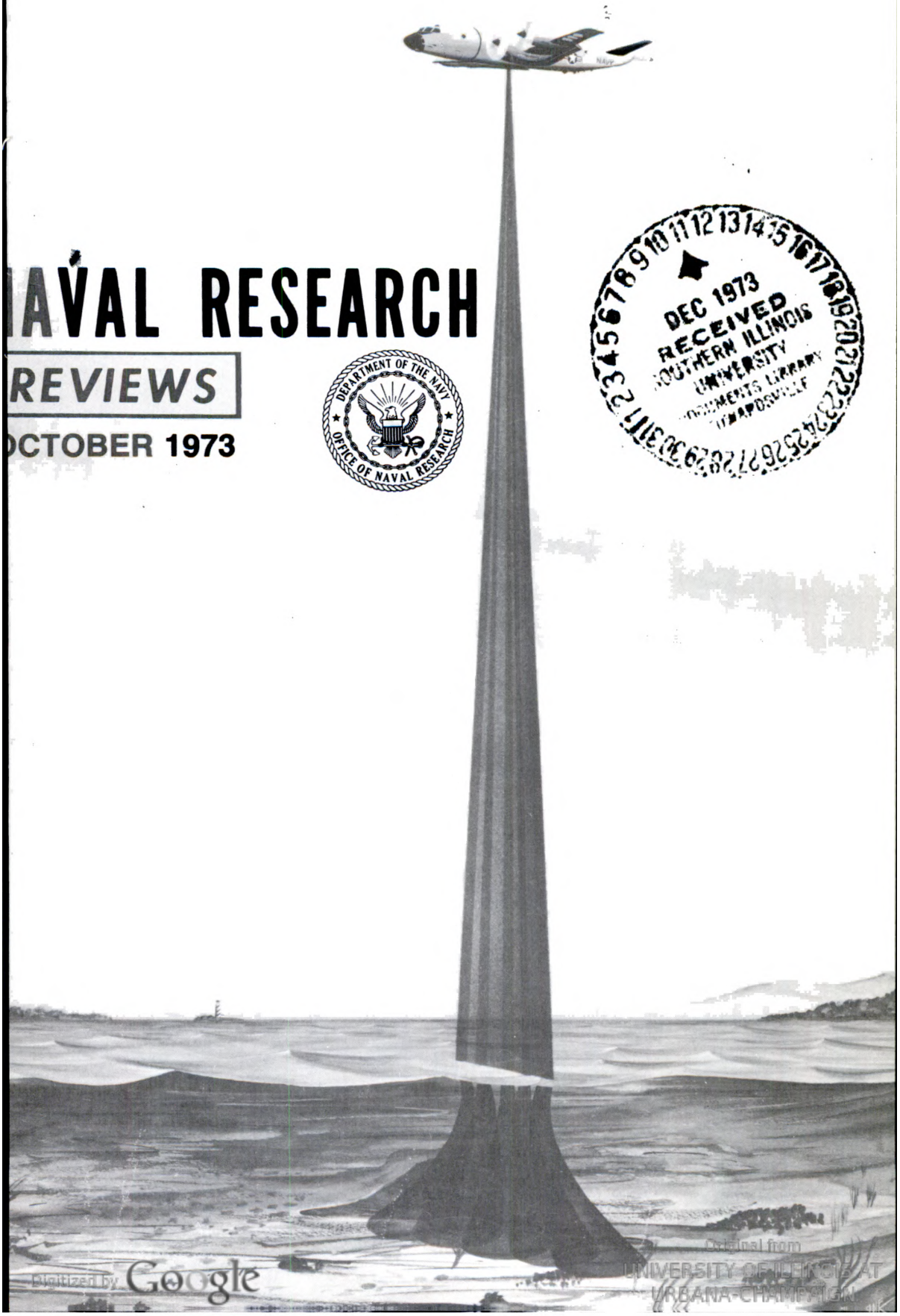
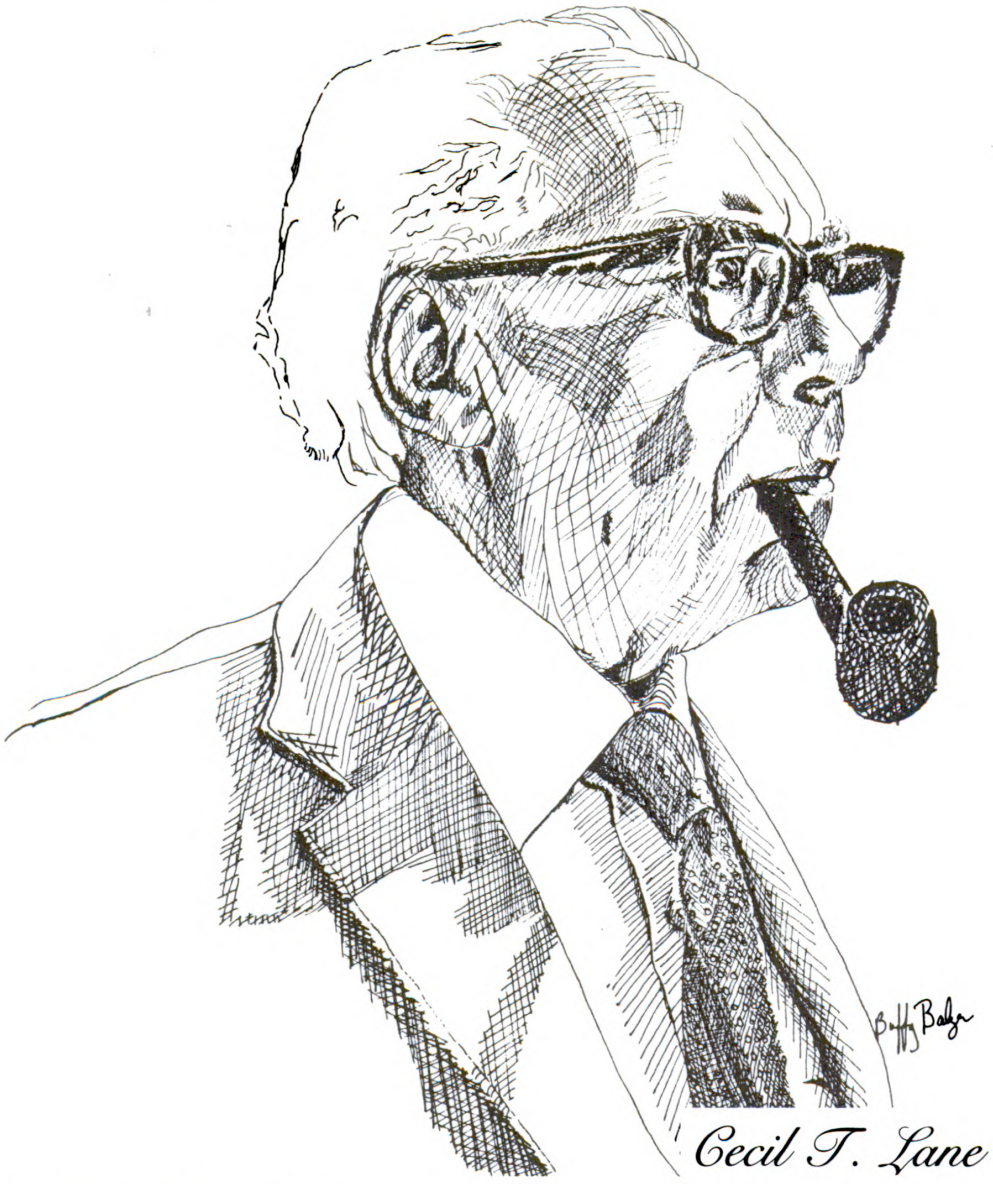
NAVAL RESEARCH

REVIEWS

OCTOBER 1973



PROFILES IN SCIENCE



Cecil T. Lane

Cecil T. Lane, Professor of Physics at Yale University, has played a leading roll in the development of low temperature physics in the United States. Born in England and educated in Canada and Germany, Professor Lane created in 1940 the first piston-engine helium liquefier in the West. During World War II Professor Lane engaged in Navy-related research and development at the Walter Kidde Company. Returning to Yale he became one of the first ONR contractors, and as such made many ingenius contributions to the understanding of superfluid helium, superconductivity, and electronic structure of metals. Professor Lane is probably best known as the originator of the revolutionary "heat flush" technique for separation of helium isotopes. He is also recognized as the leader of the effort which culminated in the remarkable demonstration of persistent currents in superfluid helium. The latter are characterized by a frictionless, circulatory flow of liquid helium which persists undiminished in time without need for a source of power to sustain it. In many important respects the success of current large-scale cryogenics applications can be traced to the pioneering efforts of Professor Lane.

ONR's Remote Sensing Program

James Bailey*
Office of Naval Research

Introduction

The Office of Naval Research has had a long and active interest in remote sensing that began in the 1950's when photographic interpretations of the coastal environment were related to a number of Navy problem areas. The term "Remote Sensing" originated in ONR about 1960. At the same time ONR initiated the international remote sensing symposium to consolidate various work in the field. At these symposia environmental scientists, physical scientists, engineers, and instrument specialists exchange information.

Present day electromagnetic sensing technology and the ability to operate from platforms above the earth have permitted the development of systems having a greatly increased ability to sense the characteristics of the earth and its environment. More information can be obtained by combining sensors each of which will exploit a different portion of the electromagnetic spectrum. Infrared, active and passive radar, and other radio frequency sensor systems show promise of providing surface and subsurface information. Much of this information is needed in target-background and signature-characterization projects.

With remote sensing devices it is possible to map large areas, obtain information about the physical characteristics of objects or phenomena, and perhaps most important of all monitor conditions that change with time. Regardless of the application, when used in aircraft or spacecraft vehicles, these devices provide a means of acquiring repetitive and synoptic data on coastal zones otherwise inaccessible because of physical limitations or political restraints. In some instances, remote sensors may be the only means of acquiring certain data; in others, they may be the most economical means, but certainly they are the only means of acquiring data from the space environment.

The most difficult problem in establishing remote sensors as practical surveillance tools is in developing the capability to extract particular information from the mass of data recorded by these sensors. Two basic approaches are used to solve this type of problem. The first is to study the data output from remote sensors and determine those characteristics that are immediately obvious such as observing that water appears hot

*Dr. James Bailey is Acting Director of the Geography Program for the Office of Naval Research. His main field of interest is marine geology and the applications of remote sensing to coastal geography.

in the 8-14 micron region of the electromagnetic spectrum and cold to a microwave radiometer when the measurements are made at night. Using this approach, little attempt is made to understand why this is true but only that it is. This is the empirical technique of the applications scientist.

The ONR Remote Sensing program has continually been conducting rigorous scientific studies into the basic physics producing and affecting each of the energy fields measured by the various remote sensors and to deriving the analytical formulations which describe the various elements of these natural (passive sensors) and man-made (active sensors) fields. This is the analytical approach of the basic research scientist.

This paper will very briefly recount some significant progress and achievements which have resulted from ONR funded programs in photography, laser, and radar sensing of the coastal and Arctic environment.

Coastal Bathymetry

An area of concern to Navy-Marine Corps planning and operations is coastal bathymetry. Bathymetric data are an indispensable input to coastal environmental predictive models and for all forms of shallow water warfare. Two programs are concerned with this problem area; one is photographic and the other is a laser applications study.

Rockwell International is conducting research on a narrow band pass filtered multispectral photographic system. Multispectral photography consists of using spectral (or narrow band) interference filters to restrict energy incident on the focal plane of the cameras to specific wavelengths. The idea is to determine the various spectral frequencies of light in a water column and relate these frequencies to film density levels. As one descends deeper into the water column, ambient light gradually decreases and a spectral shift occurs. Since different wavelengths can be associated with discrete extinction depths, the related values of reflectance for variable sea bottom depths will likewise change. Thus, ideally, the bottom at different depths will be characterized by different spectral distributions of light. The objective of these experiments is to obtain repetitive coverage of specific areas to permit statistical averaging, by computer, of the film isodensity level representing variation in the water column transmission and bottom reflectance properties (Figure 1).

These isodensity contours may be due to combinations of suspended sediment and bottom relief. The former are considered random variations and the latter relatively stable features. This statistical approach has yielded a superior estimate of actual depth contours since the random

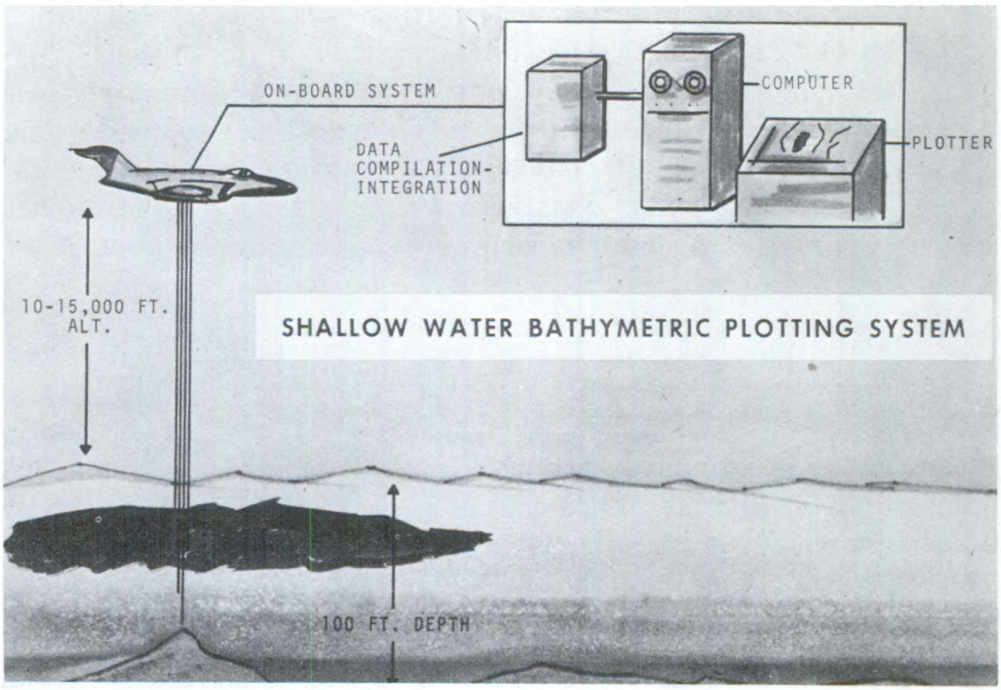


Figure 1 — Multispectral photography is used in this system to determine the various spectral frequencies of light in a water column. These frequencies are then related to film density levels.

sediment effects average out and the bottom features reinforce by roughly the square root of the number of independent measures. The results show excellent agreement of the computer derived charts with available bathymetry charts out to depths in excess of 20 meters with a 90% confidence level.

SPARCOM, Inc. is conducting a laser bathymetry study for ONR in which the capabilities and limitations of a pulsed blue-green laser are being related to bathymetric contouring (see cover picture). Laboratory and airborne tests already conducted with a blue-green laser have amply demonstrated the feasibility of using this system as an airborne optical ranging device to measure moderate water depths. The problems presently being solved are determination of the attenuation coefficients for various degrees of silty turbid water, the underwater laser beam transmission-scattering as a function of the turbidity, and the surface scattering as a function of surface roughness and scanning angle of the laser. Determining the magnitude of these constraints delimits the operation capability of the instrument and provides a basis for the calculations of scan rates, angles of scan, and area coverage *vs* aircraft altitude and speed. This laser with its 3 nsec (1 nanosecond = 10^{-9} seconds) pulse width is capable of yielding high resolution (± 1 foot) bathymetry information in water depths in the order of 30-50 feet. The high pulse rate of the laser (100-1000 pps) provides the capability for optically scanning

the laser to cover large areas with maximum speed and spatial resolution. It is quite possible that additional research on return signal characteristics will lead to determinations of sediment concentration percentages in the water column and bottom sediment type and distribution.

The criteria are now being identified for the subsequent development of an operational airborne laser bathymetry system for shallow water bathymetric mapping and other inshore warfare purposes (Figure 2).

Subsurface Investigations by Impulse Radar

A research program of great interest involves the use of an impulse radar for subsurface investigations. This system gives a continuous graphic "profile" of subsurface soil interfaces. A transmitter generates an impulse which the antenna couples to the medium being investigated. The discharges take place in the order of one nanosecond (10^{-9} seconds) at a repetition rate of 30 to 50 kHz. The pulse shape ensures that a large bandwidth (0 to 250 MHz) is propagated and the pulse components are reflected from interfaces of different conductivities and/or dielectric constants underground. Pattern analysis of the reflected pulse signal gives direct evidence of the nature of the reflector. The depth of penetration depends upon power and composition of the medium and is limited to about 60 feet with the present system. Pattern recognition is based on the amplitude and shape of the return pulse (Figure 3).

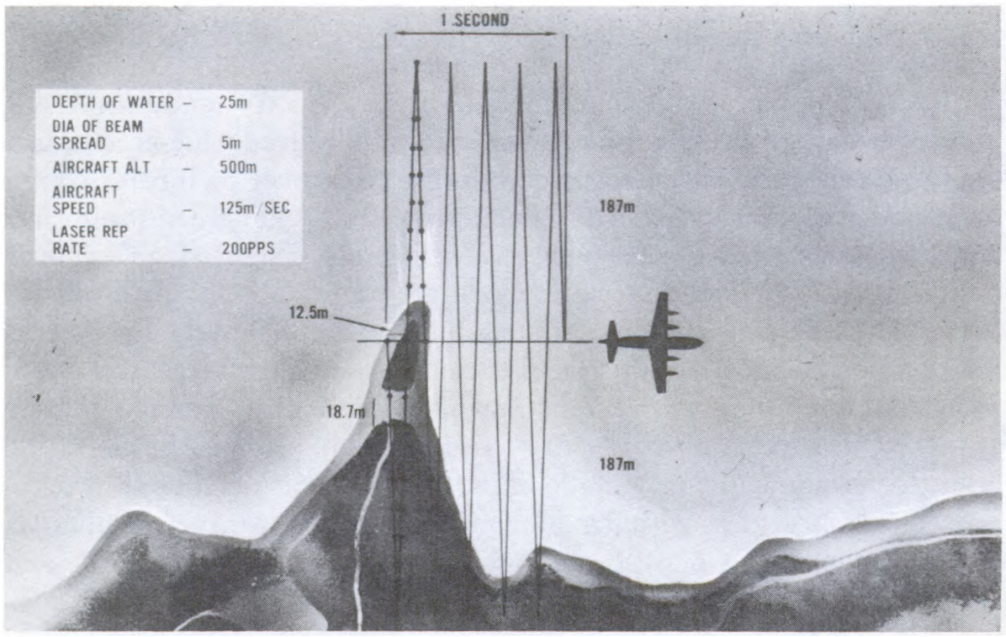


Figure 2 — Typical performance characteristics of an airborne scanning laser bathymetry system

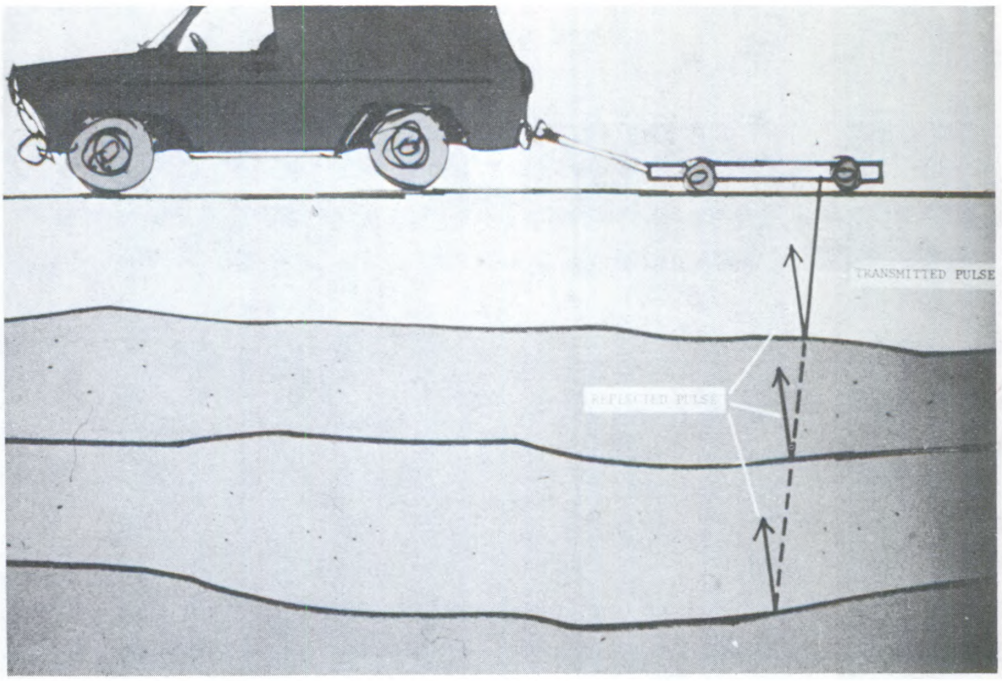


Figure 3 — An impulse radar can be used for subsurface investigations. The system can give a continuous graphic "profile" of subsurface soil interfaces

The return pulses or reflections are time amplitude wave forms and they are displayed on a sampling oscilloscope. At the same time they are stored on tape by an FM tape recorder. The stored data are then played back into a graphic line scan recorder and a continuous profile of the subsurface interfaces is produced.

If further information is needed, *e.g.*, metal *versus* nonmetal reflector, then the phase of the first part of the pulse is checked as positive or negative, and compared with the transmitted pulse.

Various experiments have shown that the system can detect and precisely locate tunnels and various objects including wire strand, wood, cement, and metal blocks buried in natural deltaic sediments. The instrument has also measured the thickness of sea ice and fresh water ice to depths of 5 feet and has located ice lenses buried under a relatively thick permafrost layer. Work is progressing to convert the current system from its present ground position requirement to a helicopter or light aircraft detection system. Work is also in progress to develop a reasonably portable system for field use (Figure 4).

Geometrical Optics

The disparity between predicted and experimental measurements of sea surface temperature noted by scientists working with microwave

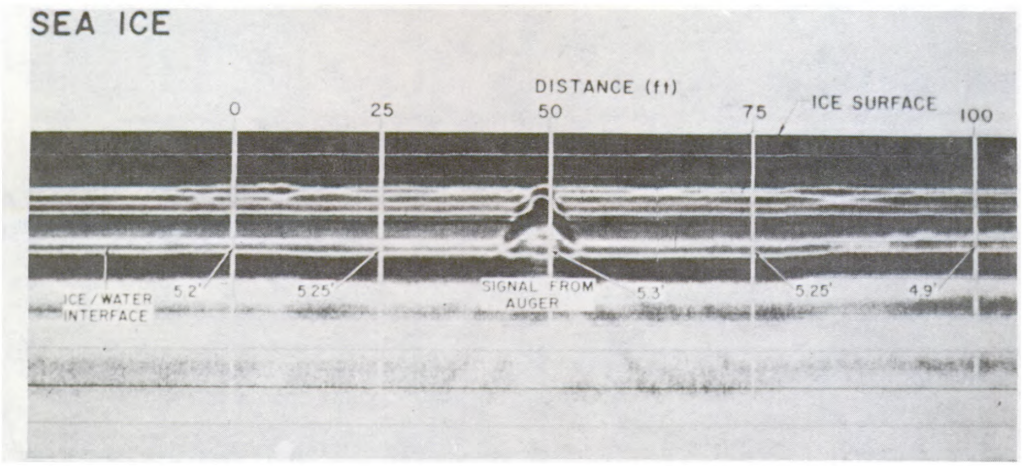


Figure 4 — The impulse radar system can measure the thickness of sea ice and fresh water ice to depths of five feet

and infrared radiometers has promoted the development of a theory of complete geometrical optics description of angular emissivity and electromagnetic scattering from randomly rough surfaces. This theoretical calculational model includes the effects of surface shadowing and multiple scatter. An additional included feature is the temperature contribution due to a wind-driven spray layer just above the water surface. The spray layer will modify, by absorption and emission, the intensity of radiation incident on, and scattered by, the sea surface. The model has the flexibility for parametric variations in frequency, polarization, observation angle, surface slope, water temperature, salinity, atmospheric water-vapor density, *etc.*

A computer model of second-order scattering has been developed using the geometrical optics approach and includes the effects of shadowing and multiple reflections. An analytical investigation of the effects of surface roughness on visible light transmission through the ocean surface has been completed, and a technical report on this work has been distributed.

The practical motivation or ultimate objectives of the sea brightness temperature study relate to (1) the design and interpretation of better research experiments on surface characteristics; (2) the development of an inversion procedure for field measurements—*i.e.,* specifying a particular combination of frequencies, polarizations, and angles at which to make measurements so that one can uniquely determine sea state, water temperature, salinity, *etc.;* (3) the potential of microwave radiometry as an all-weather means of determining water temperature and surface winds should permit, along with some atmospheric temperature and pressure profiling measurements, a substantial improvement in weather forecasting capabilities, an application which is of both tactical and strategic interest to the Navy; (4) the sensitivity of the

measurements to surface roughness suggests the remote passive detection of ship wakes, oil spills, and (perhaps) submerged submarines; (5) the equations developed for electromagnetic scattering, since they include shadowing and multiple scatter, have a direct application to the prediction of SONAR performance under various sea conditions. The measure of performance—the probability of target detection—requires a prediction of "Propagation Loss." For a sonar operating in either the surface channel or bottom-bounce modes, the Propagation Loss critically depends on the scattering by the rough surface or bottom at very small grazing angles.

Data Acquisition and Processing Program

Generally, research efforts conducted for the Coastal Remote Sensing Program are specifically related to one aspect of a problem area. The projects just referred to are typical examples. A new project supported by ONR is unique in that it will relate and integrate all aspects of a problem area at one time to a single finished product. The effort will be directed toward developing a descriptive and calculational model of advection and mixing of coastal water masses using satellite and aircraft remote sensing data. It is unique, since it will be the first time that this has been attempted and that unequivocal data of all the relevant physical parameters will be measured *in situ* and related to concurrently obtained remote sensor data. This will be an exercise in determining what data are necessary, how they are to be integrated, and how these data may be reduced to mathematical terms for formulation into the descriptive model (Figure 5).

This project to date indicates that space systems can provide the recurring synoptic data with which to construct and drive meaningful predictive models of coastal and deep ocean water mass movements and characteristics. One such system has been utilized for coastal studies and proven to be particularly significant. It is known as the Data Acquisition and Processing Program (DAPP) and was developed by the U.S. Air Force. The DAPP system processes and disseminates high resolution meteorological data which are gathered from space.

The various features of the DAPP contribute to form the most responsive operational data system of its kind. The meteorological aspects of DAPP were designed under a total system concept in which not only sensors, but communications and ground processing facilities were developed with the primary objective of providing maximum responsiveness to the military operational decision maker.

The space segment of the DAPP system consists of an infrared sensor operating in a bandwidth of 8.0 to 13.0 microns, and also visual sensors with a bandwidth of 0.4 to 1.1 microns. The IR sensor products are images of the earth and its atmosphere which are representative

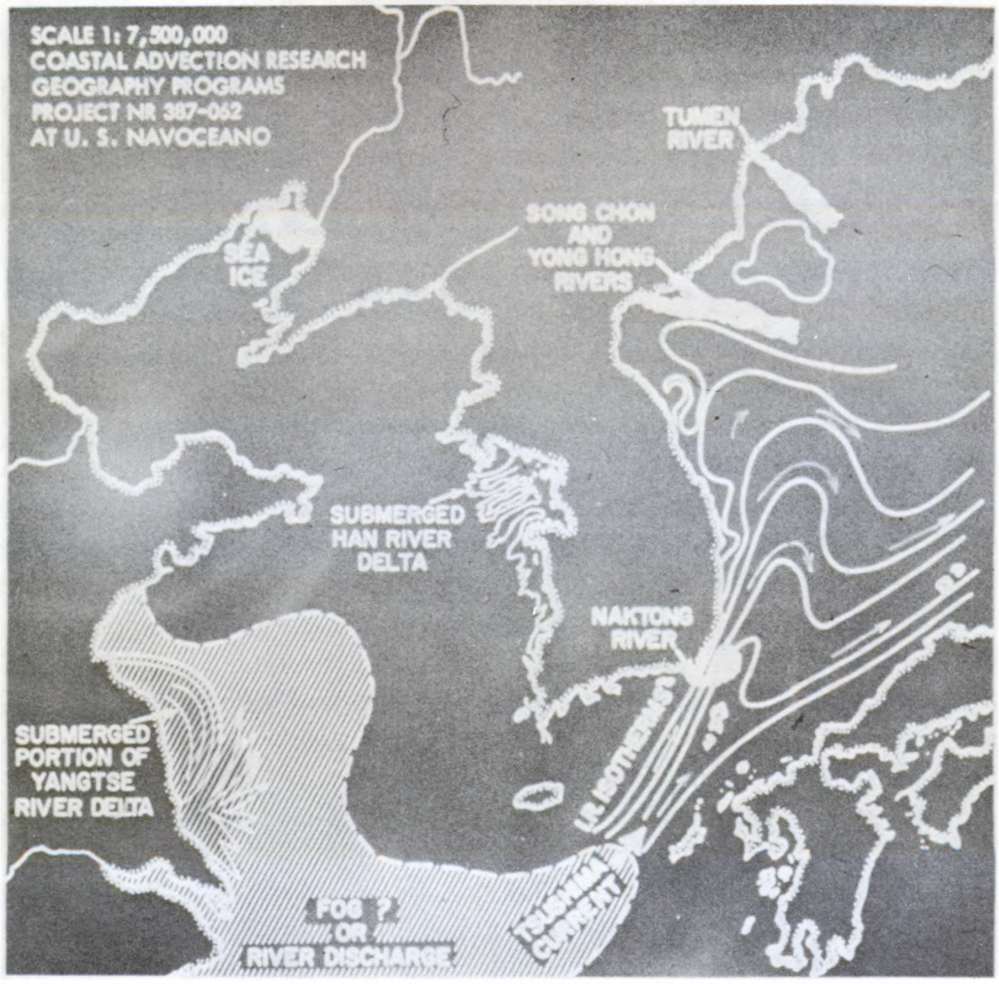


Figure 5 — A composite illustration showing advective patterns, sea ice, and bathymetric features in coastal regions of the Yellow Sea and Sea of Japan

of their blackbody temperatures rather than their radiance. The visual sensors detect the brightness levels of the primarily reflected solar illumination for their images of the earth. In addition to the imagery, another spaceborne sensor, an 8-channel radiometer, furnishes vertical temperature profiles of the atmosphere.

All of these sensors are designed to function at any local sun time. This unique attribute has proven very advantageous for operational support. The DAPP currently receives data sensed near dawn and near noon in local sun time and also during the hours of darkness anywhere over the surface of the earth. This system can, therefore, provide an instantaneous view of the areal distribution of thermally and optically distinct water masses and their hydrodynamic flow patterns. These unique data depict stream lines, fronts, eddy patterns, vortices, regional flow patterns, and the distribution and scale of horizontal (and sometimes vertical) turbulent water motion.

The physical and dynamic characteristics of the ocean have their widest range of variability and variety of distinct water types in the vast inshore and coastal areas of the world. Adequate coverage of these areas within reasonable cost and a meaningful time frame is physically impossible. Because of this two phased problem, the principle circulation and mixing processes of the world's coastal areas are so poorly known at present that fruitful theoretical analyses cannot be made. Additionally, current boundaries, the major boundaries and mixing zones between water masses, are where the steepest gradients of physical properties and highest concentrations of biologic activity occur. It is paradoxical, therefore, that these current boundaries are among the poorest known major ocean features.

It is here, too, that naval requirements of acoustic propagation, stability of oceanographic parameters, and a host of other requirements related to USW (undersea warfare), ASW (anti-submarine warfare), amphibious warfare, and atmospheric studies need heretofore unavailable timely data. The DAPP system has been designed to provide military decision makers with meteorological and oceanographic data within a matter of minutes of the time it is collected from space.

Recorded and real time data are transmitted from the space sensors to permanent receiving sites in the United States. These data are relayed through high speed wide-band data links to processing centers, where the DAPP system converts picture imagery to digital data for machine processing. Machine processing allows for hundreds of forecasting predictions to be made routinely and nearly simultaneously by computers without, in many cases, anyone looking at the picture imagery. These data from the sensors are combined with conventionally collected data and in this way integrated with other data over a vast area to derive the Big Picture. The DAPP system also has the capability for providing global analysis and forecasts based solely on sensor data (Figure 6).

This space system could also be intimately linked with an OTH (over-the-horizon radar) system for Navy environmental forecasting. Calibration, skewing correction, and visible verification of environmental conditions can be provided to OTH data by the system. It appears that the integration and development of a space-OTH system would provide the much and critically needed data source for oceanographic and meteorological data used to drive the environmental predictive models for real time Naval operations and planning missions.

The ultimate aim of the Coastal Remote Sensing Program is to put together information from all sources (ground teams, ships, aircraft, satellites, *etc.*) so that we can provide up-to-date environmental data on wave and surf heights and directions, current and wind velocities and directions, bathymetry, and trafficability forecasts for any amphibious or other inshore warfare operation (Figure 7).

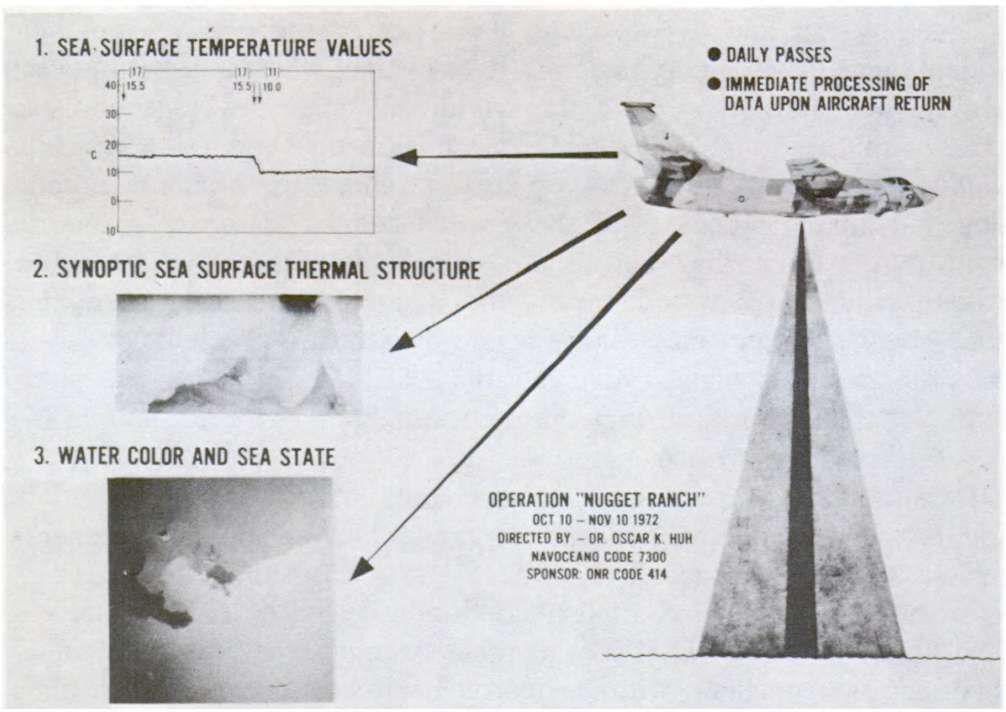


Figure 6 — Oceanographic remote sensing by Navy Reconnaissance Aircraft RA-3B

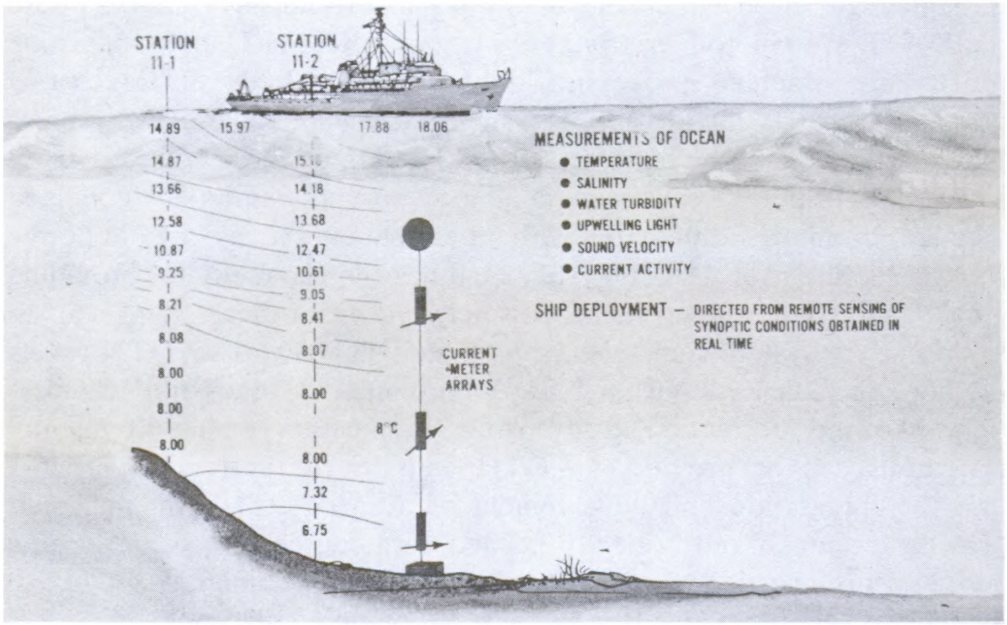


Figure 7 — Surface Truth Ocean Survey U.S.N.S. Silas Bent (TAGS-26)

The Inseparable Couple – Air and Sea

William V. Kielhorn*
Office of Naval Research

The general, long-term objective of most oceanographic programs is to provide an understanding of natural processes and mechanisms acting in or on the sea so that improved prediction of oceanographic phenomena may be attained. I mention "improved" advisedly, for it is obvious that some form of prediction may be possible without having to know even the slightest thing about the processes involved in events. Undoubtedly, even prehistoric man knew a little about the wind, the rain, and the sea. He certainly knew signs portending hurricanes, thunderstorms, ice and monsoons. It mattered little whether he ascribed these events to Thor or Zephros or whomsoever. Quite often the predictive signs were clear, and offered timely warning. When the clouds appeared the wind rose, as concurrently did the sea. Cause-and-effect were inconsequential.

Only in recent times has the human species found it necessary to go beyond the realm of lore. Gradually, "weather" superseded "climate" in importance and interest, and there came demands by farmers, soldiers, sailors, and in fact almost everybody, for prognostication of the weather. By the latter part of the nineteenth century, observing station networks became widespread and were connected by the still-new telegraph. This was the beginning of synoptic meteorology, and the various weather services began forecasting. Some say this was a mistake. Forecasts – even short-term forecasts – could be seriously in error. Even as late as World War II inaccurate forecasting jeopardized military operations in all theaters: on the beaches, in the air, and on the sea.

Part of the forecasting problem was caused (and still is) by (1) a paucity of observational information, particularly at sea, (2) by lack of upper-air data, (3) and most important by not understanding air-sea interaction. These interactions occur on all scales of space and time, and no scale is unimportant. Some of the projects sponsored by the Office of Naval Research to study air-sea interaction will be described.

Table 1 represents a general concept of the scales involved in atmospheric-oceanic phenomena. It must be recognized that the scale definitions are simplified, overlapping, and generally arbitrary, but the terms are in such common usage among oceanographers and meteorologists

*Mr. Kielhorn is Scientific Officer of the Ocean Science and Technology Division of ONR. His main field of interest is physical and biological oceanography. Mr. Kielhorn is one of the pioneers in developing aerial oceanography.

TABLE 1
Scales in Atmospheric and Oceanic Motion
(After H. U. Roll)

Name	Characteristics	Time	Horizontal Space
Microscale	Turbulent motion (molecular exchange at sea surface)	Up to several minutes	Up to 200 meters
Convective scale	Pronounced vertical motion	Several minutes to one hour	100 meters to 10 kilometers
Mesoscale	Tendency toward organized motion	Several hours	10 kilometers to 100 kilometers
Synoptic scale	Large cyclonic or anti-cyclonic vortices around vertical axis	Several days	100 kilometers to 1000 kilometers
Large scale	Quasi-stationary circulations planetary waves, large anomalies, climatic changes	Weeks to decades	1000 kilometers to entire ocean

that it is well to have a general consensus such as this proposed by the eminent Dr. H. U. Roll of the German Hydrographic Institute.

Dr. Roll, in an outstanding lecture presented at an American Meteorological Society air-sea interaction symposium sponsored by the Office of Naval Research in December 1971, divided the entire process of the interaction of energy and matter between the atmosphere and hydrosphere as follows:

- actual exchange at the sea surface,
- vertical distribution and release of the energy and/or matter gained by air-sea interaction in ocean and/or atmosphere,
- horizontal transport of the energy and/or matter gained by air-sea interaction in ocean and/or atmosphere.

Small Scale

The actual exchange at the sea surface is of course a small-scale phenomenon. Owing to the scale involved, the processes are most difficult to study directly, although ONR contractors are making attempts to do so. Sensible heat transfer between the air and the sea takes place by molecular conduction and diffusion within the upper centimeter of water where, depending upon stability and other factors, turbulence

may be initiated by even a slight disturbance. The investigators are therefore required to work with the finest and smallest sensors obtainable, and to approach the surface from below in order to avoid meniscus perturbations. Radiant energy exchange, which is of the greatest importance in heat flux between the media, takes place mostly in infrared bands to which liquid water is almost opaque. Thus, the "action" is limited to the upper tiniest fraction of a millimeter, and is measured best by an infrared radiometer operating on two closely-spaced wavelengths whose effective depths of measurement are very slightly different. The emissivity from these two depths provides an indirect measurement of temperature gradient and heat flux in this region.

The nature of the sea surface strongly affects the processes occurring there. Ordinarily, one thinks of the surface as being comprised largely of water. This is not really so, much of the ocean is covered by other matter, some of which can affect evaporation, mixing, or other processes. There are many sources for this "foreign" matter. One is petroleum oil spillage from ships, and in some places from natural oil seeps from the sea bottom; others, less publicized but quite important, are the oils and oil-like substances contained in almost all living material. The ocean is also subject to a constant rain of particulate matter settling down upon it, or being carried thereto by precipitation. Some of these materials are biodegradable; others are not. It is not surprising to learn of recent discoveries concerning the neuston and pleuston biota—that is, the micro-organisms and macro-organisms which form extensive communities associated directly with the surface of the sea. Little is known of the effects these biota or their metabolic products may have on the physics of the sea surface. One thing is certain—the presence of a small amount of surficant can reduce the drag coefficient of the wind on the sea surface by orders of magnitude, as was demonstrated recently by Professor E. L. Mollo-Christensen of Massachusetts Institute of Technology.

The sea surface supplies immense amounts of matter and energy to the immediately overlying atmosphere. Water itself is far the most important material furnished by the sea. Initially, the process is entirely molecular as water changes at the sea surface from the liquid to the gaseous state. Then, not only does the water molecule enter the atmosphere as a constituent gas, but at the same time obtains the heat of vaporization, which amounts to about 540 calories per gram. It is this evaporative process which comprises the "clutch" of the great air/sea heat engine utilizing the incoming solar energy.

Every time a raindrop splatters on the sea and every time a gaseous bubble bursts the sea surface tension, there is ejected a tiny droplet of sea water. Many of these droplets evaporate while suspended in the atmosphere, leaving behind a residue of salts and other materials contained in the original droplet. These salts and other matter become an

inanimate part of the aerial plankton, and are distributed widely, first by turbulence, then by convection, then by advection. Sea salt nucleii in the air have been examined by A. J. Woodcock and D. C. Blanchard at the Woods Hole Oceanographic Institution, and by others. It is believed that collectively these particles play a most important role in cloud physics, and may be of great significance in triggering mesoscale atmospheric phenomena such as typhoons or hurricanes. There remains much to be done in this field where there are too few investigators.

Convective Scale

We have mentioned a few of the small-scale air-sea processes, and have seen how they can lead to larger-scale effects. Among these are more-or-less organized motions of convective scale and mesoscale phenomena both in the sea and in the air. Atmospheric convection has received much attention while oceanic convection has received much less. Only recently has ONR increased its support of investigations of this subject, both in the laboratory and in the field. There has been an impetus in this direction owing largely to the recent discovery of the ubiquitous nature of density microstructure in the sea, and the possible role of oceanic convection in its formation. Furthermore, some recent technological developments, such as the scanning infrared radiometer used from aircraft, have reduced some of the earlier observational difficulties.

There are also organized horizontal motions in the upper layers of the sea which are of convective scale. These consist of evenly spaced horizontal vortices generally trending in the direction of the surface wind. These are called Langmuir circulations and have been studied intensively by Faller and Woodcock at Woods Hole. The circulations are easily visualized by observing the convergence patterns of the slightly buoyant pelagic *Sargassum* weed as it lines up with the wind at sea in evenly-spaced streaks. This phenomenon is generally ascribed to shear flow instability of upper water layers, although thermal convection may also play a part. There has been relatively little interest in these circulations in the past few years, but owing to their probable connection to mixed-layer depth and to reduction of micro-structure, it should be prudent to continue studies in this area.

Recently, Professor W. S. Richardson of Nova University observed by means of vertically-rising dye markers some persistent and strong shear patterns in the upper mixed layer of the sea. These, too, are of convective scale, and may or may not be associated with Langmuir circulations. Further research on this will be conducted.

Mesoscale and Synoptic Scale

Studying these scales of motion in the air and in the sea presents many observational difficulties. One of the earlier investigations of

mesoscale oceanic phenomena was called Operation CABOT, which involved about 12 ships and 2 aircraft in 1950 for a concerted study of Gulf Stream phenomena. This investigation, which lasted for several weeks, provided much information useful in subsequent studies of major current systems, but it was difficult and expensive. Until recently, oceanographers have generally preferred, for both economic and scientific reasons, to concentrate on phenomena not requiring such massive cooperative efforts.

But now there are new theories, new tools, and new techniques by which to study mesoscale and synoptic scale air-sea problems. Pictures from the observing satellites, and those taken by the first astronauts, clearly showed the organized nature of convective cloud "streets," which suggested a triggering mechanism from the sea beneath them. Later, many satellite photographs showed that in tropical oceanic regions there frequently appeared to be collections and organizations of cumuliform clouds up to about 100 kilometers across. There seems to be two distinct types of these mesoscale organizations: (1) a solid mass of cloud thicker in the central portion than at the edges, and (2) a mass containing a distinct clear "eye" near the center. As yet there is no adequate theory to explain why the masses form, nor why there should be two varieties. Furthermore, some of these masses intensify to become tropical storms, while others mysteriously disappear in mid-ocean. It is probable that the temperature, heat, and matter from the ocean below are directly involved.

Satellites are also providing water information on a scale never before obtainable. By utilizing various spectral sensors the surface temperature, the upper-layer chlorophyll content, sediment load, and surface roughness may be estimated.

One of the first concerted mesoscale experiments in air-sea interaction took place during the summer of 1969 about 500 km eastward of Barbados. The expedition, called BOMEX (Barbados Oceanographic and Meteorological Experiment), was comprised of about 10 ships, 20 instrumented aircraft, the spar-ship FLIP, a geostationary satellite, and several recording/telemetering buoys. Altogether, 100 separate oceanographic and meteorological experiments were attempted. The BOMEX was organized by ESSA (Environmental Science Service Administration now NOAA (National Oceanographic and Atmospheric Administration)), and was supported by ESSA, NSF (National Science Foundation), Coast Guard, NASA (National Aeronautic Space Administration), Navy and Air Force, both directly and through Contract Research Programs. Already, many scientific papers have been presented or published on experiments in BOMEX, but many more are still to be written. The volume of data obtained was fantastically large, and preconceived notions as to the relatively simple dynamic consistency of

the area proved incorrect. For example, the surface currents, which were expected to carry FLIP west-northwestward at about two knots did just that for a few days, then suddenly reversed, carrying the FLIP eastward into the trade winds. At the same time, meteorologists found much more variability then expected. This always appears to be the case. It has happened in all the large expeditions including a half-dozen air-sea pilot studies of smaller magnitude than BOMEX (Figure 1).

One should probably consider the various investigations of upwelling as falling into the mesoscale air-sea realm. Upwelling is of great significance to the fisheries because of the nutrient-rich water which appears from the depths to provide nourishment to the lower trophic levels of biota which in turn feed fish. The upwelling areas provide much more fish than those not so affected. The major upwelling areas occur where wind stresses force water offshore—often seasonally—and include the borders of West Africa north of Dakar, the West Coast of the United States, the coast of Peru, the Malabar Coast of India, and portions of New Zealand and Australia. A strong cooperative effort "CUE-1" (Coastal Upwelling Experiment One) was undertaken in 1972 to study

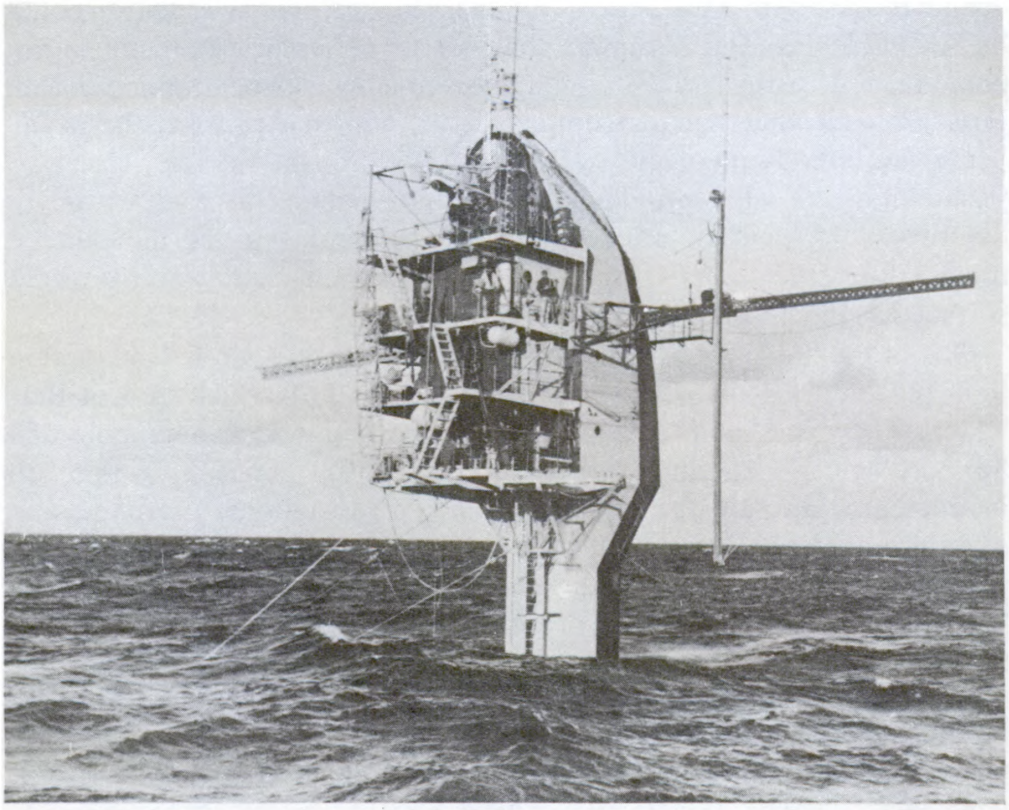


Figure 1 — The spar-ship FLIP in its vertical attitude draws more than 350 feet of water. Here it is shown rigged for air-sea studies on BOMEX. This craft recently withstood and measured 85-foot waves north of Hawaii, yet its own response motion was but a few inches.

upwelling off the Oregon coast. This effort is being followed by similar experiments in other areas. It should be noted in passing that authigenic deposition of phosphate encrustation frequently appears under the upwelling areas, but the cause of this manifestation is unknown.

Upwelling is not exclusively a coastal phenomenon. It can occur in certain equatorial bands, and it can be a most significant phenomenon accompanying tropical storms. Usually, offshore upwelling does not affect fisheries in the same manner as does coastal upwelling, but it can have considerable bearing upon the overlying atmosphere and upon water temperature structure, which is of naval interest. Both Nova University and Florida State University are exploring offshore upwelling. experimentally and theoretically, the Naval Postgraduate School and Fleet Numerical Weather Service are attempting to quantify such effects empirically for the purpose of improving oceanographic forecasts.

At present, firm plans are being made for a major meteorological/ oceanographic cooperative expedition called GATE. This acronym stands for "GARP Atlantic Tropical Experiment." GARP is itself an acronym standing for "Global Atmospheric Research Program." Unlike BOMEX, GATE is a truely international undertaking, being organized in complex fashion through the United Nations World Meteorological Organization, and the International Council of Scientific Unions. In the United States, NOAA has been assigned duties as the lead government agency. About 30 ships and 10 aircraft from various nations will be involved. Use will be made of constant-level balloons, geostationary and polar-orbiting satellites, and telemetering buoys.

Details of this major expedition, which is scheduled for the summer of 1974 in the equatorial and tropical Atlantic Ocean, are beyond the scope of this article. In fact, the operational plans are being adjusted constantly as scientific proposals and new facilities are obtained. However, it is obvious that the enthusiasm generated for "big science" to tackle geographically and scientifically extensive problems indicates the trend of things to come in air-sea interaction.

The heart of the GATE program is the investigation of a physical atmospheric process (or processes) proposed by Ooyama, and by J. Charney and R. Eliassen of MIT in 1964, known as "Conditional Instability of the Second Kind" (CISK), which is believed necessary for the intensification of cloud clusters and formation of tropical storms. The CISK process appears to be associated both with frictional forcing in the planetary boundary layer (0-1000 m above the sea surface), and the mesoscale instability it produces, plus baroclinic forcing processes and instable feedback growth in the presence of certain tropospheric conditions which may be related to some oceanographic parameters. It is essential that the detailed meteorological observations of GATE be supplemented by concurrent pertinent oceanographic observations

over a large area for a long time (several months) if the relative importance of the initiating and sustaining forcing processes are to be assessed.

Large Scale Interactions

Table 1 gives the approximate dimensions of the various scales of motion in space and in time. Some of the smaller scale motions and phenomena carry implications having large scale significance. The GATE investigation illustrates the point. In fact, GATE will include a large scale observing network (A-array) as well as the "core" experiment somewhat similar in size to BOMEX, called the "B-array." The A-array will consist of about a dozen ships stationed along and across the equatorial Atlantic Ocean from shore to shore, supplemented by a network of shore observing stations extending from East Africa to Brazil. Owing to the rapid response of the ocean to dynamic inputs at the equator, as opposed to the much-less-rapid response in mid-latitude regions, this array offers the possibility of observing large scale cause-and-effect directly, and may permit observations of "trapped waves" along the equator and their influence on the equatorial currents and countercurrents which in turn may affect the entire circulatory system of the North Atlantic Ocean.

The Mid-Ocean Dynamics Experiment (MODE) is not in itself an air/sea interaction project, but some facets of it are related. The MODE area, located roughly between Bermuda and the Bahamas, is in the trade-winds transition area, and contained networks of buoys, ships, and observing aircraft, which sampled at all levels oceanographic conditions over a wide area for an extended period of time.

Farther "downstream" in the center of the northern North Atlantic Ocean, there took place recently an internationally sponsored expedition on air-sea interaction known as JASIN (Joint Air-Sea Interaction Experiment). Scientists from several nations, particularly from the United Kingdom and the U.S.A., including several ONR-sponsored oceanographers, made detailed oceanographic and meteorological measurements in order to study the relationships between the two fluid media in the ocean at mid-latitudes. Collectively, these several expeditions will provide large-scale information on the circulation of the North Atlantic.

These are not the only investigations going on in the Atlantic and adjacent regions. The USSR has conducted recent studies of the eastern Atlantic; the French, British, and Americans have been working in the Mediterranean, and plan still more work there. The northern North Atlantic is receiving renewed attention in this regard, as is the North Sea. Also the Arctic Ocean is being explored on a program known as AIDJEX (Arctic Ice Dynamics Joint Experiment) to determine the relationships among the air, the ice, and the sea.

The most ambitious air-sea interaction program of all is now taking place in the north-central portion of the Pacific Ocean. In the mid-1960's, ONR began its sponsorship of an investigation of unexplained surface temperature anomalies in this wide region which were of such magnitude that their effects greatly influenced the weather and climate throughout the North Pacific to the eastward, and in fact continued these effects over the continental United States, and quite probably to the western North Atlantic.

Meaningful observations over a wide area for an extensive time (years) is a difficult and expensive undertaking. It was decided that the most feasible approach was to develop data-gathering buoys which were capable of being anchored in mid-ocean unattended for many months at a time. Two types of buoys were selected, (1) a radio-telemetering steel discus buoy forty feet in diameter (known as the "monster buoy") developed by General Dynamics, and (2) a large number of smaller wooden catamaran recording buoys developed at the Scripps Institution of Oceanography, and known as "Bumblebee" buoys (owing to their turtleback shape). Both buoys collect subsurface, surface, and meteorological information. The monster buoy contains its own computer and data storage capability, which can be called upon by radio to release its data for use at any time (Figures 2 and 3).

The buoy technology alone has proved to be a major advance in oceanic investigation. The Coast Guard is now using one of these buoys in the Gulf Stream, another is in use off California. NOAA's National Data Buoy Project is testing and improving them and is developing advanced generations of them. In 1972 the National Science Foundation joined with ONR in joint sponsorship of the North Pacific Experiment, known as NORPAX, and a large staff of top-ranking scientists has been assembled at Project Headquarters, Scripps Institution of Oceanography, for the purpose of analyzing and interpreting the NORPAX data.

Unless projects such as NORPAX are conducted, there is little hope that there can be a meaningful network of unmanned ocean stations which are so sorely needed for monitoring and predicting the large-scale features of the sea and the air.

On Ocean Waves

On the whole, ocean wave forecasting is in pretty good shape. The several forecasting methods do give reasonably accurate results provided the input data are good. However, this is an important proviso because there is no ocean-wide reporting network yet; also there are too few ship reports from the stormy generating areas, and the ship reports themselves can be notoriously inaccurate for a number of reasons.

Figure 2 — The Scripps Institution of Oceanography "Bumblebee" buoy in the North Pacific in winter. These buoys record much less oceanographic and meteorological information than do the "Monster buoys," but they are small (c. 25 feet) and inexpensive. They were used extensively during the early phases of NORPAX to provide ancillary data in areas surrounding the "Monster buoy."

Furthermore, the present wave generation theories are conflicting in some respects, and do not universally apply to all portions of the wave spectrum, or under all conditions. Perhaps the present success claimed by wave forecasters lies in the fact that the forecasting models employ empirical relationships which, on the average, lead to meaningful results in those portions of the wave spectrum which are of primary interest to shipping. No less than 20 separate wave forecasting methods have been in use since 1942, as well as numerous combinations and modifications of these methods. Figure 4 explains how waves actually look.

Table 2 indicates the generally accepted definitions of the several portions of the sea wave spectrum. The energy available in the several parts of the spectrum varies widely, the greater amounts appearing in the gravity and infragravity waves (sea, swell, and "surf beat"), and with two discreet spikes of energy at about 12 hours and 24 hours, representing the semi-diurnal and diurnal tides. Long period waves carry only a little less energy than to infragravity waves, and represent seiches, tsunamis, and moving storm system inputs. The total amount

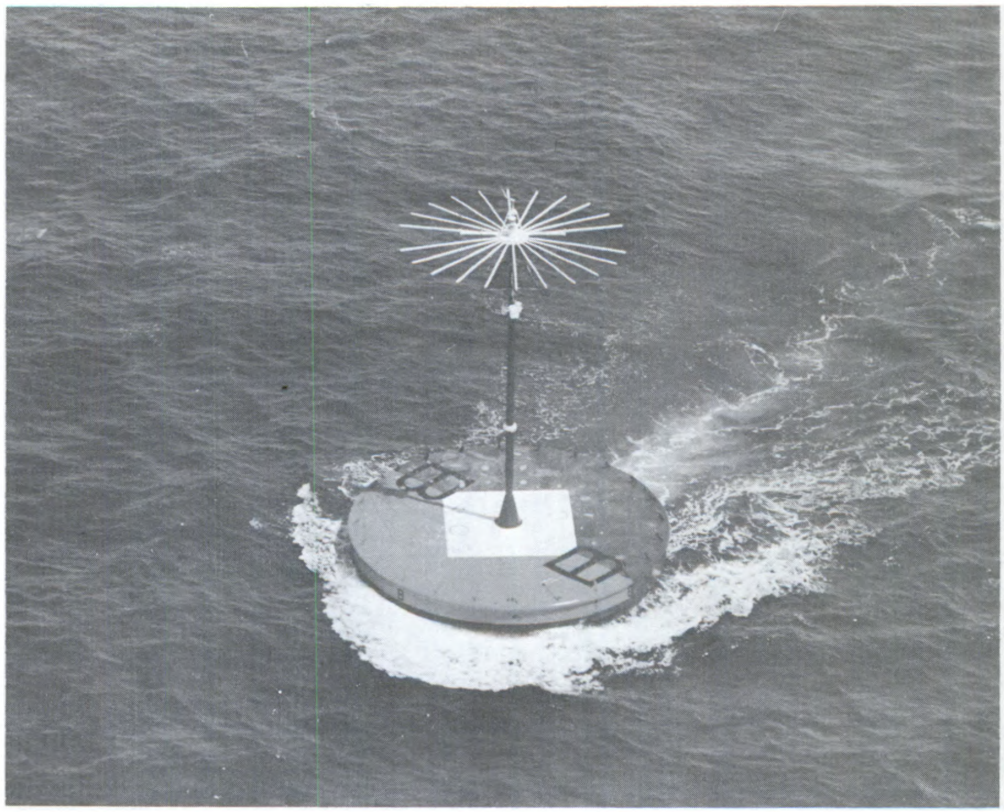
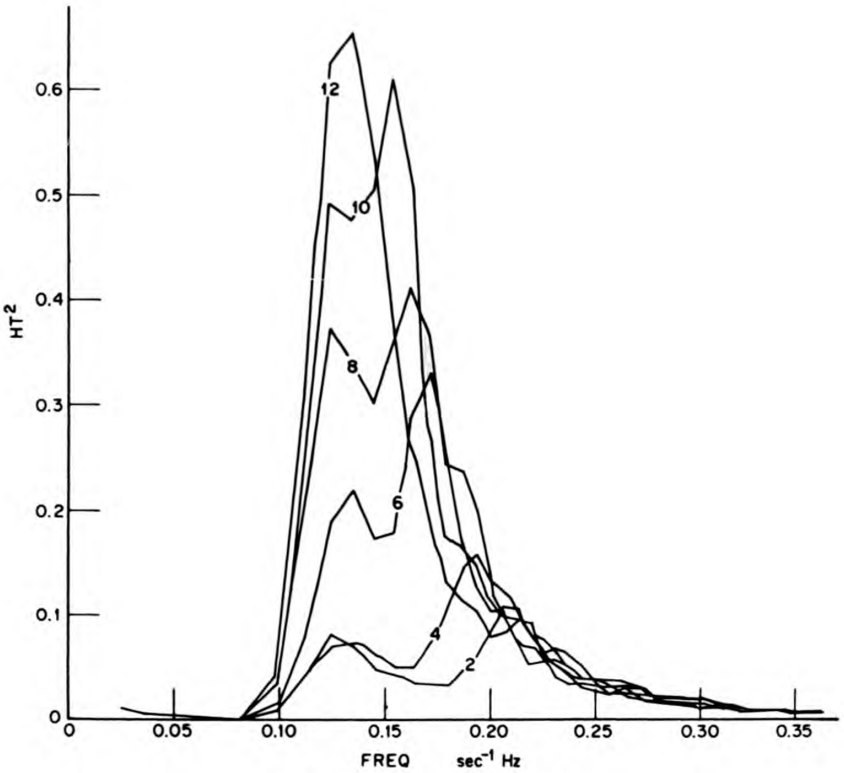


Figure 3 — "Monster-buoy" "BRAVO" anchored in the axis of the Florida Current off Miami. This long-life long-range telemetering buoy records and transmits meteorological and oceanographic information. This 40-foot diameter buoy withstood a direct hit by a hurricane, transmitted perfectly, and was undamaged.

TABLE 2
The Sea Wave Spectrum (after Kinsman)

Wave Band Name	Period Range	Freq. (Hz)	Primary Disturbing Force	Primary Restoring Force
Capillary	0.1 sec.	$10\text{-}10^{2}$	wind, waves	surface tension
Ultragravity	0.1-1 sec.	10-1	wind	surface tension gravity
Gravity	1-30 sec.	$1\text{-}10^{-1.5}$	wind	gravity
Infragravity	30-300 sec.	$10^{-1.5}\text{-}10^{-2.5}$	wind, waves	gravity
Long-Period	5 mm-1/2 day	$10^{-2.5}\text{-}10^{-4.6}$	earthquakes, storms	gravity, coriolus
Tidal	12 hr., 24 hr.	$10^{-4.6}\text{-}10^{-4.9}$	sun, moon	friction, coriolus
Transtidal	1 day-1 year	$10^{-4.9}\text{-}10^{-6}$	storm systems, climate	coriolus



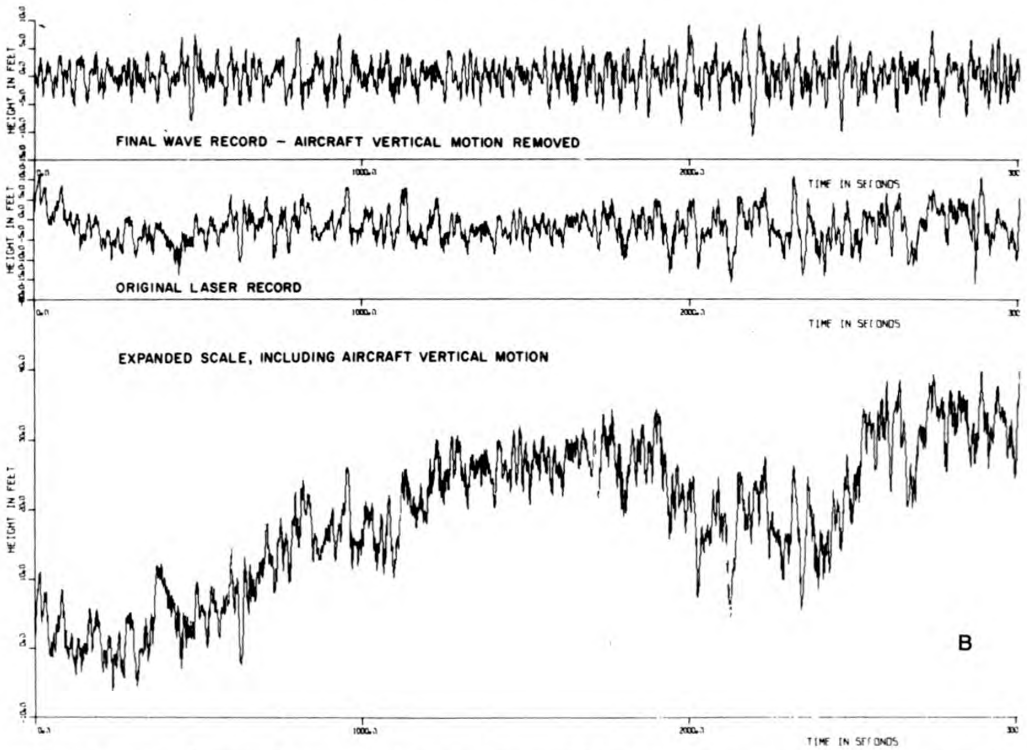


Figure 4 — A. Shows the output from a downward-looking laser mounted in an aircraft. From this record the spectrum of energy in the various wavelengths can be determined. B. Shows how the wave spectra change with increasing fetch (distance downwind).

of energy in the spectral regions does not necessarily indicate the relative importance of each region. It must be remembered that there is a constant flux of energy from one region to another, and that a group of capillary waves may in moments translate parts of its energy to a gravity wave—or *vice versa*.

Just what caused a wave in the first place? It seems like a simple-enough question, the answer to which is, "the wind, of course." This implies that if one knows the wind, one knows the waves. Unfortunately, this is not quite the case. There are many factors working at once, such as atmospheric and ocean turbulence and stability, relative densities, varying drag coefficients, initial roughness, wave-wave interaction, and so forth. We should examine a few of the more modern and useful theories of wave generation simply to illustrate a few of the reasons why this subject is so difficult.

In 1957 O. M. Phillips at Johns Hopkins developed a theory wherein he assumed a turbulent wind field being carried advectively across the water at some mean velocity, and that pressure fluctuations of the turbulent wind act randomly on the water surface, giving rise to random resonant response by the water. This theory is probably applicable to gravity waves, but not to capillaries. It is difficult to test this theory, but Dr. Russell Snyder at Nova University is presently conducting experiments in the field using extremely sensitive barometers, and his data, which are not yet published, may shed some light on the Phillips theory.

At about the same time, J. W. Miles at the University of California proposed a shear flow mechanism for the generation of surface waves. This theory assumes the existence of a viscous sub-layer at the air-water interface, and a coupling between air and water whenever the wind speed is equal to the phase velocity of the waves within this sub-layer. This theory appears to be important with regard to capillary wave growth, but breaks down in the presence of gravity waves. A combined theory (Miles-Phillips) is often employed, but this, too, has not proved universally applicable.

A much older wave generation theory has recently received new attention. In this theory, proposed initially by H. Jeffreys in 1925, one assumes a periodic pressure component exerted on the sea surface owing to air flow separation in the lee of a wave crest, and resulting in momentum transfer downward. This idea is realistic where the waves are steep enough to allow air flow separation, but not until then. Nevertheless, the basic idea has found recent favor among investigators at NRL, Hydronautics, and elsewhere, in describing the mechanisms involved in the growth of gravity waves at sea.

In any discussion of ocean waves, one must recognize that transfer of momentum is not exclusively in one direction, but that the sea waves themselves feed back into the air some of their momentum energy.

Also, much remains to be done in the study of the energy role played by "white-capping," or breaking waves, and of the effects of rain, spume, and foam. Wave forecasting as an art is in pretty good shape today so long as the inputs are accurate, but there remains generations of effort before one may expect a really good understanding of the complex processes which result in wind waves at sea.

Conclusion

Much has been learned about air-sea interactions during the past 50 years. By far the best summary of this progress has been given by the aforementioned Dr. Roll, from whose work I have paraphrased liberally.

In 1941, the Russian academician A. N. Kolmogorov published an important theory on the nature of turbulence spectra which affects the thinking of most meteorologists and oceanographers to this day. He suggested that there exists an "inertial sub-range" in turbulence spectra where energy is transferred from larger scale eddies progressively and predictably to the smaller scales. This so-called "cascade process" terminates when the scale of the turbulence becomes so small that its kinetic energy is dissipated and converted into heat through molecular viscosity. We see numerous papers in which the Kolmogorov wave-number relationship "$K^{-5/3}$" is proven or indicated time and again. There can be no question about the validity of his theory so long as it applies to three-dimensional isotropic turbulence.

But in nature, both in the atmosphere and in the oceans, the necessary prerequisite for the classical cascade do not exist at the larger scales. The convective motions in the tropics include mesoscale activity first in the vertical plane, then in the horizontal; the ocean below is very highly stratified in density and thus strongly favors the horizontal motions. Thus, both media must be considered, at least on this scale, to be *two*-dimensionally isotropic, and, as indicated in 1969 by E. R. Reiter of the U.S. Atomic Energy Commission, the theory then would require a reversal of sign or direction in which the energy cascade moves, that is, the energy would go from the small-scale motions to the large-scale. It is apparent that the energy really goes in both directions at once. For example, an individual small-scale puff of tropical cumulus convection may well be dissipated in the classical manner, whereas a collection of these, representing the mesoscale, can transport the energy to the larger motions—in other words, it can "organize." This mesoscale range, then, which is not covered by present observing networks, is of fundamental importance in the understanding of atmospheric and oceanographic processes, and points to the scientific desirability of carrying out such difficult and expensive tasks as NORPAX, BOMEX, and GATE.

On the Naval Research Reserve

Contributory Support Projects Performed by Naval Reserve Research Companies

Current Navy policy is that the "One Navy" concept be implemented expeditiously. This concept requires that the Inactive Reserve Forces be integrated as closely as possible with the Active Force so as to form a strong One Navy.

The need to continue the Research Reserve Contributory Support Policy to strongly support ONR and Navy Laboratories is necessary to further the Research Reserve support of the Active Forces. Below is a partial list of projects underway with several reserve units.

Contributory Support Projects of Naval Research Reserve Companies

NRRC 5-8, Washington, D.C.	Using a CO_2 laser measuring vibrational relaxation rates of carbon monoxide by hydrogen iodide for NRL.
NRRC 9-3, Ann Arbor, MI	Graphic and tabular summarizations of complex statistical analysis findings
NRRC 9-6, Minneapolis, MN	Developing mathematical techniques for the solution of enlisted personnel training input problems on a Navy-wide basis and in the general area of management Science Applications concerning enlisted personnel management systems
NRRC 9-21, Denver, CO	Research the application of Solar astronomical techniques to prediction of propagation disturbances for ionospherically-reflected terrestrial radio waves
	Identify elements of coastal environment for ONR
	Research use of thermoluminescent dosimetry to determine radiation emission from dental x-ray units and the amount of radiation operating personnel and patients for ONR

NRRC 11-5, San Diego, CA	Project "Dialogue," a Research Reserve presentation to facilitate public awareness of the broad aspects of Naval technology and its contributions to society
NRRC 11-3, Sunnyvale, CA	Setting up a computer program for the Chemistry Department of the U.S. Naval Postgraduate School
	Setting up a mini-computer program for the Electrical Engineering Department of the U.S. Naval Postgraduate School
	Assisting the Physics Department of the U.S. Naval Postgraduate School in a research project
NRRC 13-1, Seattle, WA	Research project on revising Navy standard forms 88 and 93 for Bumed
NRRC 13-4, Portland, OR	Participating in war games
NRRC 5-9, NRL, Washington, D.C.	Sponsored Research Reserve Seminar at the Naval Research Laboratory in August 1972. Seminar was attended by 40 officers.
	For 16th consecutive year, members of NRRC 5-9 served as judges for Navy Science Cruiser Program.
	Presentation of Science Cruiser Award. Judge International Science Fair.
	Studies resulting in written reports while on ACDUTRA in FY 73 include: a. Revision of Naval Reserve Research Program Brochure (for ONR) b. Revision of Naval Reserve Research Training Program (for ONR) c. Science to Seapower (for ONR) d. Review of Independent R&D Reports (for NAVSHIPS) e. Navy Task Assignments for Vocational Schools (for NAVSHIPS) f. Feasibility of Total Integrated Capability to Produce Replacement Parts (for DNL) g. Reduction of Chaff Test Data (for NRL)

NRRC 4-11, Cincinnati, Ohio	Studying laser communication for ONR
NRRC 1-2, Providence, R.I.	Assist Destroyer Dev Group Newport R.I. in analysis of fleet ASW and other projects.

Studies of Freeze-Dried Skin Grafts

Freeze-dried skin grafts taken from a tissue bank may one day accelerate wound healing following periodontal surgery.

This study is being conducted at the Naval Medical Research Institute, Dental Sciences Department, in order to determine whether skin taken from one individual and freeze-dried would be compatible with the oral tissues of a different individual under conditions similar to those following periodontal surgery. Preliminary evaluation using Rhesus monkeys has shown that healing is much more rapid in the surgical sites where the freeze-dried skin was applied than in the control sites without freeze-dried skin. Microscopic examination revealed that the freeze-dried skin was biologically compatible with the oral tissue, exhibiting an actual biologic adherence to, and blending with the underlying connective tissue.

This technique is proven successful in humans may make possible a simple method for replacing the supporting tissues of the teeth lost due to disease or disorder.

Third International Biodegradation Symposium

The Third International Biodegradation Symposium (slight name change) is to be held at the University of Rhode Island, Kingston, Rhode Island, from 17 to 22 August 1975. This symposium is under the Chairmanship of Dr. Richard W. Traxler. The executive committee is composed of representatives from the Office of Naval Research, the National Bureau of Standards, the U.S. Army, the Connecticut Agricultural Experimentation Station, and various industrial concerns.

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Research Notes

The Naval Research Laboratory: 50 Years of Achievement

Richard Baturin
Naval Research Laboratory

More than a decade ago, a group of government chemists experimenting with a commercially-developed resin, found after baking a thin layer of it onto metal, that nothing would stick to it, and it repelled water. That resin was subsequently marketed by the duPont Corporation, and became better known as Teflon. Today, a large number of familiar home appliances such as no-stick frying pans and commercial equipments such as safety valves, radio antennas, optical instruments, sporting equipment and motors are coated with this preservative. And all can be traced to the work of scientists at the Naval Research Laboratory who revealed the potential of this tetrafluoroethylene resin.

On July 2, the Naval Research Laboratory celebrated its 50th year in operation, advancing the frontiers of science for the Navy and the nation. The idea of establishing such a Navy research facility was conceived by famed American inventor, Thomas Edison. In 1915, during an interview with a New York Times Magazine reporter Edison said, "The Navy should have its own scientific staff to sift the ideas of our inventive nation."

Such a need was recognized by the then-Secretary of the Navy, Josephus Daniels, as World War I became increasingly imminent. In a personal letter, Daniels asked Edison to recruit a technical advisory group of leading scientists in various fields to draw up plans for such a laboratory. And by October 1915, the Navy Consulting Board of the United States, headed by Edison, was formed. However, men and materials were needed to answer the immediate call at the outbreak of the war, and the Laboratory plan was shelved until peace was restored.

The incubation period lasted about five years, and ground was broken on the banks of the Potomac in southwest Washington, D.C. in December 1920. What is now known as the Naval Research Laboratory was formally dedicated the Naval Experimental and Research Laboratory on July 2, 1923.

Edison's conception of the Laboratory was oriented toward war, and its program during its formative years was geared primarily to discoveries related to improving America's defense capabilities. However, the Laboratory's research effects since then have had far-reaching effects well beyond its original mission. Its achievements have contributed not only to the improvement of America's defense capabilities, but also to the betterment and welfare of mankind. Many of NRL's accomplishments which were designed to enhance the country's defense have found even wider uses in peaceful applications.

For example, in 1922 nearly one year before the Laboratory was formally dedicated, a Navy radio pioneer, Dr. A. Hoyt Taylor, reported strange fluctuations in a radio signal as a ship passed between a transmitter and a receiver placed on opposite banks of the Potomac.

These signals were actually the first radar-like detections reported in the U.S. Taylor was a member of the group which was to form the nucleus of the Laboratory the following year. He and his staff subsequently pursued this "sensing" capability of radio signals and within a dozen years had produced the first operational system of RAdio Detection And Ranging (RADAR) in the United States.

Today, radar is standard equipment on commercial, as well as military ships and aircraft. As a primary sensor for navigation and surveillance, it plays a major role in the safe and effective operation of modern transportation. Recently, NRL used its radar technology to detect and measure oil pollution at sea from a moving aircraft.

Not only is NRL credited with the discovery of radar and the continuing development of its potential, the Lab was also responsible for the development of underwater sound transmission (sonar) under the direction of the late Dr. Harvey C. Hayes, another distinguished member of NRL's original research staff.

Surface-ship and submarine sonar reached a high level of development under Dr. Hayes' leadership during World War II, when enemy U-boat operations in the Atlantic were taking their toll of Allied war efforts at sea. And when German subs began to use torpedoes designed to "home" on the sound of a ship's engines and propellers, NRL developed devices which countered these deadly weapons. Dr. Hayes was honored recently when the USNS HAYES, the Navy's first twin-hulled oceanographic research ship was named after him.

Countless life-saving developments have resulted from research efforts conducted at NRL. Among them are the only successful shark repellant, which is still in over-water survival kits (1944) and the first application of sea markers for personnel adrift at sea (1939). These markers were responsible for saving the lives of more than 150 persons during World War II. And NRL-developed life-support systems for submarines have led to the development of life support-systems for space travelers.

The first successful flight of a pilotless plane was accomplished by NRL radio men in 1923, the year the Lab was formally dedicated. And in 1928, the Laboratory maintained regular radio schedules with Admiral Byrd's South Pole expedition and the ships delivering supplies to it. NRL built the radio equipment used in the first aircraft which flew over the South Pole.

Lubricants, coatings and fluids are important areas of study at NRL and in which the Lab has been a major contributor. Moving parts in various types of machinery as well as nuclear-powered vessels would burn themselves out too quickly if it weren't for "made-to-order" lubricants developed at NRL. In 1952, the first synthetic lubricant for aircraft gas turbine engines was developed at the Lab.

Many pilots owe their lives to the many life-saving inventions developed at NRL. These include: fully automatic landing system for aircraft on aircraft carriers (1957); the directional radio beacon, a continuous signal by which pilots can orient themselves, and the landing beam which brings aircraft safely to earth under zero-visibility conditions. And in 1954, NRL solved the problem of fogging and icing of periscope head windows. This system is now used on all submarines.

Three years before Sputnik (1954), NRL scientists were credited with the first radio-voice signals reflected from the moon. Then in 1955, radio communication using the moon as a relay station was successfully accomplished by NRL communications specialists.

Although medical research is not a prime study area at the Laboratory, NRL is credited with some major contributions in response to requests for assistance from medical authorities. One was a heat exchanger which, when used in conjunction with existing oxygenators, has made it possible to quickly and safely reduce the body temperature of patients for heart surgery.

Another device developed at NRL is capable of monitoring the heartbeat of human embryos as early as 10 weeks after conception, to detect any abnormalities in the developing infant's circulatory system.

In 1962, scientists at the Laboratory developed an instrument called a piloejector for the treatment of cranial blood clots. Several hundred lives have been saved through the surgical use of this invention. And on March 17, 1972, an NRL group announced that it had joined the fight against America's No. 1 killer—heart disease, by producing a radioactive material, which when injected intravenously is used to predict heart attacks. As a result of this work, heart specialists hope that in the near future, similar material will help them predict which patients may be prone to coronary seizures, so that early definitive therapy can be initiated.

During the last three NASA Apollo missions, there were NRL-developed solar radiation monitoring satellites (SOLRAD 9 & 10) circling the earth, on guard for any unusual solar disturbances which could endanger the lives of our astronauts on their way to the moon.

Another space first for which NRL has received world-wide recognition occurred on January 10, 1972 when Laboratory scientists released the first pictures ever taken of the effects of a massive solar eruption that spurted from the side of the sun facing away from the earth. The special camera, called a coronagraph, which recorded the event, was on board an earth orbiting solar observatory (OSO-7).

Experiments like NRL's coronagraphy are helpful in forecasting the Sun's weather. This enables scientists to make more accurate predictions of the effects of solar storms on navigation and communications equipment on earth. NRL's coronagraph is still operating on the OSO satellite.

NRL is credited with innumerable "firsts" in the fields of communications and photographic techniques. It was Laboratory scientists who taught the world how to communicate by shortwave and produced the first scheduled radio broadcasts in the U.S. in 1925.

In 1964 after the search efforts of other maritime agencies proved unsuccessful, Laboratory ocean scientists located and photographed the hulk of the sunken nuclear submarine, THRESHER. They were called on subsequently in similar search missions and successfully located the lost submarines SCORPION in 1968 and EURYDICE in 1970.

April 21, 1972 was a big day for the Lab and space technology. On that day, man's first moon-based astronomical observatory, developed by NRL, was activated by the Apollo 16 astronauts. For the first time, space explorers were

able to study and record planetary and astronomical phenomena from the moon—phenomena which may reveal the inner secrets of our earth and its history.

NRL made a giant step in the area of oil pollution control at sea when, in 1970, it demonstrated the first successful containment of an oil spill using a monomolecular surface film.

The Laboratory has grown from five small buildings to a complex of specialized laboratories, housed in some 150 buildings along the banks of the Potomac, with field stations located in Maryland, Florida, Virginia and West Virginia. Its research areas encompass electronics, materials and general sciences, space science and technology, and oceanology.

The Navy has other research facilities but each is primarily concerned with special categories of problems directly related to the mission of their parent command. NRL, however, operates directly under the Chief of Naval Research, who reports to the Assistant Secretary of the Navy for Research and Development. The Honorable James H. Wakelin, former Assistant Secretary of the Navy for Research and Development, referred to NRL as the Navy's corporate laboratory. This concept of NRL's position is perhaps the best encapsulation of the Laboratory's leadership posture in basic and applied research leading to improved materials and systems for the Navy and the Nation.

(Continued from Page 27)

This symposium series has grown out of the symposium "Microbiological Deterioration in the Tropics" held in April 1965 and organized by the Microbiology Group of the Society of Chemical Industry. The Organization for Economic Cooperation and Development (OCED) in association with the Society of Chemical Industry sponsored the First International Symposium under the Chairmanship of Dr. H. O. W. Eggins at Southampton, England, 9-14 September 1968. The second symposium was held in the Netherlands during September 1971.

New Long-Lasting Battery Results from Navy Research Study

A revolutionary compact, high-powered electrochemical cell that lasts many times longer than conventional dry cell batteries has been developed as a consequence of Navy-supported basic research. Since the battery does not deteriorate when not operating, it can last for years in flashlights or radios that are used intermittently.

The cell, which produces nearly four volts, was developed by Dr. Adam Heller, Dr. James Auborn and their co-workers at GTE Laboratories, Waltham, Massachusetts, a subsidiary of General Telephone and Electronics. The development is a direct outgrowth of an Office of Naval Research contract with GTE Labs to study the electroluminescence properties of inorganic liquids. While engaged in the study, the group discovered that certain inorganic liquids can be used in alkali metal battery systems both as solvents and oxidizers for the energy source, permitting a dense storage of energy.

Utilizing this principle, the GTE Labs group has fabricated experimental cells that are capable of producing eight times the energy per pound of conventional dry cells. The cell consists basically of three components—a lithium metal anode, a carbon electrode, and an electrolyte composed of inorganic salts in an inorganic solvent. The energy is produced by the electrochemical decomposition of the inorganic solvent material at the carbon electrode and oxidation of the lithium during the discharge of the cell.

A key feature of this electrochemical cell is that the fluid or energy source is only used up when the circuit is closed and when the battery is actually discharging. There is no current leakage or degradation of cell life when not in use, as occurs in conventional dry cells.

This means that a flashlight or similar item powered with this battery can be operated after several years of non-use with no deterioration in performance. This greatly extended shelf-life plus the unusually dense energy source are what gives the battery its extraordinary long life.

Another feature of the cell is its voltage stability. A flashlight operated with the cell retains constant light output, and a radio operated with the battery retains uniform tone quality throughout the life of the cell.

A tiny version of the battery has been installed experimentally in a wristwatch, which it can powe

various versions of the battery might be used in portable radios and television sets, cameras, and hearing aids.

Naval applications include communications, submarines, mines and missile operations. One advantageous feature for military use is that the battery can withstand temperatures ranging from −76°F to 146°F.

GTE Labs has applied for patents on the new battery, and GTE is considering the possibility of marketing it commercially.

Navy Studies Shipboard Launch and Landing of Unmanned Aircraft

Some of the Navy tasks now performed at sea by manned airplanes, could be accomplished by unmanned aircraft if shipboard takeoff and landing of these vehicles were practical.

Under a study funded by the Office of Naval Research, the Navy is now investigating the feasibility of shipboard launch and recovery of remotely piloted vehicles (RPV) and their potential missions. These aircraft could fly potentially hazardous or monotonous missions and contribute considerable savings in staffing requirements and training of pilots. Equipped with sophisticated equipment, and remotely controlled from their ship, they could safely perform reconnaissance, search, radio relay or antisubmarine duties.

Experiments in launch and recovery of unmanned aircraft have been previously conducted on land. Take-off and landing from a moving ship, however, presents many problems including limited space, motion of the ship, cross wind currents, wake (air turbulence created by the ship's superstructure), sea state, or poor visibility.

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Shipboard launch of unmanned flight vehicles has been done on numerous occasions. Most of these, though, have been target drones which must be recovered by parachute and retrieved from the sea.

The Navy's goal is a practical technique which would permit a fail-safe recovery aboard vessels with limited deck space. An important part of this technique is an effective command and control data link between the vehicle and a command room on the ship. From this command post a pilot-controller would be able to track the RPV on a computer-assisted display panel, monitor its performance and eventually guide it to the touch down point on the ship.

Recent technological advances in the area of automatic flight control avionics, navigation systems, and various VTOL and other systems now permit several possible solutions to the problem.

Among the candidate systems that will be investigated under the ONR study are several VTOL concepts which can be adapted to remotely piloted operation. One of these is a stoppable rotor concept in which a rotor-wing acts as a helicopter rotor during takeoff and landing. The rotor can be locked in a fixed position to serve as a normal wing during cruise flight. Another version of this concept is a retractable rotor used in conjunction with auxiliary wings. When not taking off or landing, the rotor is retracted and the vehicle can fly on the auxiliary wings.

Another VTOL concept that may be used in unmanned flight involves a fixed-wing vehicle whose jet exhausts can be rotated in different directions to provide vertical, or horizontal thrust for takeoff. This power system coupled with high-lift devices permits a relative speed of the aircraft, as it approaches the moving ship from the stern, of only 5 to 10 knots. At this speed the aircraft can safely be guided into a safety net for landing.

The study is being conducted by Teledyne Ryan Aeronautical, a division of Teledyne Industries, Inc., San Diego, California.

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Cover Caption

Tests conducted with a blue-green laser demonstrated the feasibility of using this system as an airborne optical ranging device to measure moderate water depths.

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