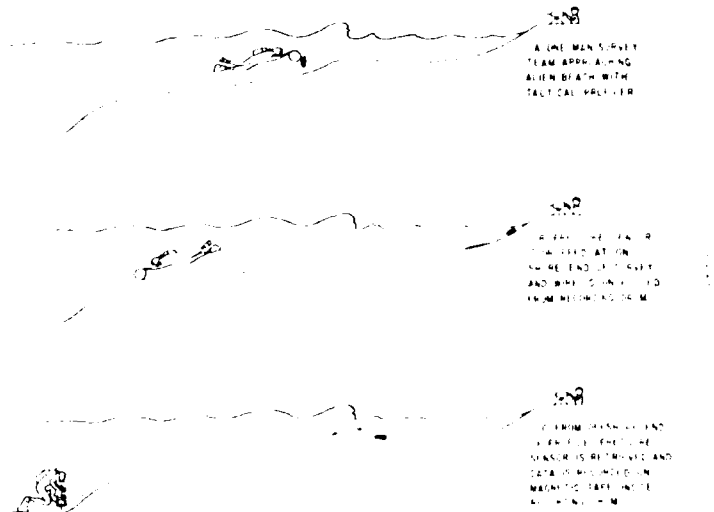
tremendous improvements in the discrimination and quantification of coastal variables. Research is conducted on sensors, their use, and on the various aspects of handling the data. Remote sensing data must be corrected for distortion related to properties (e.g., atmospheric moisture content, aerosols) of the air space between the sensor and the earth's surface, movements of the platform, earth curvature, and other factors that can cause possible aberrations (and misinterpretation) of the data. There is a steady drive to exploit the potential of remote sensing technology to the limit of the state-of-the-art. One current project

is to determine whether subsurface temperature and salinity in coastal zone waters can be measured by a laser technique that distinguishes between two forms of liquid water that are in chemical equilibrium. In laboratory experiments the technique produces results that meet the accuracy requirements for operational applications; whether laboratory results can be achieved in the natural environment is now the question. Other research uses satellite data to study the processes that control coastal variability and the radiative transfer of infrared energy from coastal waters through the clear-sky atmosphere. Surveillance maintained of the Gulf of Mexico Florida Coast during the winter of 1973 disclosed a previously unobserved orderly progression of changes in the horizontal and vertical temperature patterns of coastal waters. Currents can be distinguished by the temperature gradients at their boundaries and velocities can be derived if singular features exhibit sufficient contrast for tracking on successive images. The task of building

new, refined information extraction capabilities is a major objective of remote sensing technology development.

The Ocean Science Program does not generally distinguish between the requirements of amphibious and special warfare forces in the majority of its coastal area research, since so many basic information needs are the same. Differences emerge with the application. The Tactical Beach Profiler is a case in point. Designed for covert beach reconnaissance by special warfare experts, its purpose is to acquire a critical minimum of essential information prior to amphibious assault.

In another special warfare development, scientists have learned that porpoises, blindfolded with soft rubber suction cups, can distinguish differences in the surface texture, composition and shape of objects by echo-ranging alone, an accomplishment beyond the present capability of conventional man-made sonar systems. Through study of this ability to "see with sound," it may be possible to develop a diver sonar that will be superior to existing systems.



WITH THE TACTICAL BEACH PROFILER, a Navy diver can measure the profile of an alien beach on a magnetic tape which, when later played through an X-Y recorder, produces a depth versus distance representation of the topography. Profiles of secure beaches can be obtained with the instrument from shore by carrying the pressure sensor offshore.

## BEACH RECONNAISSANCE

Mapping bottom features in the benthic zone and determining beach composition to assess trafficability using remote sensing technology are capabilities being pursued to yield better beach reconnaissance information. The spectral reflectance of beach samples correlates well with such properties as composition, moisture content, and grain size. Most of this work is at present still accomplished in the laboratory and culminates in the development of trafficability/mobility algorithms for remotely sensed data.

A remote sensing system designed specifically for tactical beach reconnaissance combines passive multispectral scanner and active laser techniques. The scanner acquires several images in narrow spectral bands. These images depict the underwater topography in various shades of gray depending on the depth of penetration of light at different wavelengths, the optical characteristics of water, and the bottom reflectivity. Since the depth measurement is relative, however, a pulsed laser is used simultaneously to provide absolute measurements of depth along the aircraft path. The effects of water quality and bottom reflectivity can be largely removed by ratioing two or more of the spectral images and applying a new multi-channel bottom classification algorithm. The resultant images are then calibrated by the laser data to produce underwater contour maps. This system would be flown at about 3000 feet under normal operating conditions, but could operate from higher altitudes if there were no cloud interference.

## BEACH INFORMATION SYSTEM

A major milestone has been achieved with addition of a beach information catalog to the Navy's computerized planning data banks. JVAIS, or University of Virginia Information System (for its designers), not only includes a summary of observed data, but can also be queried for predicted values of certain parameters. Now on-line at the David W. Taylor Naval Ship Research and Development Center, the system uses the Ship

Analysis and Retrieval Program, SHARP, which allows on- and off-line maintenance. The current inventory contains data on Caribbean, Canadian, and U.S. areas. Development is continuing with the addition of new representative areas and model improvements.

## SPECIAL WARFARE

Special warfare involves unusual types of naval operations such as penetrating and destroying the enemy's coastal defenses, planting or retrieving intelligence gathering devices, and conducting beach reconnaissance. Many of these operations are covert and are performed by specially trained divers and other personnel. Such operations almost without exception take place in the coastal zone. In southeast Asia, riverine interdiction (the prevention of enemy movements on inland waterways) was a new Navy responsibility in Special Warfare operations. Coastal characteristics that threaten amphibious assaults are similarly important to Special Warfare activities; in fact, the effects are often heightened, more severe. Currents and turbulence in the water present difficulties for swimmers and divers; turbidity reduces visibility and degrades underwater photographs; if heavy, it can clog sensors or other devices and even impede mobility. Water depth is a factor in the safety of swimmers exposed to underwater explosions. Temperature not only affects the ability to work underwater but strong temperature gradients can enhance the damaging effects of explosions on swimmers.

Conversely, some of these same conditions favor Special Warfare activities. Surf noise can mask movement on or across beaches. Turbidity adds a safety factor to underwater activity by impairing its detection by optical means; acoustic detection is degraded by ambient noise and temperature or salinity gradients. Features of the bottom topography, if known, can be used to shield, cover, or disguise man-made devices.



## CHAPTER 4

### SUPPORT

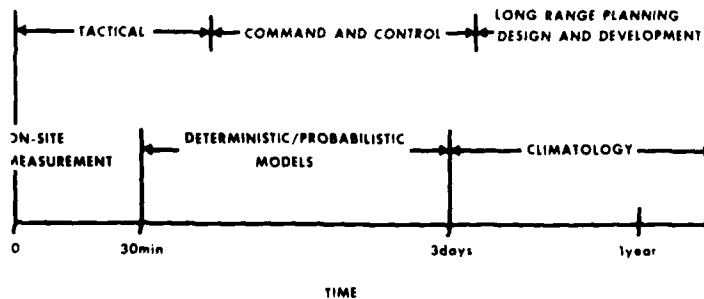
The Navy performs a host of activities to provide across-the-board support to operations and forces afloat, many requiring substantial inputs from the ocean sciences: environmental forecasting, mapping and charting, search and rescue, salvage, marine construction and environmental protection. The Ocean Science Program sponsors or contributes to research and development associated with these activities, usually as separately identified programs, but occasionally as secondary objectives of effort directed to other warfare requirements.

#### ENVIRONMENTAL FORECASTING

The Navy requires the forecasting of the total marine environment. While primary parameters of interest vary with the particular application--sound velocity structure for ASW, sea and surf for amphibious operations, wind and visibility

for carrier strike forces--forecasting models cannot treat each in a vacuum, but must consider the interrelated whole. Thus the emphasis on air-sea interaction mechanisms and long term oceanic controls on climate that characterize major programs like NORPAX and POLYMODE (see Chapter 6). Common-purpose elements of forecasting are data gathering networks, computer operations, communications, education and training, and most important to Ocean Science Program objectives, the translation of research results into usable operational tools that supply quick responses to questions bearing on tactical decisions. Most Ocean Science Program support to environmental forecasting is at the Exploratory and Advanced Development levels and involves models and algorithms that express complicated theoretical relationships in terms that naval operational personnel can use directly.

TIME SPANS FOR PREDICTION OF  
THE NAVY'S NATURAL OPERATING ENVIRONMENT





PROPAGATION-LOSS GRAPHICS (FMC 9/74)

DATE - 11 / 8 / 74  
 LAT - 3318 N  
 LONG - 6818 W  
 SOURCE DEPTH... 400 FT  
 RECEIVER DEPTH... 500 FT  
 FREQUENCY..... 200 KC

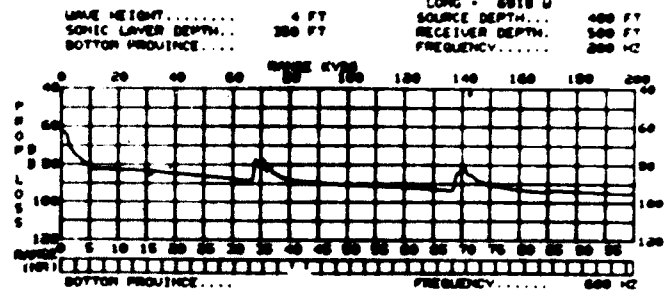
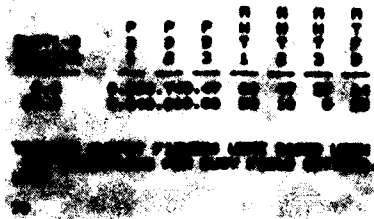


FIGURE OF MERIT = 80.0



THE INTEGRATED COMMAND ASW PREDICTION SYSTEM (ICAPS) IS AN ON-SCENE ACOUSTIC PREDICTION SYSTEM CURRENTLY INSTALLED ON SEVERAL CARRIERS AND AT ASW CONTROL CENTERS OF MAJOR COMMANDS. ICAPS MERGES ENVIRONMENTAL FACTORS AND EQUIPMENT PARAMETERS TO ESTIMATE THE IN SITU CAPABILITY OF ASW DETECTION SYSTEMS. PROPAGATION LOSS TOGETHER WITH NOISE DETERMINE THE PROBABILITY OF DETECTION AT VARIOUS RANGES; THIS IN TURN INFLUENCES SELECTION OF THE TACTIC(S) MOST ADVANTAGEOUS IN A GIVEN SITUATION. ONE OF THE TACTICAL PROGRAMS UTILIZED IS TASDA (TACTICAL ASW DECISION AID) WHICH COMPUTES OPTIMUM PLACEMENT OF A SONOBUOY FIELD IN TERMS OF DETECTION PROBABILITY, MEAN HOLDING TIME, NUMBER OF BUOYS, ETC., ANOTHER IS TAPS (TOWED ARRAY PREDICTION SYSTEM) WHICH DISPLAYS PROBABILITY OF DETECTION WITH RANGE FOR VARIOUS NOISE LEVELS AND TOW DEPTHS. ALL OF THE TACTICAL PROBLEMS CAN BE WORKED FROM EITHER END. TASDA WAS DEVELOPED BY NADC FOR AIR ASW, TAPS FOR SURFACE UNITS BY AN ONR CONTRACTOR. ICAPS' ENVIRONMENTAL FILES ARE BASED ON A SUITE OF OCEANOGRAPHIC MODELS AND CLIMATOLOGICAL STATISTICS DESIGNED AND ASSEMBLED BY NAVOCEANO.

The difficulty of providing real-time answers to ASW tactical problems of sensor depth and search pattern is a basis for the at-sea Acoustic Performance (APP) Prediction Program, which combines operational parameters of specific detection equipment in a Task Force with local environmental variables (existing or forecasted) in a suitable acoustic performance model to give probabilities of detection for various combinations of deployments.

Computer models are employed at the Fleet Numerical Weather Central to forecast sea conditions for general operational use

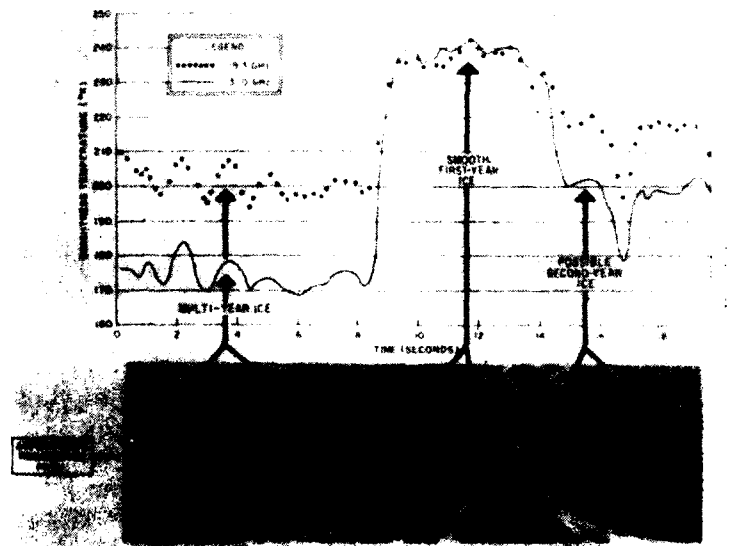
and many special purposes; e.g., ship routing, ASW predictions, search and rescue, salvage, and pollution dispersal. Wave forecasts have been greatly improved in the last decade through development of directional spectral models that permit determinations of total energy in a given wave field, rather than approximations derived from wave height and period values that are considered statistically representative. Continuing progress is being made to apply prediction model spectra to real-time problems and to expand the forecasting area. An insufficient density of observations, rather than inadequate models, is now the chief obstacle to attaining worldwide coverage.

Current developmental efforts are relying on satellites to fill the data void. Sensors, data validation, and translation techniques are being investigated so that these expectations can be realized. The greater density and accelerated data collection rates suggested by current satellite technology should enhance the probability of improving the forecasting models as well. Though vastly superior to predecessor models, the need for even more accurate forecasts is surfacing as the Navy develops smaller and faster ships and sophisticated weapons that are critically responsive to sea conditions.

For resupply operations in polar regions, ice forecasts are a primary feature of environmental support. Whether airlift or sealift, the areal coverage or concentration, type, thickness, density and roughness of ice cover are essential information needed to plan and execute the mission. Extent of ice pack limits and the opening and closing dates of ports are important for safety and scheduling--the logistical detail involved in staging a resupply operation (or an experiment) in polar areas is staggering.

Location and size of leads in the ice, and the probabilities of their remaining open, are vital to the safety of sealift cargo. Icebreakers and some larger supply ships carry helicopters to resupply these features, and icebreakers are scheduled periodically throughout the shipping season maintain a "hot" watch on them. Nonetheless, it is a rare season in the Arctic or Antarctic when icebreakers, even icebreakers, are not grounded (and damaged) by the presence of closing leads.

The dynamics of sea ice and its behavior under given conditions of wind and currents are functions of the internal and external stresses and the physical dimensions of ice features above and beneath the surface. Remote sensing technology is being applied to recognize key conditions and support experimental work on ice dynamics. When an operation is underway, the value of real-time measurements cannot be overstated. SYNRAMS, a Synoptic Remote Access Measurement System developed in 1974 as an Arctic research tool, is a self-contained device that measures atmospheric



ice overflight with microwave radiometer produces clues about the age and condition of the canopy. The separation in Brightness Temperature at two different frequencies reflects the dielectric properties of the ice (density, porosity, etc.). These in turn indicate whether the ice is new and smooth, (essentially homogeneous) or is multiyear ice, which tends to be rough because of past pressures that cause hummocking and rafting.

parameters at remote locations. Equipped with on-demand telemetry, it is a potentially excellent data source for improving short range ice forecasts.

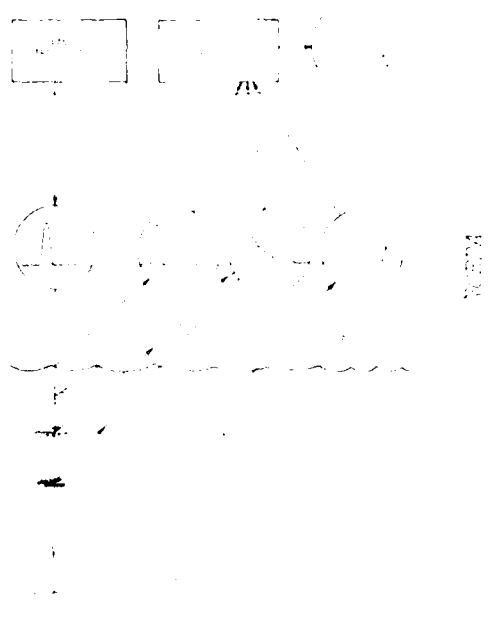
#### MAPPING AND CHARTING

Ocean science support of hydrographic survey functions includes improved techniques for obtaining coastal and deep ocean bathymetry and development of algorithms for deep sea survey design, which balances line spacing against the error inherent in a specified level of accuracy.

Beach and nearshore topography--coastal configuration, beach gradient, presence of bars and reefs--determine navigability of landing craft and ability to land. When these topographic conditions are known, present techniques of surf prediction can be used to show which parts of a section of coast will have the lightest surf under any given conditions of sea and swell, making it possible to plan military operations well in advance along with options suitable to the most probable conditions.

Coastal hydrographic surveys--with measurements obtained in closely-spaced grids precisely positioned from shore-based navigational stations--are the optimum way of acquiring nearshore data. The Naval Oceanographic Office conducts continuing program of such surveys for the Defense Mapping Agency. Using acoustic echo sounding equipment, small launches run survey lines close to shore while a large mother ship sounds the area farther out. The process is very time consuming: tracks must be tightly spaced so as not to miss small, potentially hazardous features and the launches must go slowly enough to avoid damage from such features or floating debris so common in coastal waters. This kind of operation is possible only where friendly governments control the beaches.

To expedite the survey process and eliminate the need for launches in the shallowest water, a remote sensing system, HALS (Hydrographic Airborne Laser Sounder), is being developed. HALS is an all active system that employs a neon laser transmitter and receiver and includes vertical orientation and electronic positioning to yield precisely fixed soundings in water



THE LASER BOTTOM PROFILER SIGNAL AT THE AIRBORNE RECEIVER CONSISTS OF THE SURFACE REFLECTED PULSE (SMEARED BY RETURNS OFF BIOLOGICAL SCATTERERS OR SUSPENDED SEDIMENT IN THE WATER) FOLLOWED BY A SMALL BUT DISTINCT PEAK THAT DENOTES THE BOTTOM. WATER DEPTH IS INFERRED FROM THE TIME LAPSE BETWEEN THE SURFACE AND BOTTOM RETURNS.

depths of twenty meters or more. The system will be mounted in Navy helicopters that are carried onboard the hydrographic survey ships for logistical support of survey ground crews. Although intended primarily as a navigational survey system, HALS has potential for beach reconnaissance as well. Digital cartography based on economic grids and computer economy that allow quick derivation of various maps and rapid answers to other mapping problems is a promising future capability now being developed.

#### MARINE FACILITIES CONSTRUCTION

A substantial share of the research on coastal processes supports engineering requirements for facilities construction and maintenance. Longshore currents, sediment

transport, beach erosion, surf characteristics and bottom properties influence the stability of structures and determine where they should--or should not--be placed. Designs for deep and shallow water moors and anchoring systems depend on bottom currents and seabed properties. Related to such considerations of marine engineering but not part of the Ocean Science Program directly, is research and development on structural components and techniques to overcome inevitable adverse environmental effects. The Civil Engineering Laboratory (CEL) at Port Hueneme, California, under the Naval Facilities Engineering Systems Command, is the Navy's principal research and development activity concerned with these problems.

In a relatively new line of investigation, coastal oceanographers are determining the importance of surf beat in nearshore dynamics. Surf beat is a low frequency surging motion generally present in the very shallow waters of the surf zone. Under certain combinations of beach slope and wave set, resonances of considerable energy are generated. Laboratory test tank studies and a recent field experiment are looking at this problem.

The vulnerability of structural materials to chemical constituents of the oceans, the degradation or destruction caused by its biological inhabitants

(biodeterioration), and methods of countering these effects are also engineering problems that the Ocean Science Program is helping to solve. Research on boring and fouling organisms--habitats, life-cycles, and various physiological properties--is being performed by biological oceanographers in order to develop effective controls. Natural nonpolluting methods are being stressed.

New and conclusive evidence on the high rates of wood borer attack in the deep ocean is a surprising result of this research; until recently deep ocean benthic populations were believed relatively benign. These borers attack a wide variety of substrates including plastics and synthetic lines.

Successful control studies are highly dependent on the ability to follow marine borers through their entire life cycles in the laboratory, a feat now possible for several critical species. Bacterial and fungal slime films that precondition surfaces for borer and fouling organism colonization have been identified. Cellulase enzymes from the fungi markedly alter initial rates of borer attack. Among several non-toxic, naturally occurring compounds found to inhibit the formation of these slimes, tannins appear to be especially effective, reducing attack by borers and fouling organisms alike.



WOOD BORERS AT  
WORK - PIER  
STRUCTURE  
WEAKENED TO POINT  
OF COLLAPSE.



An underwater cutting tool being developed for general ocean technology support has applications for both underwater construction and salvage operations. Efficiency has now reached 90 inches/hour in 1/4" aluminum plate. The technique employed is a cavitating water jet which has negligible reaction force and no torque, both of which limit cutting and drilling operations under water.

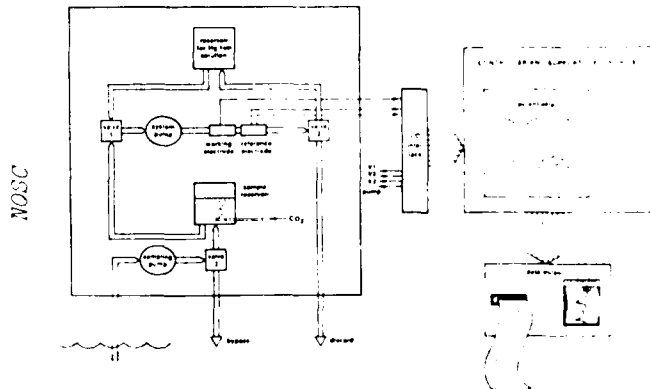
ENVIRONMENTAL PROTECTION

A major objective of the Navy's environmental protection program is to gain better understanding of the effects of naval operations on inshore and nearshore environments and ecosystems. Sites of heavy Fleet concentration--Norfolk, San Diego, and Pearl Harbor, for example--are of special concern.

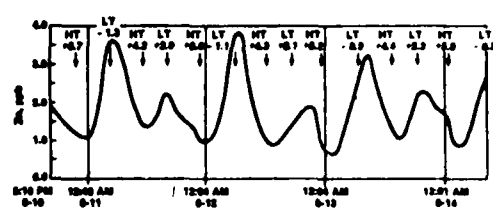
The crux of protecting the oceanic environment is having a baseline against which to evaluate the effects of changes. Since life in the ocean, which is the real concern, is inextricably linked with the supply of organic nutrients and the balance of inorganic chemical constituents of the water, it is important to know what organic and inorganic properties are "normally" present and in what proportions. The ocean can assimilate a certain level of pollution, out how much is too much? What is the rate of decontamination? How quickly can a population depleted by toxic additives or dredging operations restore itself? How to control noxious, dangerous, or damaging ocean inhabitants without creating a different, perhaps worse, form of danger or damage? These kinds of questions drive ocean science support of environmental protection objectives and have helped kindle vigorous support for marine chemistry.

In fact, no ocean science field has been more pronouncedly impacted by the interest in environmental quality than chemical oceanography, especially the analytical branch. For many years an adjunct to biological, geological and physical oceanography, chemical oceanography now has independent stature, commanding significant resources to meet well defined research goals.

The availability of minicomputers and microprocessors has helped; added to chemical sensors, clever instruments now calibrate themselves, collect samples, add reagents, mix and shake, atomize, read results and process data. Continuous and real-time measurements of chemical constituents of sea water show the same marked variability as physical properties display, pointing up the fallacy of drawing conclusions about concentrations and dispersion rates of contaminants from conventional single samples.



FLOW-THROUGH SYSTEM DEVELOPED AT NOSC FOR AUTOMATED SAMPLING AND ANALYSIS OF TRACE METALS IN SEAWATER.



FLUCTUATIONS OF Zn CONCENTRATION WITH TIDAL PERIOD IN SAN DIEGO BAY. "HT" AND "LT" DENOTE HIGH AND LOW TIDES FROM THE 10TH TO THE 14TH OF JUNE.

One of the smart new chemical instruments is an automated trace metal analyzer developed by the Naval Ocean Systems Center. The analyzer, which can be used in place or underway, employs an electrochemical technique called anodic stripping voltammetry (ASV) to measure zinc (Zn), copper (Cu), lead (Pb) and cadmium (Cd). The metals are amalgamated at constant potential with a thin mercury film plated inside a graphite tube. After being concentrated in the film for a few minutes, the applied potential is decreased. The metals are rapidly released, the diffusion out of the film causing a series of current peaks to appear on a strip chart recorder.

Many known constituents of industrial pollutants were not analyzed in sea water as a matter of course until recently. A robust

research effort is now underway to develop new techniques of analysis. The primary objective of this effort is to determine the respective roles of the various trace constituents in the sea, and to determine that determine and regulate the general character of the sea. It is also aimed at discovering a reliable method of measuring constituents. The order of the effort is to be determined. Some of the processes that take place are associated with biological phenomena in the sea, such as sediment-sediment exchanges, and biological and inorganic reactions that affect the general composition of the water.

Studies of radioactive tracers in the form of pollution have led to using the known decay rates of the tracers as indicators of circulation, water mass, and vertical mixing near the seafloor.

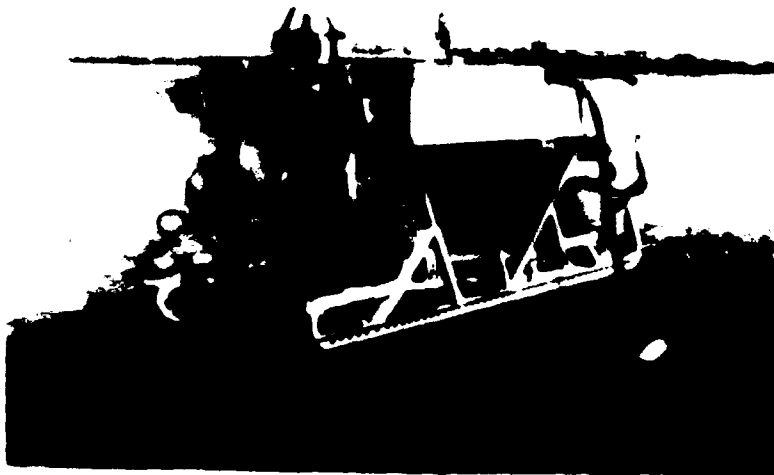


SHIPBOARD SCIENTIST HANDLING RADIOACTIVE MATERIALS FOR ANALYSIS.





THE CURV III SYSTEM, ORIGINALLY CONCEIVED AND DEVELOPED BY THE U.S. NAVY WITH A DEEP OCEAN (7,000 FT.) RECOVERY CAPABILITY, IS THE RESULT OF A SYNERGISTIC EFFORT IN BOTH TECHNOLOGY AND OPERATION WITH THE U.S. MARINE CORPS. SYSTEMS OPERATIONS HAVE INCLUDED DREDGE SPILL RECOVERY, OIL SPILL DISPOSAL AREA SURVEYS, THE RECOVERY OF THE ENTER TEAM (ET) REMAINS (ISAR) TRANSMITTER, AND REPAIR AND REINSTALLATION OF THE REMAINS COMPONENTS OF THE AZORES FIXED ACOUSTIC RANGE (AFAR).





The system uses a flying spot scanner and an argon ion laser light source, and provides optical pictures of the seafloor from a 120-foot height with a 400-foot swath width. ROMS can be towed at speeds from zero to 5 knots. Other potential uses include close range classification and inspection, extension of vision to remote undersea work systems, and salvage operations.

Salvaging very large objects from depths beyond the reach of divers poses major problems. The Large Object Salvage System (LOSS), developed by the Naval Coastal Systems Center, provides the Navy an improved capability to recover large objects in depths to 350 feet. The objects can have any shape and displacement, can weigh as much as 3000 tons, a weight range that includes submarines and submersibles, surface ships, missiles, and aircraft. Operational demonstration of the system has been successfully completed.

LOSS consists of large pontoons with rigid shells that are remotely controlled through an umbilical cable, and a Pontoon Replacement Vehicle (PIV) that "flies" the pontoons down to the exact location of the object to be recovered. Once down, the pontoons can be adjusted to fit the object being recovered by means of adjustable arms, fitted with automatic grappling or explosive stud attachments, which rigidly attach the pontoon to the sunken object. Once the pontoons are attached, gas or air is used to force water out of the pontoons and provide the necessary lifting power to bring the object to the surface in a controlled ascent. Upon reaching the surface the control umbilical is disconnected and the entire assembly is towed to port.

In shallow water, where the PIV is not needed, the pontoons can be lowered directly from the salvage ship and attached to the object. All controls of the pontoons and PIV are executed from the salvage ship through control umbilicals.

Buoyancy generation for the LOSS is provided by the self-contained liquid nitrogen system (LN<sub>2</sub>) or air. The LN<sub>2</sub> is stored in cryogenic dewars, and heat is extracted from the ocean to vaporize the LN<sub>2</sub> to provide dewatering gas. The entire pontoon system is operated at depth near ambient pressure, eliminating the need for heavy pressure hulls.

Controlling the lift of a system is a major problem in salvage operations, particularly at great depth. An overbuoyant condition is required to break an object free of the bottom. When the breakout occurs, however, conventional systems start a rapid, uncontrolled ascent to the surface, which usually spells disaster for the salvage attempt.

The LOSS pontoons have a 100-ton lift capability per pontoon and use a rigid shell to control the amount of gas and water to maintain constant buoyancy and thereby eliminate uncontrolled ascent. The system uses ballast chain as anchors. As the object/pontoons rise, they lift links of the anchor chain off the bottom until the suspended chain compensates for the lift forces of the overall system and neutral buoyancy is achieved. The LOSS pontoons and object are then brought to the surface by paying out cable attached to the anchor chain which retains control of the lift.

#### OTHER

Technology advancement in computer science, remote sensing, deep ocean moorings, underwater photography and navigation support almost every area of ocean science research. The quality of underwater photographs today is approaching an art form. The detail and scope of coverage obtainable permit very fine analyses of the ocean floor that are providing new insight into dynamic processes and theoretical concepts of seafloor formation and sediment distributions.

Accurate navigation is essential to a rapidly growing proportion of research at sea. Electromagnetic positioning first gave us accuracies of less than a mile in limited areas by means of Loran A nets. These characteristically were of limited use a few hundred miles off coasts along which transmitting stations were operated. In a favorable place in a Loran A area navigational accuracy exceeded one mile. Loran C extended the area over which LM navigation could be used, but essentially worldwide navigation to the order of a mile or better came only with the advent of TRANSIT, a system of satellites from whose signals positions of receivers could be had roughly every 1.5 hours. TRANSIT made a

major improvement in scientific navigation, but more accuracy, say, to the order of meters. Even less than 1 meter is needed for a significant number of Navy research projects. These needs will be filled in part by LSTAR, a system of satellite transmitters capable of higher accuracy than TRANSIT.

The Navy has long been aware of acoustic means of achieving highly accurate positioning by employing the transmittal of

precisely scheduled sound waves. Such systems are used to control the height of cameras above the sea floor to within a few meters. More recently, they have also been used for relative motion underwater with precision of the order of a few centimeters in a space of kilometers.

Except for LSTAR, which has a unique capability, all these systems are part of or their equivalent are being developed now.



THE INTERACTIVE DIGITAL SATELLITE IMAGE PROCESSING SYSTEM (IDSIPS) is a computer-based system that provides for easy human interaction in the processing and analysis of satellite remotely sensed data. Data exploitation is stressed as opposed to data collection. The IDSIPS facility is connected by phone line to the NOAA-NESD Satellite Field Services Station in Washington, D.C. for near real-time reception of GOES and selected VHR data. Users operate a display terminal with trackball controlled cursor; graphic information such as bathymetry charts can be entered via a camera input system. Analysts have over one hundred applications and routines to call upon for image enhancement or geometric correction, statistical analysis, image enhancement, etc.

## CHAPTER 5

### INTERNATIONAL/NATIONAL COOPERATIVE PROGRAMS

The Ocean Science Program encourages the conduct of large multidisciplinary programs by Navy laboratory/contractor consortiums or in conjunction with other national or international organizations. It is only by combining resources and expertise that some large-scale problems can be attacked at all. The benefits of these programs to the ocean sciences are enormous: large data bases of many different variables measured concurrently in space and time, advanced technology for instruments and other potential Naval hardware, and increased knowledge and understanding of complex oceanographic/meteorological phenomena which are important to the Navy's environmental prediction requirements. The programs described in this chapter are representative of the national and international cooperation that the Navy Ocean Science Program sponsors or contributes to in a supporting role.

#### United States Climate Program Plan (USCPP)

The U. S. Climate Program Plan (USCPP) is designed to enable the nation to respond effectively to climate-induced problems by anticipating climatic fluctuations in domestic, national security, and international contexts, and to identify man's impact and potential influence on regional and global climate. The plan is a guide and reference to developing a National Climate Program for Federal agencies involved in various aspects of climate and weather research and services.

The Department of Defense (DOD) Climate Program Plan that responds to the USCPP focuses first on integrating observations in space, atmosphere, cryosphere, ocean and the terrestrial area into timely analytical data sets for an extended forecasting base.

Since large-scale oceanic processes play a fundamental role in controlling climatic fluctuations, climate research and technology require the expertise of oceanic

as well as atmospheric scientists. Improvements in the ability to predict the climate involve a better understanding of atmospheric interactions with oceanic heating and cooling patterns and of the differences in these patterns, now and in the future.

The Navy Oceanographic Program has a major investment in oceanography and climatology, particularly in ocean forecasting, environmental impact assessment, and ocean data collection. The Fleet Numerical Oceanography Center (FNOC) analyzes distributions of weather variables and prepares synoptic analyses of wave heights and sea surface temperatures based on ship and satellite data every day. FNOC has the capability of model simulation for environmental forecasting and impact assessment as well as for dynamic data base generation and operation.

Major research programs relevant to climate problems and funded at least partially by the Office of Naval Research (ONR) include the North Pacific Experiment Program, NORPAX; Indian Ocean Experiment, INDOEX; Joint Air-Sea Interaction Project, JASIN; and POLYMODE, all of which are described in this chapter. Such Navy research activities, performed as an integral component of the national security mission, complement and support a National Climate Program.

#### International Decade of Ocean Exploration (IDOE)

The International Decade of Ocean Exploration (IDOE) was an international cooperative program with the overall objective of promoting oceanographic research efforts that would contribute to better understanding, preservation, and utilization of the global ocean for the benefit of all mankind. IDOE projects were structured to meet program goals in four major problem areas: environmental quality, environmental forecasting, seabed assessment, and living resources. Developing a world monitoring system,



improving worldwide data exchange, and increasing opportunities for international sharing of responsibilities and costs for ocean exploration were correlative goals. In the United States, the IDOE was planned, managed and funded by the National Science Foundation (NSF), which promoted substantial interactions with other U. S. agencies, including the Navy. Several of the large multidisciplinary projects supported by the Office of Naval Research over the past several years have been joint enterprises with NSF (IDOE) and are described below.

#### GARP Global Weather Experiment (GWE)

The Global Atmospheric Research Program (GARP), jointly sponsored by the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) through adopted resolutions of the General Assembly of the United Nations, is an international program utilizing the newly emerging capability of space-based observing techniques in meteorology to improve weather forecasting worldwide. GARP's basic goal is to understand the factors and processes that control weather fluctuations. Lack of global data has been a major obstacle to further progress in predicting large-scale motion of the atmosphere and long range weather forecasting.

GARP is comprised of five research and/or observational programs: numerical experimentation, global, tropical, air-surface interaction, and radiation programs. The global program receives input from all other GARP units and is designed to assemble a complete data set appropriate for study of large-scale motion of the atmosphere for periods of one day to a season.

The GARP Global Weather Experiment (GWE), also called the First GARP Global Experiment (FGGE), is the main observational part of the program. Begun in 1977, GWE is a effort to measure the large-scale state and of the entire atmosphere over a period of approximately one year with two one-month periods of intensified observations.

Another GWE objective is to develop methods for assimilating, processing, and disseminating the observational data in near-real time. The GWE Data Management Plan includes a network of worldwide, regional and special data centers. As part of the U. S. contribution, the Fleet Numerical Oceanography Center (FNOC) has been designated the Specialized Oceanographic Data Center (SODC). As SODC, FNOC assumes the responsibilities of GWE Level II-b (Global Experiment Research Data Set) oceanographic data management.

The GWE may be the largest concerted international scientific effort ever attempted. The detailed planning and coordination of all programs involved and prospects of accomplishing GARP goals have stimulated activities in more than a dozen countries.

#### The North Pacific Experiment (NOPPAX)

The North Pacific Experiment (NOPPAX), now in its ninth year, has as its objective to analyze and understand the interactions between ocean and atmosphere on space scales of weeks to years, with the aim of learning more about the causes of low frequency fluctuations of the ocean-atmosphere system. Emphasis is placed on the role of the upper ocean, and research is conducted chiefly on phenomena of the Pacific Ocean. A better understanding of the dynamics of ocean-atmosphere interactions on these scales should eventually lead to improved long range weather and climate predictions for the Northeast Pacific Ocean and North America.



Prior to 1971 the Office of Naval Research was the sole source of support for NORPAX; subsequently, by formal interagency agreements, NORPAX has undergone an expansion of effort under joint sponsorship with NSF (IDOE). At the present time, there are about thirty co-principal investigators at fifteen academic institutions and government laboratories here and abroad engaged in NORPAX. Although the main sources of support are ONR and NSF (IDOE), some individual NORPAX investigators are subsidized by other Navy sponsors, NASA, and NOAA. Participants from Germany, France, England and Japan are supported mostly by their own governments.

Management of NORPAX resides with the co-principal investigators, who annually elect representatives to an executive committee which oversees the entire program, formulates plans and policy, coordinates various activities, and represents NORPAX to the sponsoring agencies and the outside scientific community. Members of the executive committee select a chairman who is assisted by the program administrator.

Most of the NORPAX activities can be subdivided into three general groups: the Anomaly Dynamics Study (ADS), the Equatorial Dynamics Study (EDS), and the Atmospheric Climate Study (ACS).

The Anomaly Dynamics Study focuses on the several processes responsible for the development of large-scale, near-surface, thermal anomalies. Navy support is primarily directed to this study because of its application to underwater sound propagation. To test various hypotheses about these processes, a major field experiment is underway in the central mid-latitude North Pacific. Planned for a minimum of five years (1976-1981), the experiment consists of the measurement of surface currents using satellite tracked drifting buoys, measurement of the ocean thermal structure to the 500 meter depth using expendable bathythermographs from ships and aircraft, measurement of the

density field over limited time and space intervals, calibration of the wind stress fields used by FNOC for forecasting, and the computation of surface heat fluxes from standard ships' weather reports.

The ADS treats oceanic phenomena too large and long lasting to be studied by classical observational techniques. Research vessels, for example, cannot cover broad areas in all seasons for the years necessary to adequately characterize the development of anomalies. A particularly successful data collection program implemented for the ADS has been TRANSPAC, which utilizes ships-of-opportunity to obtain about 500 XBT observations per month along the trade routes from the U.S. to Japan. Half of these ships are of Japanese registration. In addition to serving the scientific needs of ADS, TRANSPAC provides over 50% of the synoptic XBT data radioed into the FNOC from the Pacific region. A TRANSPAC extension into the equatorial Pacific between 20°S - 20°N (called EQUAPAC) involving French scientists from the Office de la Recherche Scientifique et Technique Outremer (ORSTOM) in New Caledonia is also operative.

The NORPAX Equatorial Dynamics Study (EDS) focuses on the banded east-west current system that exists in the low-latitude Pacific. Immediate goals are to describe the space and time variability of the currents and to establish the design for a relatively inexpensive observational system for monitoring long-term interannual fluctuations. A major field experiment, coinciding with the period of the GARP World Weather Experiment, is now in progress. Although the EDS is primarily an NSF-funded effort, the Navy is assisting with data collection. For a previous experiment, eight long range P-3 aircraft provided by the Naval Reserve, NAVOCEANO and NOAA, dropped AXBT's to obtain frequent temperature profile sections between Hawaii and Tahiti. Similar assistance is being provided for the current experiment.

A third component of NORPAX, the Atmospheric Climate Study (ACS), is designed to investigate ocean/atmosphere interaction on climatic time scales. Scientists working in this area use large historical data bases to develop statistical/phenomenological models of the response of the atmospheric circulation to sea surface temperature anomalies. Using these techniques NORPAX scientists were able to forecast the general patterns of surface temperatures in the U.S. during the winters of 1976-77 and 1977-78.

NORPAX has already demonstrated some of the potential benefits to be derived for terrestrial and marine weather forecasting. Though the research objectives are fundamental in nature, the scientific philosophy of the program has been pragmatic, emphasizing quantitative results, and pacing experimentation with data processing, analysis, modeling and evaluation.

#### POLYMODE

POLYMODE is an international cooperative investigation of low frequency, medium-scale motions in the sea. The program focuses on the statistics and dynamics of mesoscale eddies, which, since the early 1970's have been recognized as a dominant factor in the medium frequency processes in the ocean. Little is understood, however, about the role of eddies in the large-scale oceanic circulation or their possible influence on underwater acoustics applications, meteorological phenomena, marine biology, and the distribution of chemical and physical properties in the sea.

POLYMODE participants are the U.S., U.S.S.R., U.K., France and West Germany (F.R.G.). The U.S./U.S.S.R. activities are coordinated under a bilateral agreement administered by NOAA; the Canadian and European work is coordinated through UNESCO/International Oceanographic Commission's Scientific Committee on Oceanographic Research (SCOR). U.S. efforts are funded by ONR and NSF (IDOE). Initial publication of results is expected in 1980.

POLYMODE builds on two previous large-scale, intensive eddy experiments conducted in the 1970's. The POLYGON (USSR) and MODE-1 (US/UK) programs studied and documented the presence of mid-ocean eddies and tentatively explored their nature and importance. POLYMODE experimentation began in 1975 and concluded in 1979. The experimental program is divided between statistical-geographical exploration and local dynamics. These areas are complementary, and were carried out simultaneously with some overlap in space.

The statistical-geographical work is aimed toward determination of the geographic occurrence and variability of eddies in the North Atlantic Ocean. Arrays of 6 to 12 moored stations were set by the U.S. on either side of the Mid-Atlantic Ridge and in the North Equatorial Current; by the U.S.S.R. on the Hatteras Abyssal Plain; by Canada in the Gulf Stream Extension region; and by a U.K./France F.R.G. group in the northeastern basin of the Atlantic. Each of these arrays was in place for a year or more. The final U.S. array was recovered in October 1979.

The local dynamics work was designed to examine one or more eddies closely for a shorter time in one location and provide a quantitative assessment of the processes involved and the dynamics of an eddy. The intensive experiment (Local Dynamics Experiment) took place in May-July 1978 on the Hatteras Abyssal Plain.

Theoretical efforts in POLYMODE included modeling eddy processes and comparing the results with field observations. A number of theoretical and empirical modeling efforts are in progress both within the U.S. and in cooperation with the U.S.S.R. Exchange and interpretation of POLYMODE data will take place on several levels. All data will eventually be archived in the World Data Center.

## Mixed Layer Experiment (MILE)

The Mixed Layer Experiment (MILE) was a joint U.S.-Canadian investigation into processes governing the structure of the upper ocean, with the ultimate goal to predict the state of the upper ocean for any given set of atmospheric influences. Particular attention was given to the deepening of the well-mixed layer during the passage of storms.

The observational phase of the experiment took place about 600 miles west of Vancouver Island in the vicinity of Ocean Station P (50°N, 145°W) during the late summer of 1977. Three ships and 10 major experimental groups, supported by ONR (lead agency), NAVOCEANO, NOAA, NSF, Environment Canada, Canadian Coast Guard, and Canadian Forces, worked together to obtain detailed meteorological measurements and spatial/temporal observations of currents, temperature and salinity at numerous depths with particular emphasis on the upper 100 meters of the water column.

Most oceanic current models are two-dimensional with a horizontally uniform ocean assumed. Development of more realistic models depends on understanding how the three-dimensional near-surface structure evolves under storm conditions. For this, measurements of vertical mixing processes as well as meteorological and other oceanographic data are required.

MILE brought together a coordinated experiment that was possible only because of successful instrumentation developments supported in previous years by the Ocean Science Program. MILE was designed to achieve the next level of understanding of the mixed layer and to assist in establishing a capability for calculating from external parameters (surface fluxes) the future state of the upper ocean in terms of mean and statistical representations of currents, temperature and salinity. Such a predictive capability of upper ocean dynamics would have valuable applications to supporting surveillance and ASW systems.

Data analyses will be conducted over the next several years with emphasis on timely completion of the analyses and dissemination of results to the scientific community.

## Joint Air-Sea Interaction Project (JASIN)

The Joint Air-Sea Interaction Project (JASIN) was initiated by the United Kingdom by a proposal of the Royal Meteorological Society in 1966, and is part of the Global Atmospheric Research Program (GARP). JASIN's objectives are to observe and distinguish between the physical processes causing mixing in the atmospheric and oceanic boundary layers to relate them to mean properties of the layers, and to examine and quantify aspects of the momentum and heat budgets in the atmospheric and oceanic boundary layers as well as the fluxes across and between them. Approximately half of the project is devoted to meteorological observations and half to oceanography, with many of the programs strongly overlapping the disciplines. Although the meteorological aspects of JASIN involve both large- and small-scale processes, many of the oceanographic efforts are on scales smaller than some tens of kilometers in the horizontal, and time scales less than a day. The goals and methods overlap those of MILE, the advantage of JASIN being a greater concentration of ships, aircraft, and people during a longer and larger field experiment.

Field trials in 1970, 1972, and 1977 were devoted to preliminary exploration of scientific and engineering aspects of the intended major joint experiment, which occurred in July-September 1978 northwest of Scotland in an area bounded approximately by 57-60°N and 9-14°W. The site was chosen to maximize the chances for a sequence of strong meteorological inputs to the upper ocean, and the experiment was designed to observe both the inputs and the oceanic response to them. Meteorological ships and buoys were stationed at the corners of a 200 km-on-a-side triangle embedded in a

larger area covered by oceanographic moorings. Roving hydrographic ships continuously surveyed the larger area, and six to eight oceanographic ships maintained work schedules in an intensive mooring zone in the middle of the meteorological triangle.

The Royal Society is the lead agency; other participants are Australia, Canada, Denmark, Ireland, F.R. Germany, Netherlands, and the United States. The last four countries provided ships and aircraft for the observational programs. Eleven U. S. laboratories representing private academic institutions, NOAA and the Naval Postgraduate School are involved. There is also other Navy scientific participation for satellite sensor validation and imaging. Major funding for the U. S. contribution is provided by ONR and NSF.

A data meeting held in 1979 will be followed by a science workshop in 1980, probably in Europe. Scientific results are expected to appear in 1980-1981.

#### Indian Ocean Experiment (INDEX)

The Indian Ocean Experiment (INDEX) is the oceanographic complement to the international meteorological Monsoon Experiment (MONEX), both being parts of the First GARP Global Experiment (FGGE). INDEX is exploring the interactive role of the ocean with the Indian summer monsoon, the strongest, large-scale, long-period variable forcing that the atmosphere exerts on the ocean. Preliminary field work was begun in 1973, with especially intense observations in 1975 and 1976, in order to design the experimental program for the FGGE period, 1979. The areas of principal interest during FGGE are the development of the structure of the upper layers in the Arabian Sea in advance of the monsoon; the onset and structure of the Somali Current, especially the various inflows and outflows; the time and space variability of eddies off East Africa and their relationship to other circulation phenomena; and the vertical distribution of current along the Equator in the western Indian Ocean, particularly the

zonal and temporal variation in the upper thousand meters.

INDEX was designed as an IDOF project and is being supported in the United States by NSF, ONR, AND NASA. Foreign participants, comprising research groups from the United Kingdom, West Germany, Soviet Union, Italy, India, France and Australia, are supported for the most part by their own governments. Much local work is being accomplished through significant cooperative efforts with Kenya and Somalia.

Data sources include satellite, ships-of-opportunity, and military ships and aircraft, including Indian naval vessels, in addition to the research platforms of several participating organizations.

Less than a decade ago, little was known about the Indian Ocean beyond the general outlines of the circulation systems. The large data base provided by INDEX efforts contributes not only to understanding the dynamic processes in the air-ocean environment, but are highly supportive of anti-submarine and environmental prediction in this complex ocean area where the United States has growing economic and military concerns.

#### FRAM (Arctic Research Program)

The first field phase of the Arctic research program FRAM, after Fridtjof Nansen's notable Arctic research vessel and expedition (1893-1896) of the same name, commenced in March 1979. Investigators from seven institutions in four countries (Canada, Denmark, Norway and the United States) encamped on a drifting ice island approximately 200 nm north of Greenland. Studies are being conducted in oceanography and meteorology, sea floor properties, ice dynamics, underwater acoustics and polar bear migration. The field program encompassed about four weeks, serving as a successful pilot project for FRAM II, for which experimental work is scheduled to begin in March 1980. Plans are to locate the scientific party again on a large floe, and about 200 nm

farther to the north, if possible.

#### RIVERA OCEAN SEISMIC EXPERIMENT (ROSE)

The Rivera Ocean Seismic Experiment (ROSE) is a multi-institutional project to study the structure and physical properties of a young oceanic plate and its associated fracture zones and ridge crest. Emphasis is on propagation of low frequency seismic energy in oceanic crust. Early in 1979, approximately 60 ocean bottom seismometers (OBS's) were deployed on the East Pacific Rise near 12°N off the west coast of Mexico. This area is a young ocean basin still being formed as the continental crust drifts away from the Mexican mainland. The experimental plan included an active phase in which air guns and explosives provided controllable seismic sources, and a passive phase, which used the large number of earthquakes on the active Rivera Fracture Zone as high energy, low frequency sources. Scientists had estimated no less than a ninety percent chance of a measurable quake occurring during the experiment; in fact, one quake measuring 4.5 on the Richter Scale did occur, as well as several smaller disturbances.

Energy levels recorded at the OBS's during both phases are being analyzed for seismic propagation, attenuation, and anisotropy in the oceanic crust. Additional experiments included digital multichannel seismic profiling, ocean volume acoustics using a vertical hydrophone array embedded in the OBS array, and seismological recording stations on Baja California and mainland Mexico. The field work required approximately two months. It will be a least two more years before all the data analysis and interpretation are completed. Special arrangements have been developed for sharing and ultimately archiving a mass of data that will probably equal a year's output of the World-Wide Seismological Network.

ROSE is being jointly sponsored by ONR and NSF. In addition to six private U. S. universities and institutions engaging in this project, scientists from two Navy laboratories and investigators from Mexico and France also participated.

The scientific objectives of the experiment cover a wide spectrum of interests.

Thickening of the lithosphere with age will be investigated from seismicity along the Rivera Fracture Zone and thickening of the crust with age from refraction data. Other planned studies concern acoustic wave propagation across the ridge crest; shear velocity of the crust and upper mantle; geometry of any magma chamber at the rise axis; correlation of variations in "layer 2" velocities with age, and anisotropy in the upper mantle and variation with age. Such Ocean Science Program research not only contributes fundamental scientific knowledge of geophysical properties of the Earth, but has the potential of demonstrating how low frequency seismic energy propagates in oceanic crusts, a phenomenon with practical ramifications for the Navy in its sea control mission.

#### GEOSECS

GEOSECS (Geochemical Ocean Section Study) is an IDOE program and the most extensive chemical oceanographic research project ever conducted. The objectives, to establish global ocean baselines for monitoring environmental quality and provide input for quantitative analyses of oceanic mixing and circulation modelling, require that the analytical methods used by all participants be standardized. Years of instrument and technique development preceded the six-year sampling program, which concluded in 1978. Nearly 400 stations were occupied in the Atlantic, Pacific and Indian Oceans. The stations were located along north-south transects that generally coincide with the paths of bottom water movement. Samples of water and suspended materials collected at up to 44 depths are being analyzed for nearly 40 physical and chemical constituents. By comparing the concentrations of these at the various levels and locations, it should be possible to draw quite reliable conclusions about the mixing and reaction processes in the deep ocean, and interchange of material between the deep and surface layers and the exchange of water and gases with the atmosphere. GEOSECS involves laboratories and scientists from seven European and Asian countries, Canada, and fourteen institutions in the United States. The R/V's MELVILLE

and KNORR, AGORs assigned to the Scripps and Woods Hole Institutions of Oceanography, respectively, conducted most of the field work. Although the National Science Foundation is the principal funding agency, the Ocean Science Program contributes through support of research facilities and individual scientists. In exchange, the Navy's oceanographic technology base is significantly enhanced by addition of an extensive, unique data set that will support environmental protection and ocean modelling research for many years.

#### HIGH ENERGY BENTHIC BOUNDARY LAYER EXPERIMENT (HEBBLE)

The High Energy Benthic Boundary Layer Experiment, HEBBLE, is a series of investigations to determine the role of high energy bottom current events in causing variations in the structure, composition and acoustic properties of deep ocean sediments. The probability that this goal can be successfully accomplished is to a large extent contingent on a second goal: to apply NASA's system engineering expertise to oceanographic problems, and transfer the technology to ocean scientists.

The HEBBLE plan evolved from workshops sponsored by ONR in 1977 and 1978 to promote interaction among diverse groups working on boundary layer problems. The benthic boundary layer is defined as extending from a few tens of meters above the ocean floor to a few tens of centimeters below it in the oceans' abyssal plains. Surprisingly strong currents occurring intermittently within this layer mark the high energy zones, which are associated, in general, with the western boundary currents.

The site selected for HEBBLE is in the western North Atlantic, on the Scotian Shelf. There are several elements to the project: site surveys and physical reconnaissance to identify suitable areas; laboratory experiments; modelling and simulation; several 3-day deep sea experiments to determine necessary measurement rates and positions; and one or more 6-month experiments to

investigate the temporal and spatial variations of the high energy boundary layer and its interactions with the seabed. The 6-month phase is designed around a network of seafloor landers, which are being developed under NASA contract by the Jet Propulsion Laboratory of the California Institute of Technology. A Master Lander and nearby vertical array, surrounded by 3 or more Outstation Landers several kilometers away, will be placed on the ocean bottom in the Western Boundary Undercurrent at about 5000 meters depth. Individually, the landers, holding vertically mounted, multi-instrumented arrays, will provide measurements of the current velocity, temperature, conductivity, and concentration of suspended particulate matter at several depths as a function of time. Simultaneously, the network will provide data on the horizontal distributions and spatial gradients of these variables. The Master Lander array will also obtain shear stress within the Layer by means of an acoustic sensor; sediment characteristics using a shear vane; particulate size, density and flux, using acoustic backscatter, holographic and optical techniques; and photographs of the bottom with five cameras. All systems have data storage capacity for up to 6 months.

At least a dozen ONR contract institutions and Canadian research organizations are planning participation in HEBBLE. The Navy's practical interest in the benthic boundary layer involves numerous questions about physical, geological, chemical and biological effects on hardware and the resultant implications of these interactive processes on various strategic concerns. Results of HEBBLE will also bear on the feasibility of nuclear waste disposal beneath the sea floor. In view of the Navy requirements and the interest of several of the civilian agencies; e.g., the Department of Energy, DOE's planning efforts and future support of HEBBLE are timely new thrusts in the Ocean Science Program.



## Maritime Remote Sensing Experiment (MARSEN)

MARSEN, a field measurement program focussing on coastal zone and shallow water problems, took place from July to October 1979 in the North Sea. Over 200 investigators from the United States, West Germany, France, Netherlands and the United Kingdom participated. U. S. sponsors were ONR, NASA and NOAA.

The experiment was designed around several major research objectives, the most important being to investigate the interactions of surface wind, waves, currents and storm surge, including in particular the transformation of waves and currents in the nearshore zone. This is one of the most difficult coastal zone oceanographic problems, and its successful treatment requires the simultaneous measurement of many different processes. The goal is a joint storm surge/wind wave prediction model that will take full account of the interaction among the various processes and with the variable bottom topography.

Surface currents in the presence of ocean waves and the ocean wave spectra were measured by means of HF- and Dual-frequency microwave scattering. Wave rider buoys, pressure sensors and wave staffs provided direct wave measurements; aircraft obtained data by synthetic aperture radar (SAR) techniques. Laser profilometer records were also obtained by aircraft. Currents and sea level measurements were provided by conventional meters and tide pressure gauges.

A second experimental objective was to obtain sufficient data to construct new models to predict the dependence of the modulation transfer function on ocean wavelength, microwavelength, wind speed, wave and wind direction, concentration and type of surface active material, and other environmental parameters. This effort comprised tower-based measurements with microwave scatterometers operating at different frequencies, satellite and aircraft data, and *in situ* measurements of two-dimensional wave spectra and other variables for comparison with the remote sensing data.

Measurements of the wave-induced modulation of the atmospheric boundary layer immediately over waves were also taken.

MARSEN also investigated the feasibility of using infrared and microwave radiometers and synthetic aperture radar imagery from both aircraft and satellites as an all-weather capability to track oceanic fronts.

Other objectives involved chemical sea-truth measurements, artificial sea slick experimentation, and a study of aerosol generation by white caps.

The observational density achieved is probably the most intense ever attempted. Oceanographic and meteorological data were collected by seven ships provided by West Germany and the U. K., two research towers and several oil platforms already in the North Sea and at 10 island and coastal stations. Additionally, about 25 moored buoys and 25 drifting buoys recorded wave motions. Eleven instrumented aircraft were provided by the U. S. and West German Air Forces, NASA, and participating agencies from France, The Netherlands, and West Germany. The TIROS-N and NIMBUS-G satellites obtained areal data in almost real time. NIMBUS primarily observes atmospheric phenomena. TIROS-N, with the highest resolution infrared sensor capability of all the spacecraft, was most useful for detecting oceanic fronts and general mapping of sea surface temperature in clear air.

MARSEN exemplifies the advantages of multi-institutional, interdisciplinary research. By combining resources, a spectrum of scientific objectives involving interactive processes and observational techniques could be approached as a continuum on realistic time and space scales, a feat never before possible and one that none of the countries participating would have been able to accomplish independently.



## NORWEGIAN SEA EXPERIMENTS (NORSEX)

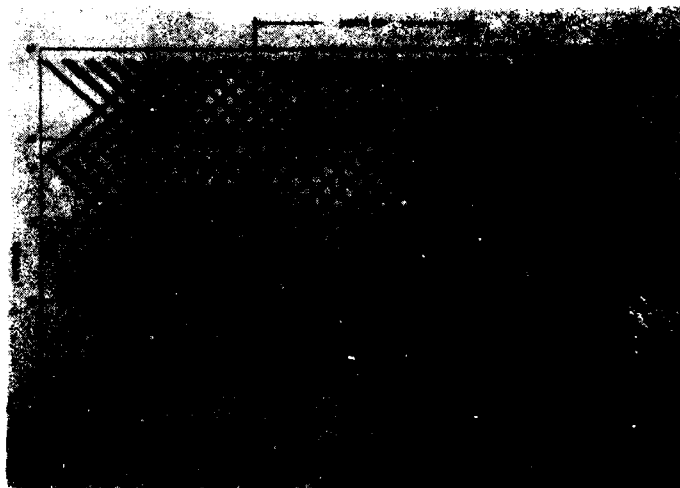
The Norwegian Sea Experiments are a set of bilateral experiments conducted by the Navy in cooperation with Norway and are concerned with oceanography including remote sensing, ice in the Barents Sea, and near-shore oceanography west of southern Norway. ONR contractors and NRL scientists participated in the "Coastal Experiment", one of many in NORSEX, carried out in March 1979 within a rectangle of 5 degrees longitude by one degree latitude near Bergen, Norway. The scientific goals of that experiment were to obtain data on internal waves and to investigate frontal processes and their relationships to waves, eddies and biological variations; mixing processes, in particular the mixing of fjord water with coastal and Atlantic water; and the time and space variability of surface currents and surface waves under the influence of meteorological processes, upwellings and fjord inflow. The U. S. participants, using an NRL aircraft (P3) and U. S. satellites collected microwave and dropsonde data for atmospheric and aerosol investigations. The Norwegians are providing an extensive program for surface measurements using five special research vessels plus ships of opportunity, six moored buoys, several drifting buoys, and thirteen oil platforms.

## SEASAT-A

Developed specifically as an oceanographic observational platform, SEASAT-A failed in orbit after 99 days owing to electrical system malfunction. Despite a disappointingly short life, the satellite nonetheless achieved its primary objective: to demonstrate the utility of microwave sensors for nearly all-weather remote sensing of the oceans. SEASAT covered 95% of the global oceans every 36 hours, transmitting information on sea surface winds, sea surface temperature, wave heights, internal waves, atmospheric water, sea ice features, ocean topography and the marine geoid. The wealth of unique data obtained is without precedent in the ocean sciences, and the evaluations thus far completed indicate that, in most cases, the measurement resolution obtained either met or

surpassed expectations.

Due to the global research effort required to prove the new sensors carried aboard SEASAT, international cooperation was essential in proving the satellite. A significant degree of European interest has been shown in this program and several activities are involved. The Navy Ocean Science Program will maintain interest and possible cooperation with the international SEASAT research activities. SEASAT Users Research Group of Europe (SURGE) -- a working group of the European Association Remote Sensing Laboratories (EARSEL) affiliated with the European Space Agency (ESA) -- has been formed to coordinate the application of data from SEASAT in European oceanographic research. The first priority interest of SURGE is the validation program which is being coordinated by NASA for proof-of-concept of the SEASAT sensors in detecting ocean phenomena quantitatively. Areas selected on the basis of quantity and quality of usable sea truth are the North Sea and the JASIN area.



SEASAT-A COVERAGE FOR A 60-DAY PERIOD WHEN CORE IS EXTRACTED EVERY THIRD DAY.

## CHAPTER 1

### FACILITIES OF THE OCEAN SCIENCE PROGRAM

Oceanography is more than a bench science. The character and quality of oceanographic research, and the achievements attained in understanding oceanic processes, are directly related to the platforms, instruments and other special equipment that ocean scientists have available to them.

#### SHIPS

The ROBERT D. CONRAD (AGOR-3) delivered in 1962 was the first new construction ship built by the Navy especially for ocean research, and only the fourth U.S. ship built for that purpose alone. When the Navy embarked on a vigorous oceanographic ship building program in 1960, it culminated ten years of effort by the Office of Naval Research to generate support for a modern U.S. ocean research fleet. Through the 1960's the Navy funded some twenty new vessels for oceanographic research and exploration. The AGOR - Auxiliary General Ocean Research - class ships underwent several design changes in the course of the construction period. MELVILLE (delivered 1969) has cycloidal propellers fore and aft that enable her to maintain a fixed geographic position (station) in currents of 1 knot and 40-knot winds. HAYES (d1 1971) is a catamaran. The last AGOR, MOANA WAVE (d1 1975) and her sister ship, GYRE, are configured after the supply boats used in the oil industry. They have long, open afterdecks ideally suited for easy installation and removal of heavy equipment, and for handling large instrument arrays. Some of these ships were provided to ONR's principal contractors; others were assigned to various of the Navy laboratories.

The high cost of ship operation, however, has reduced the number of AGORs still in service to 12, and has led to a search for more efficient ways of managing the limited assets.

The Naval Oceanography Command now operates a "pool" of three AGORs for use by the Navy Laboratories. At ONR contract laboratories, university and institutionally owned research vessels are often used in addition

to the Navy owned fleet. The University of Texas at the National Oceanographic Laboratory System and other coastal universities have independent divisions in the Navy program. In addition to the academic research fleet, the NEW HORIZON, built for and delivered to the Scripps Institution of Oceanography, is in the State of California.

Additionally, NA contributes to the management of the University-National Oceanographic Laboratory System (UNOLS), an association of academic laboratories created to provide a mechanism for planning and coordinating the use of oceanographic ships and other facilities. The Coast Guard, National Marine Fisheries Service, Bureau of Sport Fisheries and Wildlife, and the National Oceanic and Atmospheric Administration (NOAA) also provide ships to support or participate in Navy research projects from time to time.

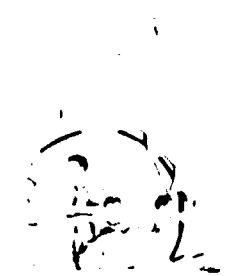
#### SUBMERSIBLES

Dreams of using submersibles to make direct observations that would supplement and verify surface measurement data, at least, from Alexander the Great. In more recent times, as oceanography matured to a full-fledged science, there has been an increasing desire for a means of direct observation, particularly at the seafloor/water interface, or benthic boundary layer. After the United States' entry into the deep submersible field with the Navy-purchased (from Jacques Piccard) bathyscaphe TRIESTE, a diverse family of manned submersibles has emerged, ranging from small, one-man submarines for exploration of the continental shelf to vehicles capable of extended operation at great depths and under the Arctic icecap. In the continuing development of deep sea research vehicles, the goal is to operate at any depth safely. Materials are being fabricated and tested; techniques of life support, navigation, communications, bottom mapping photography, direct viewing and in-situ measurements and sampling have been and are being developed to improve vehicle capability. New methods for providing power for propulsion and life support at great depths are under investigation.

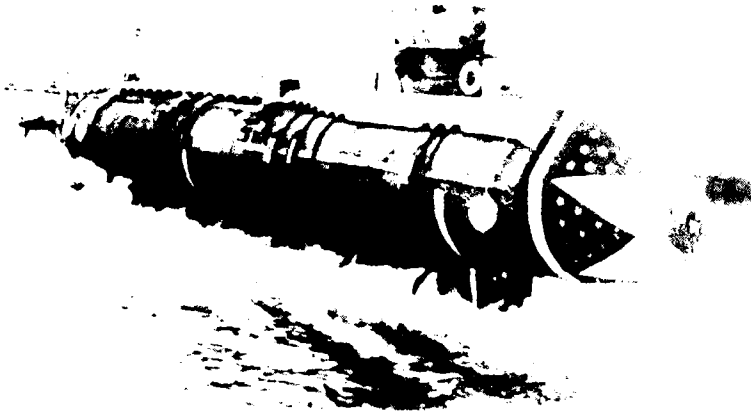
The ALVIN (Albatross Light Vehicle) was developed by the Naval Oceanographic Laboratory, San Diego, California, for the Navy's deep-sea research program. It is the world's first manned submersible capable of operating at depths of 6,000 meters (20,000 feet) and is the only one of its kind. The ALVIN was designed to provide a safe and comfortable environment for the crew while operating at depths of 6,000 meters (20,000 feet). The ALVIN is a self-contained, self-sufficient, and self-sustaining submersible. It is capable of operating at depths of 6,000 meters (20,000 feet) and is the only one of its kind. The ALVIN was designed to provide a safe and comfortable environment for the crew while operating at depths of 6,000 meters (20,000 feet). The ALVIN is a self-contained, self-sufficient, and self-sustaining submersible. It is capable of operating at depths of 6,000 meters (20,000 feet) and is the only one of its kind. The ALVIN was designed to provide a safe and comfortable environment for the crew while operating at depths of 6,000 meters (20,000 feet).

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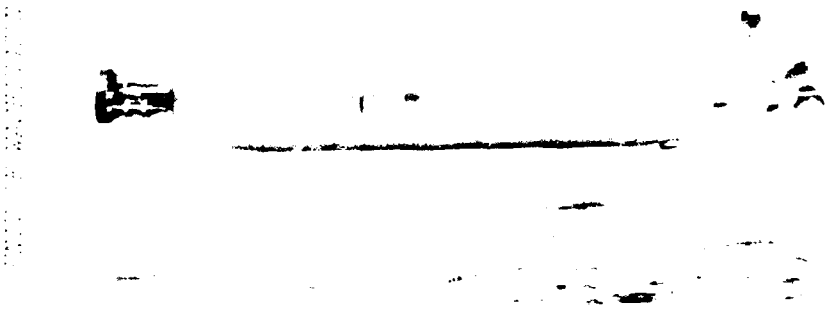
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(A) SCHEMATIC OF ALVIN SHOWING LOCATION OF INSTRUMENT PACKAGES, NAVIGATION EQUIPMENT, PRESSURE SPHERE, ETC.

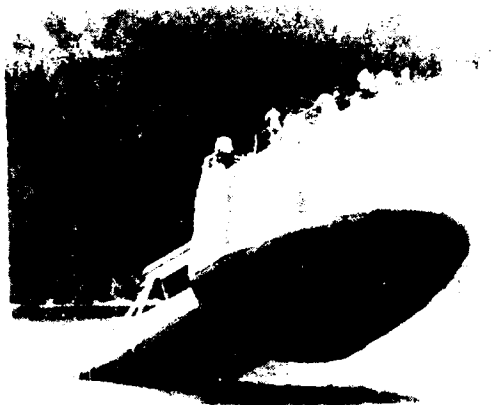


THE NUCLEAR RESEARCH SUBMARINE NR-1.

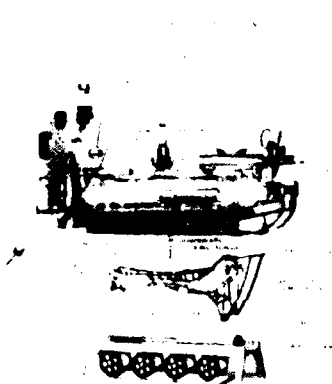


SELF PROPELLED UNDERWATER RESEARCH VEHICLE (SPURV) IS AN UNMANNED VEHICLE WITH A DEPTH CAPABILITY OF 3600 M. (12,000 FT.). THE VEHICLE IS CURRENTLY BEING USED IN THE STUDY OF MICROVARIATIONS IN THE OCEAN STRUCTURE.

FLOATING INSTRUMENT PLATFORM (FLIP), A SIO RESEARCH PLATFORM, BEING ERECTED (FLIPPED) TO A VERTICAL POSITION FOR ON-STATION OCEAN ACOUSTIC DATA COLLECTION.



VERSATILITY OF THE DEEP TOW INSTRUMENTATION SYSTEM, DEVELOPMENT OF WHICH BEGAN IN 1960 BY THE MARINE PHYSICAL LABORATORY (SIO), IS INDICATED BY OPTIONAL ADDITIONS SUCH AS THE REMOTELY CONTROLLED PLANKTON NET FOR DEEP OCEAN BIOLOGICAL SAMPLING, AND REMOTELY CONTROLLED WATER SAMPLE BOTTLES.



ALVIN PREPARING FOR LAUNCH. THE BABY SUBMARINE IS OPERATED BY THE WOODS HOLE OCEANOGRAPHIC INSTITUTION FOR THE U.S. RESEARCH COMMUNITY. COSTS ARE SHARED BY NAVY (ONR), NOAA AND NSF.



## AIRCRAFT AND SATELLITES

Several aircraft specifically designed and equipped for oceanographic research support numerous studies in the Navy Research Program. The Naval Research Laboratory technically controls and operates four aircraft: an NC-121, two P-3As and an S-2. The Naval Oceanographic Office technically controls and operates three aircraft: two P-3As and a P-3D. Services of other aircraft owned by the Navy and/or other government agencies are utilized frequently for scientific investigations through special arrangements. These highly specialized aircraft are equipped with an extensive array of oceanographic, acoustic, and meteorological instruments; integrated, computer-operated navigation systems consisting of inertial, satellite, and Loran A-C navigation capabilities; and sophisticated, computer-controlled data recording/processing systems. The basic oceanographic/meteorological sensors include an infrared radiation thermometer, a helium-neon laser for profiling ice ridges and ocean surface waves; expendable telemetering bathythermographs for vertical sea temperature profiles; an infrared scanner for mapping surface thermal features; meteorological instruments for measuring flight-level air temperature, humidity, pressure, and dew point; mapping camera and strip camera. In addition, the aircraft are capable of accurately placing sonobuoys and SUS (Sound Underwater Signal) charges for acoustical measurements, and charting the earth's magnetic field with magnetometers and gradiometers. Low light level television (LLLTV) systems and photometers have also been used experimentally to obtain measurements of bioluminescence. New applications of these aircraft in oceanographic research and surveys are added each year. Their employment for checking-out and demonstrating the validity of different satellite sensor systems was (and is) an important step toward using satellites to obtain near-synoptic oceanographic observations globally.



RP-3A ORION AIRCRAFT USED BY NAVAL RESEARCH LABORATORY FOR OCEAN RESEARCH

The global nature of oceanographic and meteorological monitoring problems of the Navy make satellites uniquely suited to many of the required observations, and a number of these are already being made. Two navigational satellites are benefitting ocean research at sea, so much of which is dependent on very accurate positioning. Measurements of current speed obtained from an ice platform, itself in motion, have been improved by accurate positioning, which permits determination of rate of drift. Use of satellites for telemetering oceanographic data from remote buoy systems has been successfully achieved in several research incidents (e.g., MODE, TORPAX).

Satellite measurements of the sea surface temperature (SST) have been refined to the extent that NOAA's National Environmental Satellite Service (NESS) recently initiated an operational SST product with an accuracy of  $+1.5$  to  $+2.0^{\circ}\text{C}$  absolute ( $+1.0^{\circ}$  relative) using the NOAA Scanning Radiometer sensor. Refinements of the data processing scheme involved corrections of atmospheric attenuation by humidity and cirrus clouds and inclusion of surface truth information from ship observations. Beginning in 1978, more precise measurements ( $+1.0^{\circ}\text{C}$  absolute,  $+0.5^{\circ}\text{C}$  relative) were obtained from the Defense Meteorological Satellite Program (DMSP) satellite and the

TIROS-N Advanced Very High Resolution Radiometer and Operational Vertical Sounder. Scanning Multichannel Microwave Radiometer (SMMR) data from NIMBUS-G and SEASAT-A should provide all-weather SST measurements with an accuracy of approximately  $\pm 1^{\circ}\text{C}$ .

SEASAT-A, the only satellite designed solely for ocean monitoring, produced proof of a satellite's potential for quantitative research purposes, as well as for synoptic environmental observations. SEASAT-A was jointly sponsored by Navy, NASA and NOAA to investigate the feasibility of microwave sensors for obtaining near all-weather observations. A wealth of data was transmitted before an electrical failure occurred after only 99 days in orbit. SEASAT's suite of sensors included a radar altimeter, microwave radar scatterometer, synthetic aperture imaging radar (SAR), microwave radiometer and a visible and infrared radiometer (VIRR). The altimeter measures wave height to within a meter, and the ocean geoid (as departures from a perfect spheroid) to within 10 centimeters. Repeated measurements of the surface topography permit detection of changes caused by gravity variations, deep ocean tides, surges and currents. The scatterometer measures fine scale surface roughness to obtain wind speed and direction; the SAR provides imagery of ocean waves, ice roughness and concentration, and coastal conditions to a resolution of 25m over a 100 km swath. The radiometers measure the temperature of the sea surface and image ocean, coastal and ice features. The microwave sensor also obtains a measure of foam brightness, from which wind speed can be derived, and can "see" through clouds. The visible and infrared radiometer can only image the earth's surface in clear weather; otherwise, cloud cover patterns are produced.

Although Navy environmentalists already make fairly heavy use of satellite data for prediction and research, the potential has barely been tapped. Satellites already -- or soon to be -- in orbit have been variously designed and instrumented for particular purposes, but the spin-off benefits for ocean science can be great, even so, and the Ocean Science Program supports efforts to ensure that these possibilities are not overlooked.

Methods for data handling and exploitation are being developed at a number of laboratories for a wide range of applications.

Environmental data used by Navy activities for various research, development, and operational projects and programs have been obtained from the DMSP, NOAA (TIROS), NIMBUS, HCMM, LANDSAT, SKYLAB, GEOS, SEASAT, and APOLLO satellites. Direct readout facilities have been developed for operational use aboard ships and at shore stations. The Satellite Processing Center at the Fleet Numerical Ocean Center began operations in 1978, and is capable of receiving and processing data from DMSP, TIROS, GEOS and SEASAT. Several R&D facilities for processing, analyzing and enhancing satellite data products for project support, sensor communications, and technical development also exist within the Navy program.

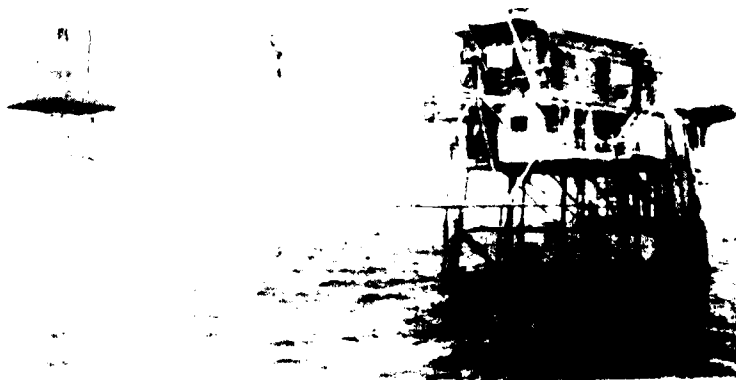
#### SPECIAL PLATFORMS

Data requirements for the diverse research sponsored by the Ocean Science Program cannot all be met by ships, submarines, satellites and aircraft. Long term records of shallow water phenomena can best be obtained from fixed ocean platforms, and three such platforms, or towers, are used in the Program: the Naval Ocean Systems Center tower near San Diego and two Naval Coastal Systems Center (NCSC) towers near Panama City, Florida. Sensor stability is extremely important in deep ocean acoustic research and cannot be achieved with ships. FLIP (Floating Instrument Platform) was developed by Scripps' Marine Physical Laboratory under ONR sponsorship to resolve this problem. FLIP is very stable in high sea states; it moves vertically less than one foot in waves 40 feet high. It is 350 feet long, can be towed from place to place while floating horizontally, and up-ended (flipped) to a vertical position on site. This technique allows transport at moderate speeds and permits equipment installation at dockside. In the vertical position, maximum draft is 500 feet, with facilities both above and below the waterline. FLIP, a veteran of many successful vigils on the high seas, can accommodate six to eight men for 30 days at a time.

DISCUS BUOYS, 12 M. IN DIAMETER, ARE BEING DEPLOYED BY THE NOAA DATA BUOY OFFICE (NDBO) TO SELECTED SITES IN THE DEEP OCEAN TO OBTAIN SYNOPTIC DATA FOR WEATHER FORECASTING AND RESEARCH. THESE LARGE BUOYS, WEIGHING 20 TONS WITH MASTS EXTENDING 10 M. ABOVE MEAN SEA LEVEL, CARRY INSTRUMENTS FOR MONITORING METEOROLOGICAL VARIABLES (AIR TEMPERATURE, BAROMETRIC PRESSURE, WIND SPEED AND DIRECTION, AND RELATIVE HUMIDITY), WAVE HEIGHTS, AND SEA SURFACE TEMPERATURE, AS WELL AS ON-BOARD DATA HANDLING/PROCESSING CAPABILITIES WITH UHF AND HF RADIO/SATELLITE COMMUNICATION SYSTEMS.



OCEANOGRAPHIC RESEARCH TOWERS SUCH AS THE ONE OPERATED OFF SAN DIEGO BY NOSC PROVIDE FIXED PLATFORMS IN COASTAL WATERS FOR MONITORING OCEANOGRAPHIC AND METEOROLOGICAL PARAMETERS TO SUPPORT RESEARCH IN THE OCEAN SCIENCE PROGRAM.





Yet another special type of platform is the Oceanographic Research Buoy, ORB. ORB is a large square barge used to handle heavy objects at sea; a big center well protects instruments being lowered from the effects of wind and waves. ORB is not self-propelled and must be towed to its work site at sea.

The requirement for long term measurements at selected deep sea sites has led to use of platforms moored to the ocean floor to support instruments at desired depths. The largest of these are the "Monster" buoys, 40 feet in diameter, with sensors that measure and record 100 channels of scientific data and telemeter these to shore stations thousands of miles away on command. Both short and long (up to a year) memory devices store collected data. The first Monster buoy deployed in 1975 served as a master in an array of smaller buoys moored between Hawaii and Alaska for NORPAX. Synoptic, simultaneous measurements of atmospheric and ocean variables were obtained for air-sea interface studies. The family of deep sea buoys were developed by NOAA's Data Buoy Office, which is chartered to service interagency buoy requirements; much of the early technology behind such developments derived from research supported by ONR.

#### OTHER FACILITIES

The Navy Laboratories have unique, specialized facilities which, although not part of the Ocean Science Program, benefit it greatly. Such facilities are also used by other federal agencies. The arctic research pool at the Naval Ocean Systems Center is also used by the Coast Guard, for example. Operational test facilities such as the model basin and the pressure facility of the Naval Ship Research and Development Center are used by many agencies. The Civil Engineering Laboratory operates a deep ocean simulation laboratory, polar environmental laboratory, shallow water ocean simulation facility, diving locker and seafloor soils laboratory. The Naval Air Development Center maintains a ship motion simulation facility and an inertial navigation facility which are utilized in system integration and technical direction of the oceanographic survey vessels, including the Navigation and Sonarray Subsystems. Navy Coastal Systems Center's Ocean Simulation Facility is a unique hyperbaric tank housed in a three story building and consists of five dry

chambers and a large wet chamber capable of simulating water depths to 2250 ft. The principal purpose of this facility is to support development, testing and certification of manned and unmanned diving systems.

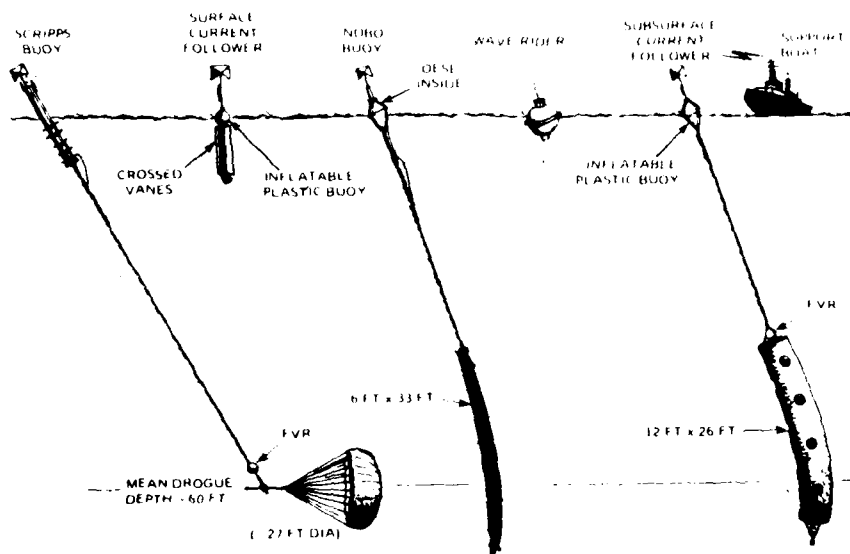
#### INSTRUMENTATION

Within the last five years, there have been significant new thrusts in oceanographic instrumentation development, driven by requirements for long term data from remote areas, and survey measurements of greater precision and resolution. Oceanography is benefitting from advances in electronics, cable and solid state technology; measurements which could not be made a few years ago are now not only technically possible but economically feasible.

Major advantages for ocean research will be the ability to measure ocean phenomena such as current shear directly and *en masse* and to obtain measures of certain properties, sound velocity, for example, directly rather than by computation.

The Expendable Current Profiler (XCP), which completed successful testing in October 1979, typifies the new generation of sensors. The XCP measures the variation in horizontal current velocity, or shear, between the sea surface and a depth of 800 meters. The measurement technique relies on geomagnetic induction principles: the interaction of layers of sea water moving horizontally through the earth's magnetic field sets up weak electric currents in the water proportional to the rate of movement. By measuring the voltages between horizontally spaced electrodes in a free falling body, it is then possible to obtain a vertical profile of current shear from a moving ship. Several hundred units have been fabricated for research programs in 1980 and effort is now directed toward achieving an efficient production design that will enable survey ships and ships-of-opportunity to obtain vertical shear measurements as easily as temperature profiles are obtained now. The original work through proof-of-concept was funded by the Ocean Science Program as a tool for basic research in physical oceanography; further development was supported under an advanced development task.

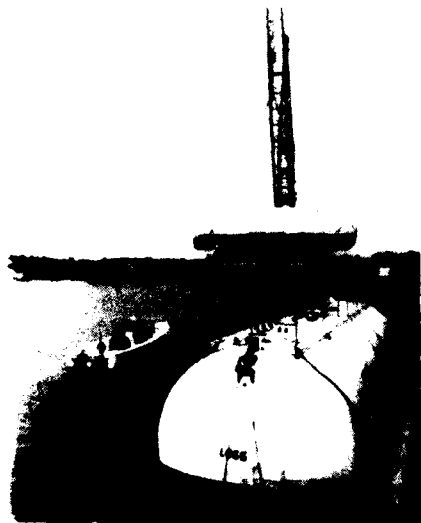
### DRIFTING BUOY CONFIGURATIONS (TYPICAL)



DRIFTING BUOYS ARE AMONG THE MOST PROMISING OF THE NEW TOOLS OCEANOGRAPHERS ARE USING TO STUDY OCEAN DYNAMICS AND AIR-SEA INTERACTION. TYPICAL CONFIGURATIONS SHOWN HERE ARE THE NOAA DATA BUOY OFFICE (NDBO) BUOY THAT WILL BE USED IN FGGE, THE WAVE RIDER BUOY TO BE USED IN MARSEN, AND OTHERS WIDELY EMPLOYED BY THE SCIENTIFIC COMMUNITY. TRACKING IS USUALLY ACCOMPLISHED WITH RADAR OR BY SATELLITES. FORCE VECTOR RECORDERS (FVRs) ARE USED TO MEASURE DROGUE DYNAMICS. THESE SELF-CONTAINED, BATTERY-OPERATED MOTION SENSING PACKAGES HAVE SIX SENSOR CHANNELS AND RECORD DIGITAL DATA ON INTERNAL TAPE CASSETTES. THE DATA RECORDED INCLUDE ACCELERATION, AZIMUTH REFERENCE, AND PRESSURE OR TENSION. THE FVRs SAMPLE EACH SENSOR CHANNEL APPROXIMATELY TWICE PER SECOND. BUOY MOTION IS MEASURED BY THE OCEAN ENVIRONMENT SENSING EQUIPMENT (OESE) AT THE SAME RATE AND TIME AS THE FVRs. DROGUES PREVENT THE BUOYS FROM RESPONDING TO WIND FORCES RATHER THAN WATER MOTIONS.

The Remote Environmental Data System (REDS), Cyclesonde, and Moored Vertical Profiler (MVP) are examples of programmable, self-contained sensor packages that can be implanted and left unattended for periods of weeks to several months. REDS is designed for coastal research and is placed on the bottom by underwater swimmers. The Cyclesonde and Moored Vertical Profiler are deployed from a ship by the anchor last technique and comprise a

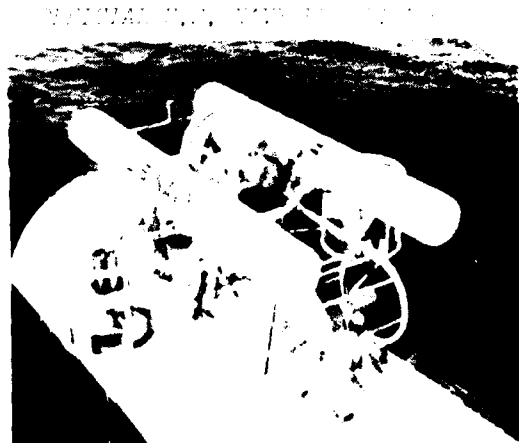
series of cable tethers and floats with an instrumented package that varies buoyancy via electronic command and measures water temperature, conductivity and pressure as it moves vertically through the water column at programmed intervals. The REDS and MVP, while operationally usable, are still one-of-a-kind instruments, but the Cyclesonde is now available commercially although not a mass production unit.



OFFICIAL U.S. NAVY PHOTOGRAPH

ALL SET FOR LOWERING TO OCEAN FLOOR-- THE PONTOON IMPLACEMENT VEHICLE (PIV) IS SHOWN BEING READIED FOR PLACEMENT ATOP ONE OF THE LOSS PONTOONS FOR ITS DESCENT TO THE OCEAN FLOOR. SCIENTISTS AND ENGINEERS AT THE NAVAL COASTAL CENTER DEVELOPED THE LOSS SYSTEM FOR SALVAGING LARGE OBJECTS FROM DEPTHS OF 850 FEET.

FIRST LEG OF THE JOURNEY-- ONE OF THE LOSS PONTOONS IS LOWERED INTO THE WATER WHILE THE OTHER RESTS AT DOCKSIDE AT THE NAVAL COASTAL SYSTEMS CENTER. EACH OF THE 50-FOOT LONG, 80-TON PONTOONS IS AN INTRICATE SYSTEM OF ELECTRONIC CONTROLS, HIGH PRESSURE VALVES, AND GAS GENERATING EQUIPMENT



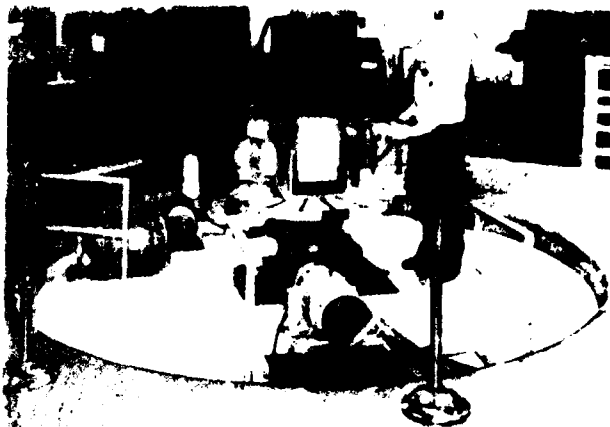
OFFICIAL U.S. NAVY PHOTOGRAPH



PONTOONS BEING READIED FOR TOW-- NAVAL COASTAL SYSTEMS CENTER DIVERS COME TO GRIPS WITH THE TASK OF PREPARING THE LOSS PONTOONS FOR THE TRIP TO PORT AFTER LIFTING THE TEST OBJECT, WHICH IS SUSPENDED BELOW. EACH OF THE PONTOONS HAS A LIFTING CAPABILITY OF 100 TONS FROM A DEPTH OF 850 FEET.



NADC'S INERTIAL NAVIGATION FACILITIES



NADC'S SHIP MOTION SIMULATION FACILITY



CEL'S DEEP OCEAN SIMULATION LABORATORY. TESTS INVOLVING IMPLOSIONS AND EXPLOSIONS CAN BE CONDUCTED IN ADDITION TO PRESSURE SENSITIVITY.



NORDA'S WAVE FACILITY



APPENDIX A

GLOSSARY OF OCEANOGRAPHIC TERMS

- Abyssal plains - Flat areas of the ocean basin floor which slope less than 1 part in 1000, mostly found at the base of the continental shelf.
- ACODAC - ACoustic DATA Capsule, a self-contained, mid-water system for obtaining vertical measurements of ambient noise.
- AGOR - A Navy ship designation, acronym for the Auxiliary, General Oceanographic Research class.
- AIS - Acoustic Imaging System.
- Ambient noise - The noise produced in the sea by marine animals, ship and industrial activity, terrestrial movements, precipitation, wind, and other underwater or surface activity outside the measuring platform and detection equipment.
- ASROC - Antisubmarine rocket, carried by surface ships.
- ASW - Antisubmarine Warfare. Includes operations conducted against enemy submarines, their supporting forces, and operating bases.
- Attenuation - The reduction in elastic or electromagnetic wave intensity caused by the spreading, absorption, and scattering of energy in air, water, sediments, rock and other materials.
- AXBT - Airborne Expendable Bathythermograph. A device launched from aircraft to obtain ocean water temperature as a function of a depth. Data are transmitted to the aircraft by radio link.

Benthic	-All submarine bottom terrain regardless of water depth.
Benthic Boundary Layer (BBL)	-The vertical layer extending from several tens of meters above the sea floor to a few tens of centimeters into the bottom of the earth's abyssal plains where the bottom depths are 1000m or more.
Bioluminescence	-The production of light without sensible heat by living organisms as a result of a chemical reaction within their cells or organs or extracellularly in the form of a secretion.
CEL	-Civil Engineering Laboratory.
CNM	-Chief of Naval Material.
CNO	-Chief of Naval Operations.
CNR	-Chief of Naval Research.
CTD	-Conductivity/Temperature/Depth sensor
CURV	-Controlled Underwater Recovery Vehicle.
DCNM	-Deputy Chief of Naval Material.
DMA	-Defense Mapping Agency.
DMSP	-Defense Meteorological Satellite Program.
DNL	-Director of Navy Laboratories.
DOD	-Department of Defense.
DOWS	-Deep Ocean Work System.
Echo Sounder	-A device for determining the depth of water by measuring the time interval between emission of a sonic or ultrasonic signal near the surface and the return of its echo from the bottom.
ED	-Exploratory Development.

EPA	-Environmental Protection Agency.
FGGE	-First GARP Global Experiment, also called Global Weather Experiment (GWF).
FLIP	-Floating Instrument Platform. A long tubular, partially submerged structure which provides a very stable platform (a spar buoy) for oceanographic observations when upended.
FNOC	-Fleet Numerical Oceanography Center, formerly Fleet Numerical Weather Central.
Fouling	-The mass of marine organisms that attach to submerged objects.
GARP	-Global Atmospheric Research Program.
Geophysics	-The physics of the earth, including fields such as magnetics, geodesy, geology, oceanography, and meteorology.
GOBI	-Geophysical Ocean Bottom Instrument.
HALS	-Hydrographic Airborne Laser Sounder.
HEBBLE	-High Energy Benthic Boundary Layer Experiment.
Hertz (abbreviated Hz)	-A unit of wave frequency equal to one cycle per second.
Hydrophone	-An electro-acoustic transducer that responds to waterborne sound waves and generates a corresponding electric wave.
Hydrothermal vents	-Tubular openings in the ocean floor near tectonically active areas from which water warmer than the surrounding bottom water emerges.
ICAS	-Interdepartmental Committee for Atmospheric Science
ICSU	-International Council of Scientific Unions.

IDOE	-International Decade of Ocean Exploration, 1960 - 1970, in which American participation was sponsored by the National Science Foundation.
IDSIPS	-Interactive Digital Satellite Image Processing System.
INDEX	-Indian Ocean Experiment.
<i>In situ</i>	-In the natural or original position. (Lat.)
JASIN	-Joint Air-Sea Interaction Project
Laser	-Light Amplification by Stimulated Emission of Radiation. Laser beams are concentrated light which can be converted to intense heat.
LLLTV	-Low Light Level Television.
LOSS	-Large Object Salvage System.
Mantle	-The shell of the earth, believed to be dense, ultrabasic rock that is nearly 2900 kilometers thick and lies just beneath the thin (5-50 km) crust of the earth.
MILE	-Mixed Layer Experiment.
MILOC	-MILitary Oceanographic field program conducted periodically by NATO members to improve ASW capabilities.
Monster Buoy	-A large (40-foot diameter) disc buoy which can be moored in deep water and instrumented to obtain and transmit meteorological and near-surface oceanographic data.
MPL	-Marine Physical Laboratory of the Scripps Institution of Oceanography.
NARL	-Naval Arctic Research Laboratory.
NAS	-National Academy of Science.
NASA	-National Aeronautics and Space Administration.
NATO	-North Atlantic Treaty Organization.



NAVELEX	-Naval Electronics Systems Command.
NAVOCEANO	-Naval Oceanographic Office.
NCAR	-National Center for Atmospheric Research.
NCSC	-Naval Coastal Systems Center.
NDBO	-NOAA Data Buoy Office.
NESS	-National Environmental Satellite Service, NOAA.
NOAA	-National Oceanic and Atmospheric Administration.
NOIC	-National Oceanographic Instrumentation Center, NOAA.
NORDA	-Naval Ocean Research and Development Activity.
NORPAX	-NORth PACific EXperiment. A large, long- term experiment to examine the relationship between prevailing weather patterns in the North Pacific and oceanographic phenomena.
NOSC	-Naval Ocean Systems Center.
NRL	-Naval Research Laboratory.
NSAP	-Navy Science Assistance Program.
NSF	-National Science Foundation.
NSRDC	-Naval Ship Research and Development Center.
OBS	-Ocean Bottom Seismometers.
OCEANAV	-Acronym for the Naval Oceanography Command which was established in 1978 and embraces all components of the former Naval Weather Service, the Fleet Numerical Oceanography Center, and the Naval Oceanographic Office. The same acronym perviously applied to the Office of the Oceanographer of the Navy.

OMAT -Ocean Measurement Array Technology.

ONR -Office of Naval Research.

ORB -Oceanographic Research Buoy.

OSP -Ocean Science Program.

OTH -Over-the-horizon.

PAR -Programmable Acoustic Recorder. A midwater vertical measurement system for recording such acoustic variables as ambient noise, propagation loss and bottom loss.

PIV -Pontoon Impacement Vehicle.

POLYMODE -A large scale, international experiment conducted in the mid-latitude region of the North Atlantic to study ocean dynamics.

Propagation -The transmission of energy through a medium.

RDT&E -Research, Development, Test and Evaluation. The Navy RDT&E appropriation is approved by the Congress annually.

REDS -Remote Environmental Data System.

Reverberation -Sound scattered toward the source, principally from the ocean surface (surface reverberation) or bottom (bottom reverberation), and from small scattering sources in the medium such as air bubbles and suspended solid matter (volume reverberation).

ROMS -Real time Optical Mapping System.

ROSE -Rivera Ocean Seismic Experiment.

RUWC -Remote Unmanned Work System.

SACLANT -Supreme Allied Commander, Atlantic - a NATO Command.

Scattering -The random dispersal of sound energy after it is reflected from the sea surface or sea bottom and/or off the surface of solid, liquid or gaseous particles suspended in water.

SCOR -Scientific Committee on Oceanographic Research, organized under UNESCO.

SEASAT -Sea Satellite, designed specifically for oceanographic observations; now inoperative.

Seismic profiler -A continuous deep-sea reflection system used to study the structure beneath the ocean floor to depths of 10,000 feet or more. The reflections are recorded on a graphic recorder whose stylus is synchronized with the initial sound pulse.

SHARPS III -Ships, Helicopter Acoustic Range Prediction System, a technique used at the Fleet Numerical Oceanography Center to estimate the performance of Fleet ASW sonars.

SIO -Scripps Institution of Oceanography.

SLUC -Sea Lines of Communication.

SMMR -Scanning Multichannel Microwave Radiometer.

SODC -Specialized Oceanographic Data Center.

SOFAR -SOund Fixing And Ranging. The method of determining the location of objects at sea by utilizing the acoustic transmission characteristics of the permanent deep sound channel in the ocean.

Sonar -SOund Navigation And Ranging. Refers to both the method and equipment for determining the presence, location, or nature of objects at sea by underwater sound techniques.

Sonobuoy -A free floating or anchored device that includes a buoy with radio telemetering equipment and a hydrophone suspended beneath.

SPURV -Self Propelled Underwater Vehicle.

SRB -Solid Rocket Booster.

SSBN -Submarine Ballistic Nuclear. Nuclear powered submarine carrying ballistic missiles.

SSP -Stable Semisubmersible Platform.

SST -Sea Surface Temperature.

Submersible -A general term designating the family of small submarines capable of useful work on the seafloor.

SURGE -SEASAT Users Research Group of Europe.

SUS -Sound Underwater Signal.

SYNRAMS -Synoptic Random Access Measurement Systems.

Thermocline -A layer of water in which temperature generally increases fairly rapidly with depth.

Transducer -A device that converts one form of energy to another, as from electrical to acoustic, or conversely.

Transponder -A device that emits upon interrogation an acoustic signal for navigation or location purposes.

Turbulence -A state of fluid flow in which the instantaneous velocities exhibit irregular and apparently random fluctuations.

UARS -Unmanned Arctic Research Submersible system.

UNOLS -University-National Oceanographic Laboratory System. An organization to coordinate research ship schedules and other facility use.

USCPP -U.S. Climate Program Plan.

WHOI -Woods Hole Oceanographic Institution.

WMO -World Meteorological Organization, an element of UNESCO.

XBT -EXpendable BathyThermograph. A device dropped from a moving ship to measure water temperature as a function of depth.

XCP -EXpendable Current Profiler. A probe dropped from a moving ship that measures current velocity as a function of water depth.

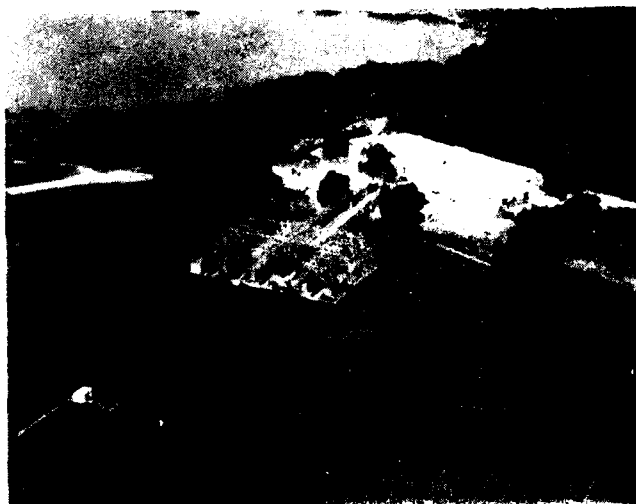
**Appendix B**  
**DIRECTORY OF NAVAL ACTIVITIES**  
**PARTICIPATING IN THE OCEAN SCIENCE PROGRAM**

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**Laboratories Reporting to the Chief of Naval Research**

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LABORATORY	MISSION
Naval Arctic Research Laboratory Barrow, Alaska 99723	To provide facilities and services for accomplishing those programs of basic and applied research which contribute to successful Navy Operations in Arctic Regions. In addition, the Naval Arctic Research Laboratory accomplishes specific tasks as may be assigned by the Chief of Naval Research in support of other Naval activities in the Arctic Region.
Naval Biomedical Research Laboratory Naval Supply Center Oakland, California 94625	To conduct research in microbiology and environmental biology.
Naval Ocean Research and Development Activity NSTL Station, Mississippi 39529	To carry out a broadly based Research, Development, Test and Evaluation Program in Ocean Science and Technology, with emphasis on understanding ocean processes through measurement and analysis, and the effects of this ocean environment on Navy systems and operations.
Naval Research Laboratory Washington, D.C. 20375	To conduct a broadly based multi-discipline program of scientific research and advanced technological development directed toward new and improved materials, equipment, techniques, systems, and related operational procedures for the Navy.



NRL's Underwater Sound Reference Detachment (USRD) in Orlando, Florida, is the Navy's "Bureau of Standards" for underwater sound measurements.

Laboratories Reporting to the Chief of Naval Material

LABORATORY	MISSION
Naval Air Development Center Warminster, Pennsylvania 18974	To be the principal Navy Research, Development, Test and Evaluation Center for Naval aircraft systems less aircraft launched weapons systems.
Civil Engineering Laboratory Port Hueneme, California 93043	To be the principal Navy Research, Development, Test and Evaluation Center for shore and fixed surface ocean facilities and for the Navy and Marine Corps construction forces. <i>Reports through NAVFAC.</i>
Naval Coastal Systems Center Panama City, Florida 32407	To be the principal Navy activity for conducting Research, Development, Test and Evaluation in support of Naval missions and operations that take place primarily in the Coastal (Continental Shelf) Regions. This includes, in particular, Research, Development, Test and Evaluation for mine countermeasures, diving and salvage, coastal and inshore defense (less ASW), swimmer operations and amphibious operations.
Naval Environmental Prediction Research Facility Monterey, California 93940	To conduct research and development directed towards providing objective local, regional and global environmental analysis and prediction techniques; and provide planning, modeling and evaluation services for determining the effect of environmental elements on Naval weapons systems. <i>Reports through NNAEP.</i>
Naval Ocean Systems Center San Diego, California 92152	To be the principal Navy Research, Development, Test and Evaluation Center for command control, communications, ocean surveillance, surface and air launched undersea weapons systems, and supporting technologies.
Navy Personnel Research and Development Center San Diego, California 92152	To be the principal Navy activity for conducting human resources Research, Development, Test and Evaluation in the areas of manpower, personnel, education and training, and to serve as the coordinating activity for all human resources Research, Development, Test and Evaluation support and services to the Systems Commands and to the CNM laboratories as necessary to augment and stimulate human factors efforts in the design, development, and evaluation of new systems for operational use.
David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084	To be the principal Navy Research, Development, Test and Evaluation Center for Naval vehicles and logistics and to provide Research, Development, Test and Evaluation Support to the U.S. Maritime Administration and the Maritime Industry.

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**Laboratories Reporting to the Chief of Naval Material (cont)**

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LABORATORY	MISSION
<b>Naval Surface Weapons Center Dahlgren, Virginia 22448</b>	To be the principal Navy Research, Development, Test and Evaluation Center for surface ship weapons systems, ordnance, mines and strategic systems support.
<b>Naval Underwater Systems Center Newport, Rhode Island 02840</b>	To be the Navy's principal Research, Development, Test and Evaluation Center for submarine warfare and submarine weapons systems.

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**ACTIVITIES REPORTING TO THE COMMANDER NAVAL OCEANOGRAPHY COMMAND**

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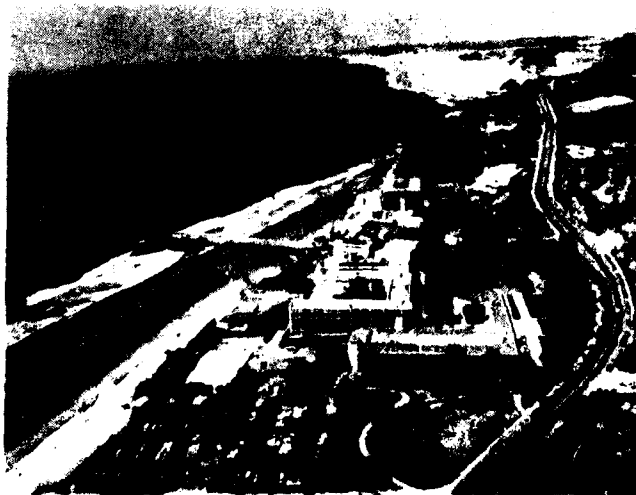
Fleet Numerical Oceanography Central Monterey, California 93940	To command assigned activities; to administer assigned oceanographic/meteorological programs relating to collection, analysis, prediction and dissemination of oceanographic/meteorological information requisite to Naval air, surface, and subsurface operations; to provide technical guidance in assigned oceanographic/meteorological matters throughout the Naval Service; to insure fulfillment of other DOD requirements for oceanographic prediction services; and to coordinate, as directed, research, development, test and evaluation related to, and supporting, the integrated Naval Oceanographic/Meteorological Program.
Naval Oceanographic Office NSTL Station, Mississippi 39529	To enhance the performance of the Navy by collecting, analyzing, and displaying oceanographic data (including hydrographic, geophysical and acoustic data) to support Fleet operations and Shore Establishment commands; to improve ocean predictions methods, data collection and analysis, and perform other related RDT&E; and to assist other DoD and U.S. activities and allied countries in training and otherwise meeting their oceanographic requirements.



FLEET  
NUMERICAL  
OCEANOGRAPHY  
CENTRAL

**Appendix C**  
**PRINCIPAL ACADEMIC INSTITUTIONS IN THE**  
**NAVY OCEAN SCIENCE PROGRAM**

NAME	ACTIVITIES
University of Alaska Barrow, Alaska 99723	Research in physical and chemical oceanography in inland waters of Southeast Alaska and the Gulf of Alaska. Air-sea interface studies. Research in sediment deposition as it affects long range sound propagation.
University of British Columbia Vancouver, British Columbia	Fundamental studies and research in oceanography. Studies of microstructure, air-sea fluxes at high wind speeds, temporal and spatial evolution of mesoscale features furthered by participation in the Mixed Layer Experiment in the Pacific and POLYMODE in the North Atlantic.
Scripps Institution of Oceanography University of California La Jolla, California 92037	Research covering oceanic circulation and variability, distribution of physical and chemical properties, and air-sea interaction; theoretical studies; geological studies; use of deep research vehicles. Development of oceanographic instrumentation, including radiological instrumentation. Development of buoy technology. Studies of electromagnetic fields, wave interactions and turbulence, physical and acoustic properties of sediments. Studies of the physiography of the ocean bottom as it affects sound propagation. Research in data collection, reduction, reports, filing and retrieval techniques. Marine Physics Laboratory works mainly in ocean acoustics.



SCRIPPS INSTITUTION OF OCEANOGRAPHY



NAME	ACTIVITIES
Lamont-Doherty Geological Observatory Columbia University Palisades, New York 10964	Research on a worldwide basis in geophysics with emphasis on acoustic properties of sediments, gravity fields over the oceans as they affect inertial navigation, development of gravity measuring instruments, geomagnetism as it affects magnetic detection, temperature structure of the ocean floor and its effect on long range acoustic propagation, physiography of the ocean bottom and the systematic collection of sediment cores throughout the oceans, and Arctic topography measurements.
Duke University Durham, North Carolina 27706	Research concentrated in marine biology, marine geophysics and oceanography in the North and South Atlantic and in the Mediterranean.
University of Hawaii Honolulu, Hawaii 96822	Research in physical oceanography and ocean currents of Hawaiian Islands and in marine geophysics of the tropical Pacific.
John Hopkins University (Chesapeake Bay Institute) Baltimore, Maryland 21218	Research on ocean dynamics in the coastal zone with emphasis on turbulence and internal waves as they affect detection systems. Studies of the generation and growth of wind waves and their scattering effect on acoustic signals. Development of mixed layer forecasting techniques for ASW planning. Study of chemical and optical properties of sea water as they affect optical or high frequency underwater systems.
Louisiana State University Baton Rouge, Louisiana 70803	Overall emphasis is given to the understanding and practical application of knowledge concerning the physical, chemical, biological, geologic and economic aspects of inshore wetlands and shallow water marine environments.
Massachusetts Institute of Technology Cambridge, Massachusetts 02139	Research in geology, geophysics, chemistry, and engineering. Development of oceanographic instrumentation, especially gravity measuring devices. Studies of gravity, heatflow, magnetics, and mantle temperature as they relate to long range sound transmission. Studies of internal waves, light scattering properties of particulates, and acoustic tracking in the sound channel. Prediction of subsurface currents based on modeling techniques.
University of Miami Miami, Florida 33124	Oceanographic investigation of tropical and subtropical regions. Emphasis on structural geology, the Florida Current, oceanic circulation, geochemistry of the ocean and sediments, and air sea interaction processes. Development of instrumentation.

NAME	ACTIVITIES
Naval Postgraduate School Monterey, California 93940	Research covering a broad spectrum of military (primarily Navy) problems performed by faculty and students. Navy Commands sponsor thesis and other research in oceanography, meteorology, air-ocean science, operations research, antisubmarine warfare, underwater acoustics and twelve additional advanced academic programs.

NAVAL POSTGRADUATE SCHOOL



Nova University  
Fort Lauderdale, Florida 33314

Studies in physical oceanography and ocean sciences. Emphasis is on modern theories of the circulation of the oceans and experimental work at sea to study these and related problems.

Oregon State University  
Corvallis, Oregon 97331

Systematic investigation of the estuaries and offshore waters of the Northeast Pacific. Study of temperature distribution, geology and geophysics, local air-sea interaction, chemical properties and processes in the ocean. Gravity, geomagnetic and chemical studies of the Northeast Pacific. Computer modeling of self-noise in acoustic arrays. Development of on-line computer techniques for sonar system performance prediction.

Pennsylvania State University  
(Applied Research Laboratory)  
State College,  
Pennsylvania 16801

Fundamental studies of transmission loss, reverberation, seismic subbottom in both shallow and deep water. Research facilities include a large enclosed water tunnel to perform hydrodynamic studies such as flow noise and cavitation and acoustic studies in support of weapon development.

University of Rhode Island  
Kingston, Rhode Island 02881

Research on background water noises of biological origin. Study of ocean circulation, geophysical structure of ocean basins, and geochemistry of marine environment. Theoretical studies of dynamic forces which influence sound propagation. Studies of contaminant dispersion and trace element concentration. Research on continental shelf sedimentation as it relates to design and tactical use of sonar systems.

NAME

ACTIVITIES



WHOI

WOODS HOLE  
OCEANOGRAPHIC  
INSTITUTION

University of Texas  
Austin, Texas 78712

Full spectrum research and development with effort for the Navy heavily concentrated in the areas of seismics, underwater acoustics, transducers, and underwater systems.

Texas A&M University  
College Station, Texas 77840

Research in the Gulf of Mexico with emphasis on circulation, geology and geophysics, chemical properties, air-sea interaction, and instrumentation development. Development of forecasting techniques. Studies of sediment as it affects acoustic propagation. Development of remote sensing techniques.

University of Washington  
Seattle, Washington 98195

Research on inshore, coastal, and open sea areas with emphasis on physical and chemical oceanography and model studies. Physical and biological oceanography of the Arctic Ocean. Geomagnetism as it affects mine warfare. Studies of nutrient and trace element distributions. Applied Physics Laboratory conducts research and development in underwater acoustics, internal waves and the effects on sound propagation, transducers, and instrumentation required for guidance and control systems and for underwater ranges. Studies include high frequency sound propagation under ice.

Woods Hole Oceanographic  
Institution  
Woods Hole,  
Massachusetts, 02543

Broad and extensive research through all the oceanographic disciplines. Study of ocean circulation for forecasting, predictions of oceanic structure for sonar design, variability studies for improved submarine detection and assistance in salvage and rescue. Prediction of acoustic properties as they affect sonar operations and long range sound systems. Gravity studies for navigation. Development of airborne environmental studies, buoy technology, and numerical modeling. Air-sea interaction studies for ASW. Studies of geology and sea floor sediments as they affect sound propagation and rescue and salvage operations.

APPENDIX D

MAJOR U.S. OCEANOGRAPHIC SHIPS  
SHIP'S MISSION

Operating Agency	Ship Name and Designator	Owner	Mission	Length (Feet)	Displacement (Tons)	No. Scientists
Department of the Navy						
Naval Oceanographic Office (NAVOCEANO)	Lynch (T-AGOR 7)	Navy	Oceanographic, geophysical research	208	1302	15
	Dredgenet (T-AGOR 12)	Navy	Oceanographic, geophysical research	208	1325	15
	Melville (T-AGOR 13)	Navy	Oceanographic, geophysical research	208	1339	15
Naval Research Lab	Linjea (T-AGOR 16)	Navy	Research in acoustics, ocean science and technology	246	3180	30
	Silas Bent (T-AGS-26)	Navy	Oceanographic surveys, acoustics, current meter implants, depth & long cores	285	1965	26
	Kane (T-AGS-27)	Navy	Oceanographic surveys, acoustics, current meter implants, depth & long cores	285	2500	26
	Wilkes (T-AGS 33)	Navy	Oceanographic surveys, acoustics, current meter implants, depth & long cores	287	2540	26
University of Alaska	Acoma	Navy	Physical, biological, chemical & geological oceanographic research	95	199	8
University of California (Scripps Institute of Oceanography)	Melville (AGOR 14)	Navy	Geological, biological, geophysical observations, geochemical & hydrographic research	245	2075	30
	Washington (AGOR 10)	Navy	Oceanographic research, heat flow, magnetics, dredging, seismic research, air-sea interaction studies	209	1330	23
	Alpha Helix	Univ.	Biological Investigations	133	512	12
	Ellen B. Scripps	Univ.	Oceanographic research	95	234	8
	Rep	Navy	General oceanography, air-sea interaction studies, acoustic studies	355	700	16
	New Horizon	Univ.	General Oceanography	170	600	13
Columbia University (Lisiant-Donerty Geological Obser.)	Corstad (AGOR 3)	Navy	All normal oceanographic observations.	208	1,425	20

MAJOR U.S. OCEANOGRAPHIC SHIPS

Operating Agency	Ship Name and Designator	Owner	Mission	Length Displacement (Feet) (Tons)	No. Scientists
	Continued.				
	<i>Vent</i>	Univ.	dredging, heat flow, magnetic, coring, gravity, multichannel seismic	197 1000	14
Duke University	<i>Endeavor</i>	Univ.	Hydrographic casts, coring, dredging, magnetic, gravity, seismic reflection & refraction	118 474	15
University of Georgia (Scripps Institute of Oceanography)	<i>Blue Fin</i>	Univ.	Marine biology, hydrocasts, bottom, midwater & plankton sampling	72 70	8
University of Hawaii (Institute of Geophysics)	<i>Kaui Moalo</i>	Univ.	Bottom sampling, subbottom profiling, magnetics, gravity, bathymetry	156 1080	15
	<i>Monza (AGOR 22)</i>	Navy	Seismic survey, biological, chemical, and geological oceanographic research	174 1034	13
Johns Hopkins University	<i>Redgey Hatfield</i>	Univ.	Oceanographic, hydrographic, biological sampling, coring, dredging	106 162	10
	<i>Hawley</i>	Univ.	Meteorological studies, biological collection, current observations, dye studies, onshore shallow water hydrographic stations	65 40	4
University of Miami (Rosenstiel School of Marine and Atmospheric Science)	<i>Gallias (AGOR 4)</i>	Navy	Oceanographic research	208 1428	19
	<i>Columbus Iselin</i>	Univ.	Oceanographic research	170 830	13
	<i>Calanus</i>	Univ.	Plankton studies, bottom sampling, Bottom photography	63 111	6
Naval Postgraduate School	<i>Acaria</i>	Navy	Oceanographic education & research	126 247	12

MAJOR U.S. OCEANOGRAPHIC SHIPS

Operating Agency	Ship Name and Designator	Owner	Mission	Length (feet)	Displacement (tons)	No. Scientists
Iowa University	Gulfstream	Univ.	Oceanographic research	55	29	5
Oregon State University	Wecoma Cayuse	Univ. Univ.	General Oceanographic research	177	962	16
University of Rhode Island	Endeavour	Univ.	General Oceanographic research	80	173	8
Texas A&M University	Gyde (AGOR 21)	Navy	All types of deep ocean research: hydrographic casts, biological, chemical, physical & geological observations	177	972	14
University of Washington	Thompson (AGOR 9)	Navy	General oceanographic research	165	950	10
	Hoh	Navy	Physical, chemical, geological & biological oceanography	209	1362	20
	Ornat	Navy	Biological oceanographic work in sheltered waters	65	81	6
	Knorr (AGOR 15)	Navy	Corium & trawling, weather observations	65	95	6
Woods Hole Oceanographic Institution	Atlatzlis II	W/OI	All types of surveys & research, instrumentation testing & evaluation	244	2100	25
	Cocacus Lulu	W/OI Navy	All types of oceanographic survey & research, instrumentation test & evaluation	210	2200	25
			All types of survey and research	177	962	15
			Twin-hulled mother ship of submersible ALVIN	98	400	15

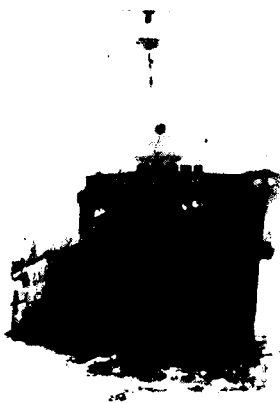
Sources: Oceanographic Ship Operating Schedules, January-December 1978, published by the Oceanographer of the Navy and the University--National Oceanographic Laboratory System Pamphlet 1-78. Sea Technology, Buyers Guide/Directory 1977-78, Compass Publications, Inc., Arlington, Va.

ACANIA



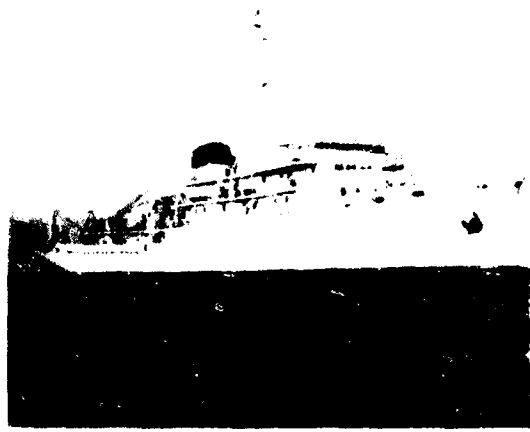
ALPHA HELIX

BARTLETT

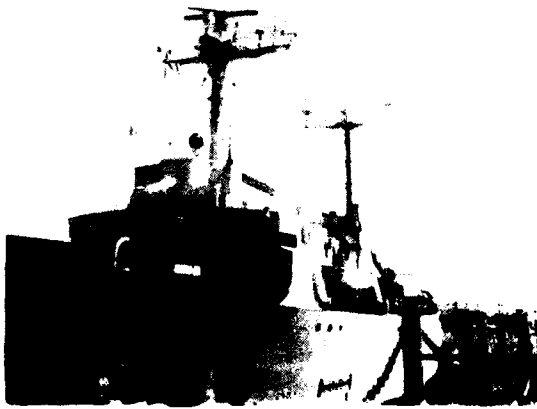


ATLANTIS II

CONRAD



SILAS BENT



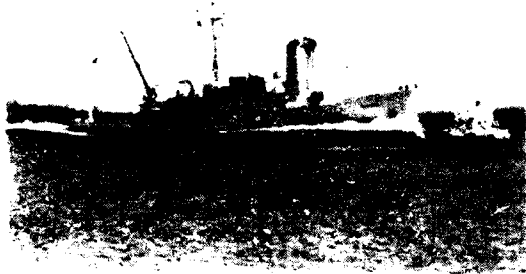
DESTEIGUER



EASTWARD

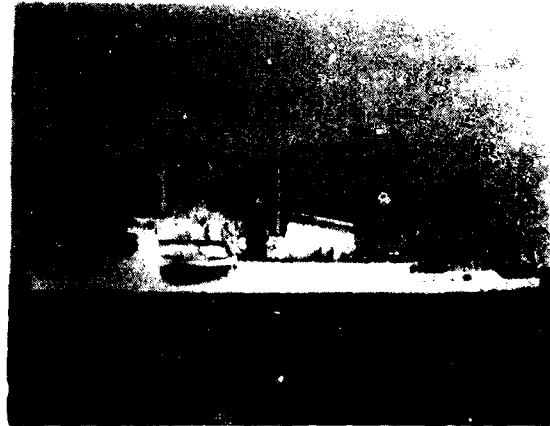


ENDEAVOR



FLIP

GYRE



GILLISS

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THE OCEAN SCIENCE PROGRAM OF THE U.S. NAVY. AN OVERVIEW.(U)  
UNCLASSIFIED NOV 79 D J KEEN, H E MORRIS, D L DURHAM  
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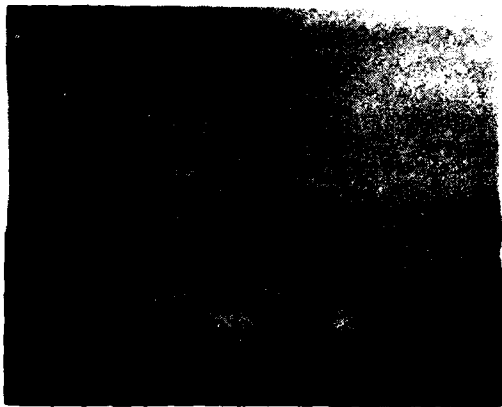
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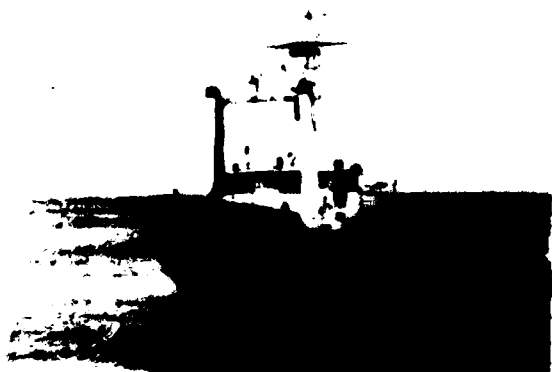


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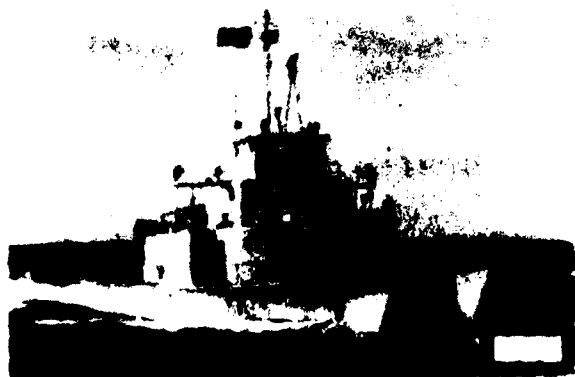
ELLEN B. SCRIPPS



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