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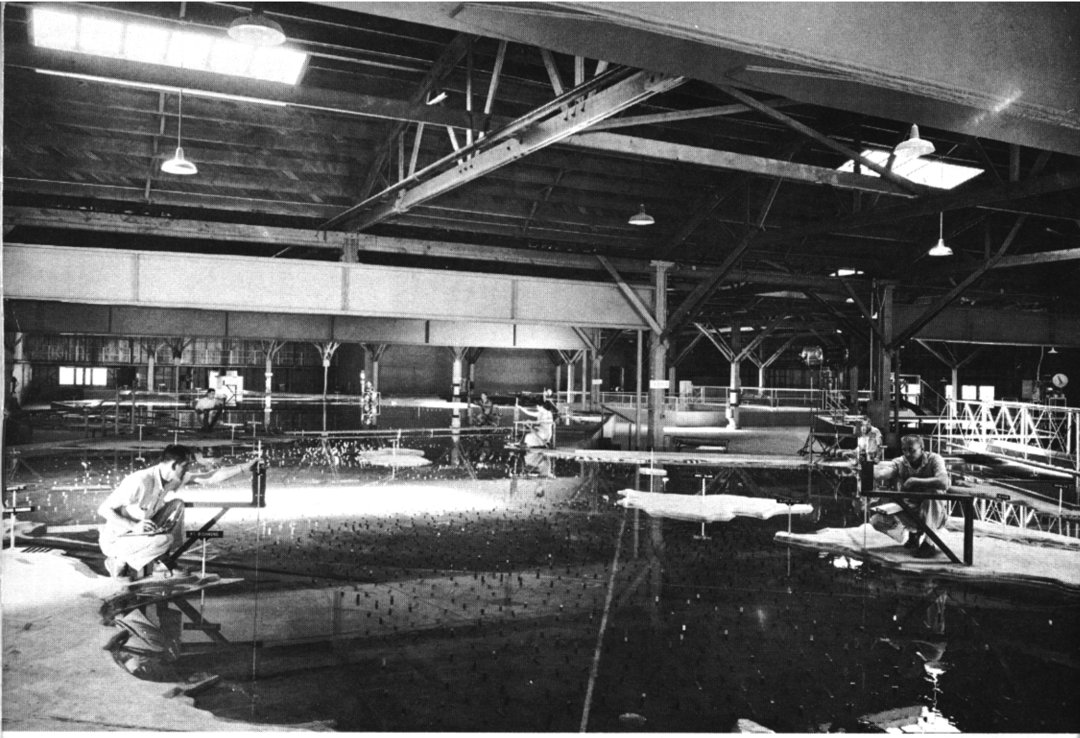
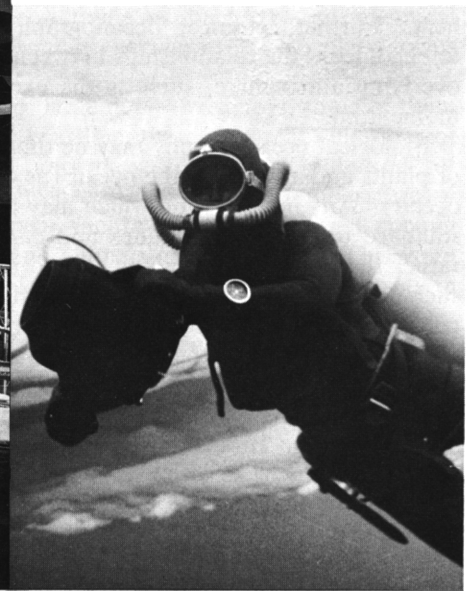
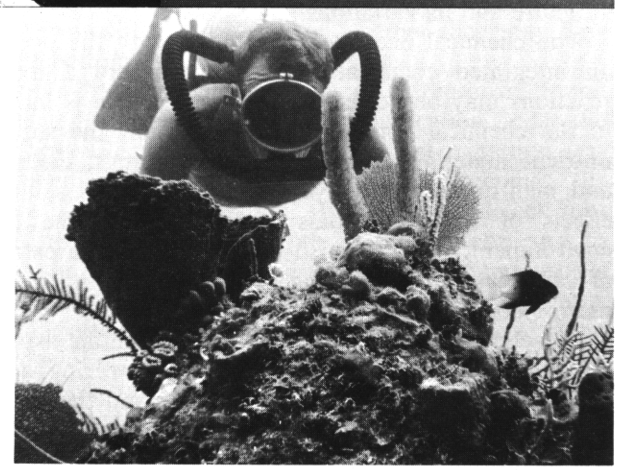




Studies in oceanography take a variety of forms. Shown above is an indoor simulation of the San Francisco Bay area. Engineers at tide stations take readings every seventeen seconds as a previously recorded tide is recreated. At the right, a U.S. Navy frogman from a nuclear submarine photographs the underside of ice in the North Polar regions. Below, a skin diver searches the ocean floor for coralline specimens.



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Oceanography

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More and more often the teacher in the elementary school or junior high school is being asked to handle a segment or even an entire course in oceanography. The segments may be in connection with a broader course in earth science, or they may be part of a series including, for example, meteorology and astronomy. In either case, few teachers can undertake such teaching without additional preparatory work. An attempt will be made here to outline the oceanographic subject matter which might be included in a school presentation and to indicate sources of information to which a teacher might turn.

OCEANOGRAPHY has been defined in many ways. It may be called the study of the oceans in all their scientific aspects—the biological, the chemical, the geological, and the physical. It considers the oceans as a unified dynamic medium, the study of which may be approached from the points of view and using the technology of the pertinent basic sciences and engineering. It has its own unique body of subject matter and its own peculiar technology.

The basic component of all oceanography is physical oceanography. Here is included the study of the various forms of motion—the wind waves and swell, the prevailing and transient currents, the tides and tsunamis, and the processes of mixing and diffusion. Here, also, is investigation of the physical characteristics of seawater, such

During its national convention in 1966, the National Science Teachers Association presented ten four-session seminars on frontier-topics in science. This article is a summary of one of the seminars, all of which are being published by the Association. Those for the elementary and junior high school teachers will appear in fall issues of **Science and Children;** those for senior high school teachers will appear in **The Science Teacher.** The summaries will also appear in a separate publication now in preparation by the Association.

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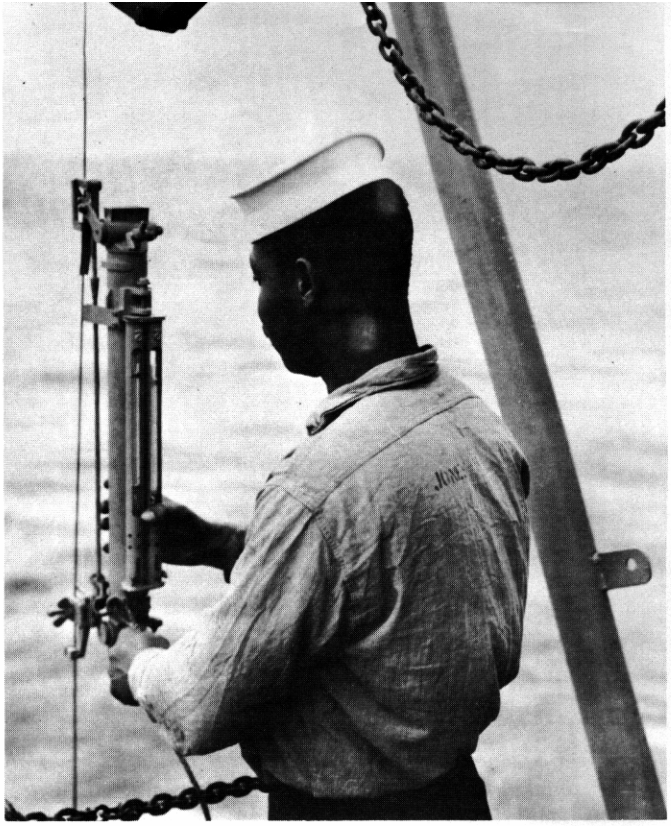
as of the manner in which it transmits light, sound, and heat. Further, physical oceanography is usually taken to encompass the relationships between the oceans and the overlying atmosphere, such as the exchange of heat and momentum.

Biological oceanography may be thought of as the study of plants and animals *in* the ocean (as opposed to *"of"* the ocean). Any investigation which may be carried out using standard biological techniques and capabilities is biology rather than oceanography and should be so called. Much such work deals with organisms from the sea and is of great value to the biological oceanographer, but his primary concern is with the ocean itself.

Geological oceanography concerns the interaction between the oceans and their solid boundaries—the bottom and the shores. It deals with erosion and sediment transport and with the description of past events based upon the analysis of bottom cores. The geological oceanographer, working with the solid earth geophysicist, attempts to understand the basic character of the earth's crustal structure and its variations.

The chemical oceanographer deals with the oceans as an integrated chemical system, one where a thousand reactions may be occurring at one time. He is interested in the chemical composition of seawater, the supply of nutrient materials essential for living things, the natural and man-made radioactive materials in the sea, and the effects of waste materials introduced into the marine environment. He may also be involved in the extraction of raw materials, including freshwater, or in studies of marine corrosion.

Closely associated with each of the scientific aspects of oceanography is a rapidly growing engineering activity. The importance of this type of activity and the extent of the interest in it is indicated by the fact that the Marine Technology Society, formed in 1963, now has sponsored four highly successful national symposia on oceanographic subjects with attendance of about 1500 at each.[1]



Sailor checks Nansen Bottle which is used to obtain water samples and temperatures at designated depths.

ONE good way to focus upon basic problems of oceanography is to consider some of the problem areas where oceanographic knowledge may be applied to advantage. As examples of such problem areas we may list weather forecasting, improvement and development of marine fisheries, proper disposition of waste materials at sea, military problems, improvement of marine recreational facilities, development of the utilization of marine mineral deposits, problems related to navigation and commerce at sea, and problems related to construction and maintenance of coastal structures.

There are many features of the weather which are greatly influenced by the oceans. Hurricanes form only over warm oceans and begin to dissipate when they cross the coast; coastal fogs are often caused by warm air moving across a cold sea; squalls and thunderstorms are generated by heating from below; and there are good indications that many of the major cyclones of the mid-latitudes may be traced to the influence of the oceans upon a cold, dry air mass moving out over the water and meeting a contrasting warm moist mass there. The atmosphere exerts a strong influence upon the oceans. It generates wind waves, sets up wind-drift currents, and modifies the internal distribution of mass in the oceans by evaporation, conduction, and radiation; and thus affects the semi-permanent ocean-current systems and the mixing of the surface-water layers.

Since most incoming solar radiation passes directly through the atmosphere and is absorbed in the oceans, the oceans are generally warmer than the air. Thus, the oceans influence the atmosphere primarily through the processes of heat transfer by evaporation, conduction, and radiation. The first two of these are dependent upon the differences in humidity and temperature between the air and water and upon the wind speed which helps to mix the heat transferred to upper levels. The most important ocean variable in this sea–air interaction process is the sea–surface temperature. This is a subject for considerable emphasis in oceanography. Fogs are formed when air is warmed and moistened over a warm sea surface and then transported to a cold one. Gustiness and convective clouds are observed when cold air moves over warm water. Hurricanes appear to follow broad tongues of warm water. The climate of coastal communities, particularly where there are prevailing onshore winds, is governed by the temperature of the adjacent sea.

Factors affecting the sea temperature include not only solar radiation and transfer to the air above but also many influences that are internal to the sea such as transport by ocean currents. Learning to forecast sea–surface tempera-

[1] Another organization, the National Oceanography Association, established this summer, announces that its membership of representatives of industry, colleges and universities, and the general public will promote public interest in oceanography.

ture and to understand better its influence upon the weather is one of the most promising of possible ways to improve and extend weather forecasts. The specific heat of seawater is several thousand times that of air so that sea temperature is a much more conservative property than the meteorologist usually has at his disposal.

FISH in the sea, like people on land, have a definite preference for certain types of environment. The tuna like warm surface water. The cod like deeper cold water, and so on. Thus, sea temperature is important to biological oceanography. In this case, however, the temperature at depth may be more useful than the sea–surface temperature. The two are closely interdependent. In the winter in mid-latitudes there tends to be a deep surface layer of water with uniform temperature while in the summer, with less mixing by the winds and less cooling at the surface, the stronger incoming solar radiation tends to heat up a thin surface layer only.

The great fishing areas of the world are found in what are called "upwelling" areas. One of these is found off the California coast. These areas are areas where winds along the coast are such that the surface layers of water transported to the right of the wind, as they are in this hemisphere, will be transported away from the coast. These waters must be replaced, and the only source is the deep water below. The rising of these cold deeper waters, bringing with them the richer nutrient materials found at those depths, is called "upwelling." Not only does it create good conditions for a fishery but, in the case of California, it makes a pleasant year-round coastal climate. Because of it, there is little difference between summer and winter sea temperatures in this region. Actually, at small depths, the temperature of the sea is higher in midwinter than it is in summer in certain locations here.

There are many other oceanographic factors that affect the fishing industry. The chemical constituents of the water, the large ocean-current systems, the transparency of the water, and the characteristics of the bottom are but a few of these. Many of the problems of the fisheries concern the interrelation of species of plants and animals. The tiny drifting plankton are the base of the food chain, and much attention is given to their study. Their location and rate of growth and concentration appear to be heavily dependent upon the hydrography of the oceans. Thus, we come back again to the study of ocean currents, temperatures, salinities, and topographic features.

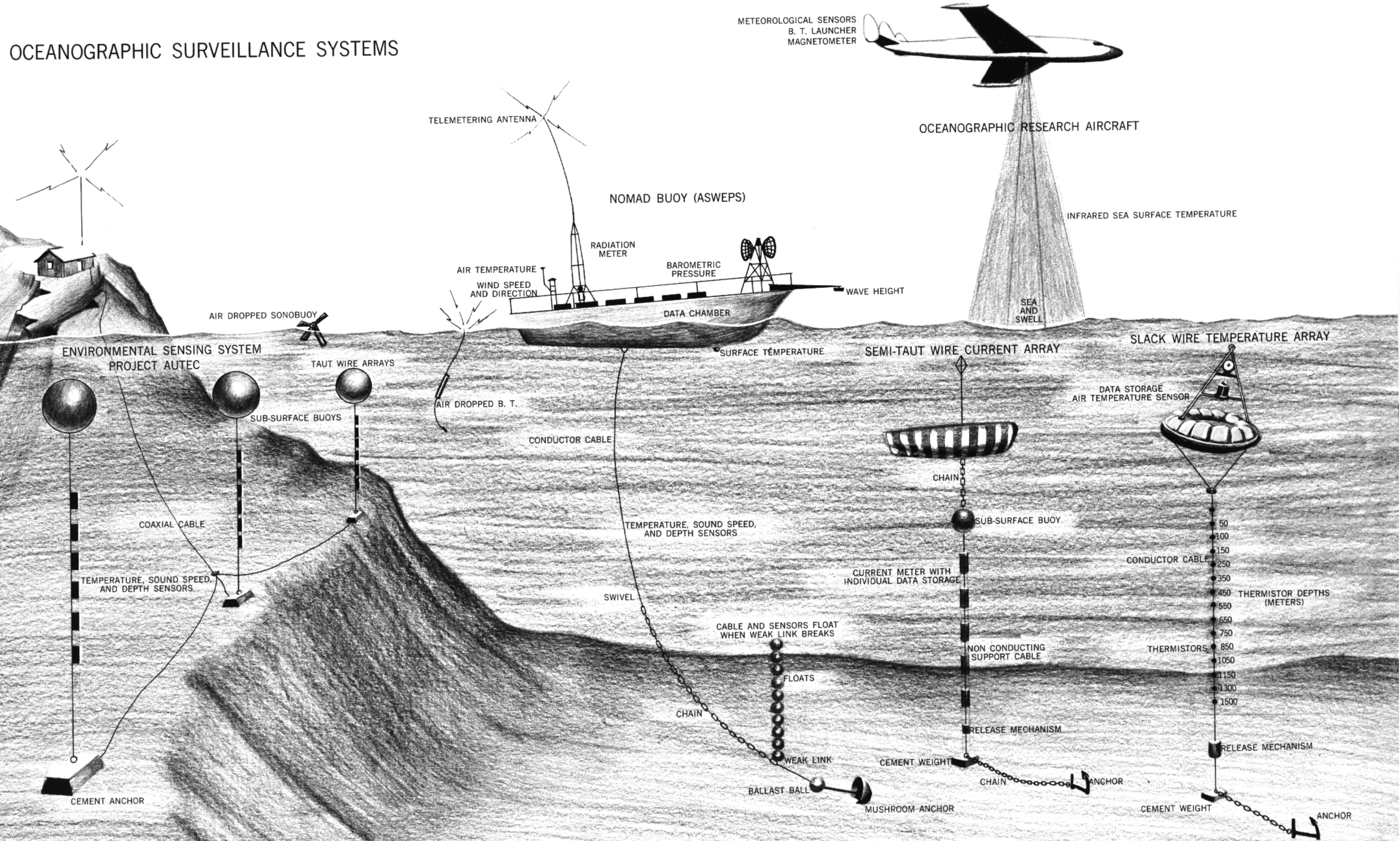
Proper utilization of the sea in the disposition of waste materials is a rapidly growing area of oceanographic applications. The sea is a remarkably efficient agent in such disposal, but improper uses can result in contaminating swimming areas and beaches and destroying valuable fisheries resources. Before large quantities of pollutants are released in the sea, attention must be given to the processes by which they will be mixed throughout large volumes of seawater and transported by currents away from centers of population. Something must be known about the undisturbed flora and fauna of the disposal area so that they can be monitored and any adverse effects noted and corrected. The activity of bacteria and chemical processes in transforming the wastes to harmless forms must be measured.

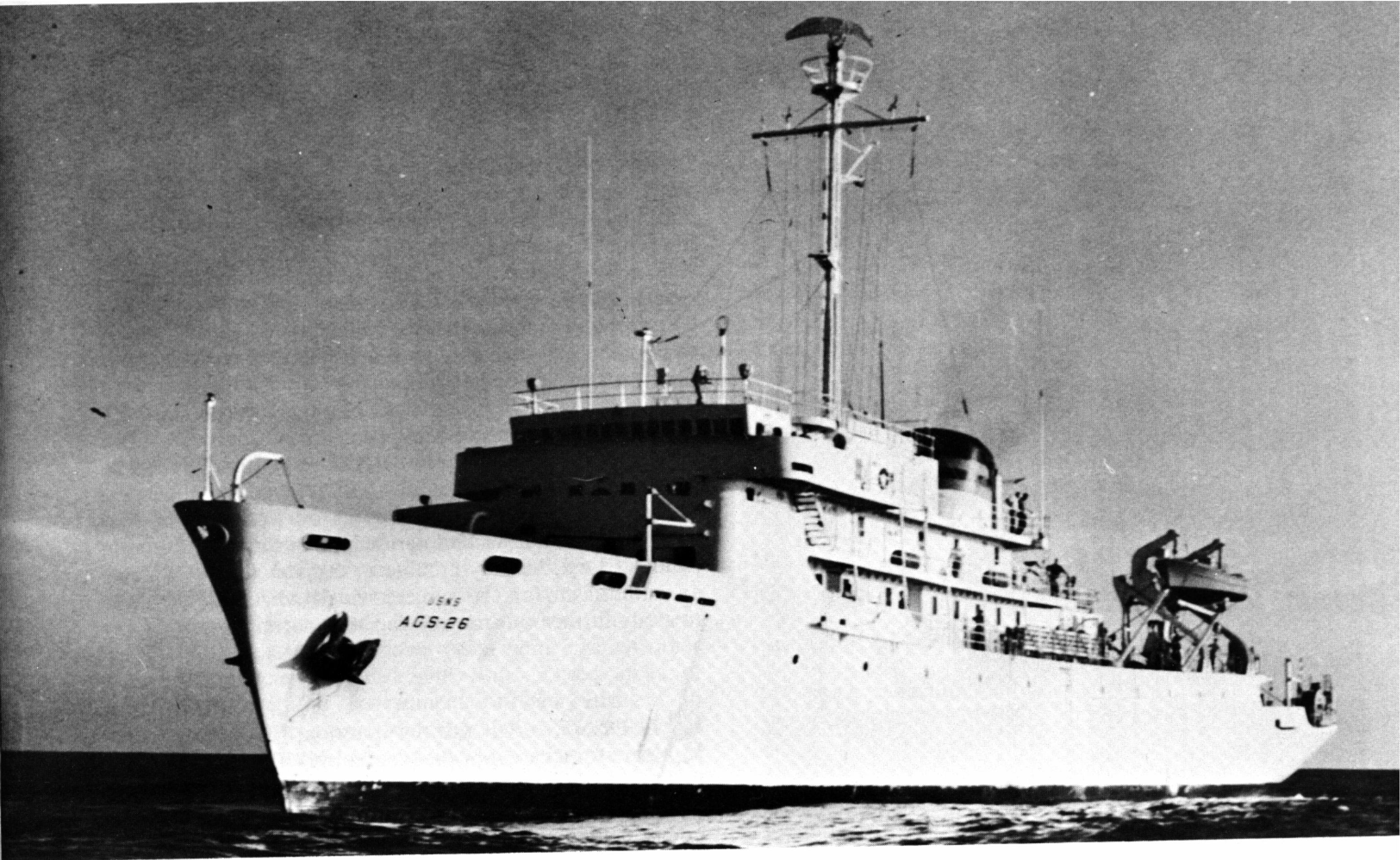
With the coming of large nuclear reactors, some of them to be used along the coastline, there are great quantities of heat to be removed, and the wording "heat pollution" of the ocean has now been coined. Will the temperature of the sea in an area near such a reactor be altered enough to affect the plants and animals growing there? This is an oceanographic problem. Among the factors involved in the release zone is the behavior of waves, which determines the amount of mixing and diffusion. Also, the tides and associated tidal currents are important, especially in the the release zone is the behavior of waves, which determines shallow waters. The prevailing longshore drifts, which often result from the nature of the incoming waves and the direction of their approach, must be known. The bottom topography is a factor determining the direction of flow. The relative density of the seawater in the local area must be compared to that of the introduced wastes to determine whether they will float or sink or whether they may flow along the bottom.

As for military applications, many of these are found to be related to the methods of communication under the sea surface. Electromagnetic waves do not penetrate seawater significantly, and, therefore, sound becomes the basis for most communication. It is used to detect submarines, to determine the depth to the bottom, and to describe the character of the sub-bottom. Sound travels faster and farther in water than it does in air. However, it does not often travel in a straight line, and this is where knowledge of oceanography comes in. The speed of sound in the sea is a function of temperature, salinity, and pressure. Thus, accurate depths can be measured acoustically only when these are known. Also, a sound ray passing at an angle through water which varies in temperature will be refracted. Unless the temperature structure is known, the position of an object detected acoustically will not be known. Further, noises are generated in the sea itself by the animals or by motions such as breaking waves. It must be possible to distinguish the desired signal from such background noise if it is to be useful.

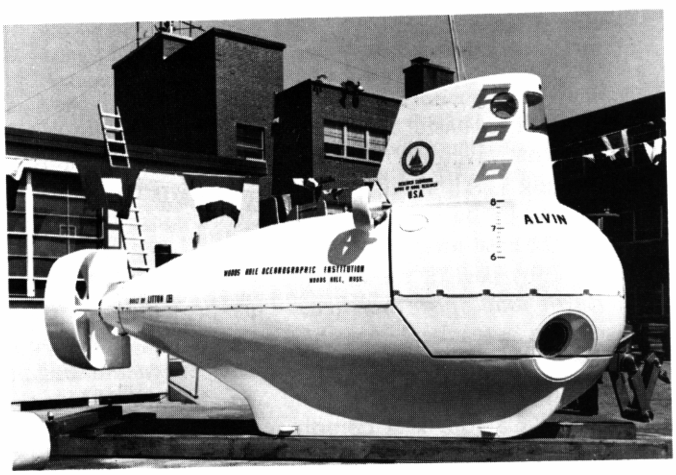
THERE has been rapid development in oceanographic instrumentation and in survey methods. The small, converted vessels used until very recently have now been largely replaced by modern, larger vessels designed specifically for work in oceanography. There are ships of special design, such as FLIP and SPAR which are several hundred feet long and of cylindrical form. These particular ones are floated vertically so that they extend to depths greater than those most influenced by wind waves. Thus, they become stable platforms for work at sea. There are small submarines of many designs and it is becoming much easier for the geologist and biologist to see firsthand their objects of study to depths of some 6,000 feet. There have been manned stations at the bottom of the sea in several hundred feet of water, and the depth range of such stations is being extended steadily.

OCEANOGRAPHIC SURVEILLANCE SYSTEMS





The USNS Silas Bent *is the latest addition to the U.S. Naval Oceanographic Office's fleet of research and survey vessels. The two-man deep submersible, Alvin, was used to discover the lost H-bomb off the coast of Spain.*

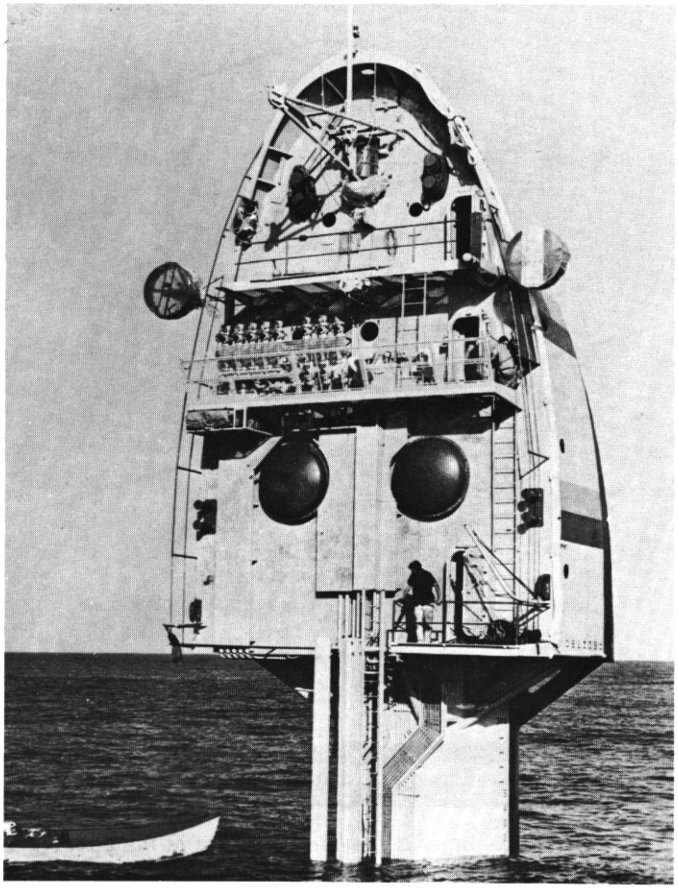


Many new types of buoys are being made available. They can be anchored in any depth of water and will report observations regularly by radio or will store information for long periods on tape. One such buoy, called the NOMAD, has operated successfully in 2,000 fathoms depth in the Gulf of Mexico. The observations have been continued for many months in each hurricane season over a period of more than eight years. It reported regularly during the passage of Hurricane Hilda in 1964.

Electronics continually provides new instrumentation. Within the last two years it has become possible electronically to measure temperature and salinity to 1,000 meters depth with the accuracy required by physical oceanographers—to within 0.02° C and 0.02 parts per thousand. The mechanical bathythermograph now has an electronic equivalent which is expendable and reaches some 1,200 feet in depth. Depth recorders are capable of showing the layering of the sediments beneath the bottom in some situations. Detailed analysis work, formerly done on shipboard by hand, may now be handled by computers. The earth's magnetic and gravity fields may be measured accurately. Schools of fish may be detected by sonar gear. Navigational equipment, the key to all accurate oceanographic work, is being made more and more precise and dependable.

Airplanes are coming into regular use for ocean survey work. The Naval Oceanographic Office operates a fleet of five. From them can be measured, for example, the height of wind waves and the horizontal gradients of sea surface temperature. Currents may be distinguished by water color, floating debris, or by a difference in the state of the sea. Early experiments are underway to extend such observational capability to satellites. Even now, pictures from manned satellites provide the first broad two-dimensional observations of cloud patterns over the sea. Also, the satellite makes possible the almost perfect determination of a ship's position.

THE teacher faced with the problem of teaching a course in oceanography has an "ocean" of material to choose from. It is difficult for him to know what to select. There are several presentations which give representative



Manned ocean buoy, FLIP (Floating Instrument Platform), provides a platform for making oceanographic measurements.

selections. The basic classical presentation of the whole subject is that given in *The Oceans* by Sverdrup, Johnson, and Fleming.[2] Although this book was written in 1942, there seems to be no comparable work since that time. One of the authors, R. H. Fleming, has written the oceanography part of the new junior high and high school text, *Earth and Space Science*. This presentation would be useful to a teacher. Another reference of this type is the article on oceanography in the *Encyclopaedia Britannica* by John Lyman. Also, *The Sea Around Us* by the late Rachel Carson, is a comprehensive and readable introduction to the subject, is sufficiently accurate, and gives a real feeling for the nature of the oceans and their phenomena.

For newer information about oceanography, with discussions of some of the modern methods and problems, the books *Ocean Sciences* edited by Captain John Long for the Naval Institute, and *Secrets of the Sea* by Lloyd Mallan may be mentioned. The most authoritative and comprehensive recent work is probably the three-volume set, *The Sea* edited by M. N. Hill.

There are many other sources of information which may be useful. The Woods Hole Oceanographic Institution distributes a good list in a *Reader's Guide*. The Earth Science Curriculum Project of the American Geological Institute has compiled a set of references in earth science which include oceanography, a list of films on the subject and how they may be obtained, and a list of institutions in the field.

The *Scientific American* has published many articles on special oceanographic topics which are written for the layman by noted authorities on the subject. The *National Geographic Magazine* is another source of good general oceanographic information.

The content and presentation of any course in oceanography is greatly dependent upon the background and interests of the teacher. If he tries to present the whole subject he may end in confusing himself and discouraging his students. However, if he picks out some of the features of the ocean which interest him and which he is able to understand, he may be able to transmit to his students an enthusiasm for the subject which will motivate them to study further as time and facilities permit.

STUDENTS often ask the question, "How can I prepare for a career in oceanography?" The teacher might first respond by attempting to make sure that the interest of the student is of the type which might make a career in his field a possibility. There are several indications. One is that the student should have a breadth of scientific interests and capabilities. This may be difficult to judge in elementary or junior high school, but if the student has had some mathematics, biology, physics, or some chemistry and finds whatever he has had attractive, this is a good sign. The interest in quantitative subjects is essential. Also, a natural curiosity about his physical environment is a favorable indication. The level of scholarly capability is important since the oceanographer must qualify for a college education and probably for graduate work.

If it appears that a student is truly a good prospect for a career in oceanography, he should be advised to take a good solid college preparatory curriculum in high school, with as much mathematics and science as he can include. If he is able to work as a laboratory assistant or as a paper grader for one of his teachers, he would find the experience valuable.

When it is time to decide upon a college major, the potential oceanographer must choose between the various areas of science or engineering, according to his own interests. In any case, he should include as much mathematics and physics as is practical and should broaden the program usually specified for science or engineering majors by taking electives in other sciences. Every student should have at least one good course in geology, and one in biology, even if his major is physics, chemistry, or meteorology.

For many years it has been possible to obtain a bachelor's degree in oceanography at one university, the University of Washington. Several other institutions are now initiating similar programs. Most other institutions offering formal work in this field require a bachelor's in a basic science field or in engineering before the student embarks

[2] For complete citations, see Bibliography.

upon any extensive work in oceanography. There are many opportunities for those with a bachelor's in oceanography, but a more advanced degree opens up many additional and possibly more desirable possibilities.

It is the custom for many graduate students in this field to be supported either through part-time research assistantships or fellowships. In these cases a master's degree may be obtained in about 18 months and the doctoral degree in about three additional years.

Present indications are that the universities offering programs will not be able to meet the need for oceanographers within the next five years, even if they operate to capacity. This is particularly true in the area of greatest demand, physical oceanography.

A recent trend has been the establishment of training programs for oceanographic technicians. Such programs may be completed in about two years and qualify interested students for good jobs.

Salaries of oceanographers have improved in recent years and now are at or above the general level of other categories in science and engineering. Three areas of employment are the government bureaus engaged in oceanographic work, the research programs of universities and nonprofit institutions, and industry. The number of professional oceanographers in the United States varies depending upon the definition used, but it is more than 600.

THERE is no scientific society of oceanographers which uniformly represents all of the profession. The American Geophysical Union has a section in oceanography which emphasizes the physical, meteorological, geological, and geophysical aspects. The American Society of Limnology and Oceanography leans heavily toward the biological and chemical. A new organization, the American Society for Oceanography, is attempting to bring together a wide segment of interested persons from universities, government, and industry. However, there is no one source to which a teacher may turn for complete authoritative information.

There are 22 bureaus of the U. S. Government which have oceanographic activity in their programs. These have organized the Interagency Coordinating Committee (ICO) which has provided many useful documents. Three of the most recent are listed in the bibliography and deal with personnel, curricula, and undersea vehicles.[3]

For many years the National Academy of Sciences–National Research Council has sponsored a Committee on Oceanography (NASCO). This committee has made various recommendations for the development of the field, such as its well-known report, "Oceanography 1960-1970." It has produced authoritative statements on the subject and has even undertaken an analysis of the economics of oceanographic research. (See Bibliography.) In this it was pointed out that the long-term benefit-to-cost ratios for various types of oceanographic research were high, and the practical results which might be expected from such research were great.

[3] A new statute (Public Law 89-454), which was signed by President Johnson in June, establishes a National Council on Marine Resources and Engineering Development, with cabinet-level membership. It will make recommendations to President Johnson about the nation's program in oceanography.

In the area of international affairs, in which the role of oceanography is unique, there are many organizations. One of these is the Scientific Committee on Oceanographic Research (SCOR) which is a committee of the International Council of Scientific Unions. Another, operating through official government representatives, is included in the Food and Agriculture Organization of the United Nations. The oceanographic program of the International Geophysical Year was a truly large-scale international effort and was one program where the representatives of the Soviet Union met regularly with representatives of the United States and many other countries and worked effectively with them.

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