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RESEARCH REVIEWS

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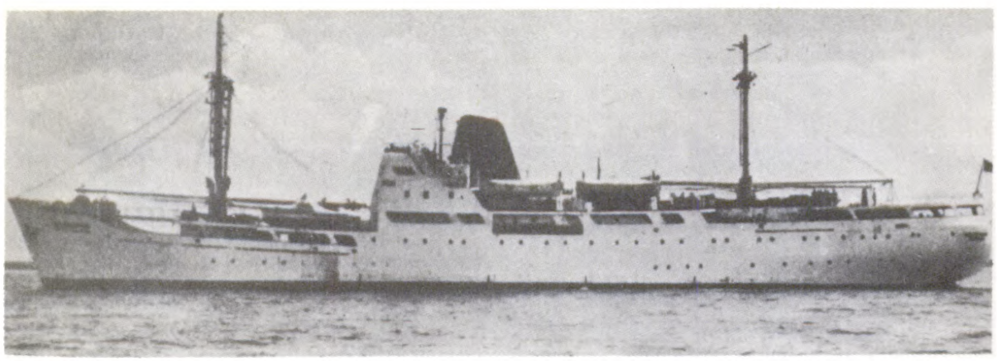
DEPARTMENT OF THE NAVY · OFFICE OF NAVAL RESEARCH

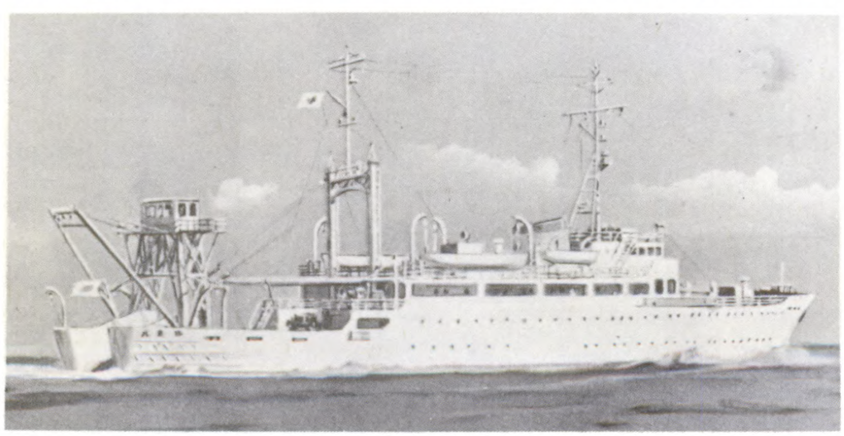
NAVEXOS P-510

The ATLANTIS of the Woods Hole Oceanographic Institution, the only United States ship designed specially for oceanographic research.



The MIKHAIL LOMONOSOV, built for oceanographic research by the U. S. S. R. She was commissioned in 1957.

The UMITAKA MARU, training and research ship of Tokyo University of Fisheries. She was completed in August 1955.



Ships for Research*

Recent adventures with rockets and satellites give one the impression that space is our last big frontier. It is true, of course, that space does present a gigantic challenge. However, we should not let it consume so much of our attention that we forget that another great frontier awaits exploration, too; this one right here on earth—the vast depths of the seas.

Man has been curious about the seas since the earliest times, but his progress in learning about them has been so slow that many features of the marine environment remain unknown. This situation exists not because of lack of interest or effort, but because of the vastness of the oceans and the inadequacy of the equipment that has been available for studying them. Of critical importance on this list of required equipment is the research ship, particularly the ship designed specifically for the task. A few nations, especially the United States, Japan, and Russia, have invested in such ships and are putting them to good use. But only a handful exist throughout the world, and only one in the United States.

Compared with Russia's new research ship MIKHAIL LOMONOSOV, the one United States ship built specially for research looks pitifully small. The latter—the ATLANTIS of the Woods Hole Oceanographic Institution—displaces only 298 tons, whereas the Russian ship displaces 5,960 tons. A further comparison—also unfavorable to the United States—can be made of the ages of the two ships. The LOMONOSOV was commissioned in 1957, whereas the ATLANTIS first ventured to sea 26 years earlier. This difference gives some indication of the adequacy of facilities aboard the two ships for conducting up-to-date research.

All of the other United States ships used for research have been converted from such vessels as yachts, warships, tugboats, and fishing craft (see table on page 2). Because these ships were designed originally for purposes other than research, their facilities for both crew and scientific work are inadequate. Many of them have limited range or are unsafe for oceanographic work in sea states greater than 3 or 4.† In addition, they are noisy, making it difficult or even impossible to conduct certain studies, such as of sound-propagation. Furthermore, the larger ships have improper scientist-to-crew ratios; that is, they require many more crew members than scientists, which in the research business is economically unsound. Also, most of the ships are slow, which is costly in scientists' time and in Navy funds.

What, then, is our standing in research capability at sea? We have only to look at the efforts being made by Russia and Japan toward

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*Discussions in this article concerned with the status of U. S. research at sea are based on material contained in a paper entitled "Oceanographic Research Ships," by G. G. Lill and A. E. Maxwell of the Geophysics Branch, Office of Naval Research, published in the Journal of Underwater Acoustics (ONR), April 1958.

†"Sea states" are graded in order of severity from 1 to 9. Sea state 4 sends most landlubbers to their bunks.

Principal Oceanographic Ships in the United States[1]

Ship	Owner	Type	Year Built	Displacement (tons)	Length (feet)	Beam (feet)	Scientists Accommodated	Size of Crew	Daily Cost of Operations (dollars)	Range (miles)
Private Institutions										
ATLANTIS	Woods Hole Oceanographic Institution[2]	Ketch	1931	298	142	28	9	19	1,000	4,000
BEAR		Coastal freighter	1941-42	200-300	100	22	10	14	500	2,500
CRAWFORD		Standard cutter		280	125		9	17		6,000
LIL JOY (bay work only)	Narragansett Marine Lab., U. of Rhode Island	Dragger	1947	12	37	12	3	1	400 (per month)	175
ACTION	Dept. of Oceanog. & Meteorology, New York Univ.	Racing schooner	1930	28	65	15	Berths for 9		100	Coastal water
VEMA	Lamont Geological Observatory, Columbia Univ.	Auxiliary schooner	1923	533	202	33	15	17	1,000	4,000
ALLEGHANY (Navy Crew)	Hudson Lab., Dobbs Ferry, Columbia U.	ATA	1945	760	143	33	2	38		9,000
JOAN BAR II (bay work only)	Chesapeake Bay Institute, Johns Hopkins Univ.	Motor yacht	1927	60	85	15	7	4	200	Estuarine water
GERDA	Marine Laboratories, U. of Miami	North Sea trawler	1949	70-80	75	21	7	4	536	3,000
HIDALGO	Dept. of Oceanog. & Met., Texas A&M	EX-PCS	1944	243	136	27	12	8	525	2,000
S.F. BAIRD	Scripps Inst. of Oceanography, U. of California	Ex-ATA	1944	505	143	33	18	17	1,000	18,000
HORIZON		Ex-ATA	1944	505	143	33	18	17	1,000	15,000
PAOLINA-T		Purse seiner	1948	111	80	22	5	7	500	3,500
ORCA		USCG patrol		200	100		Carries 14		500	
STRANGER		Yacht								
BROWN BEAR	Dept. of Oceanog., U. of Washington	Ex-FS	1934	270	114	27	22	10	400	
Government Installations										
EPCE(R) 857	U.S.N. Electronics Lab., San Diego, Calif.	EPCE(R)	1944	818	184	33	10	64		2,500
EPCE(RP)	U.S.N. Underwater Sound Lab., New London, Conn.	EPCE(R)								
YF-854	U.S.N. Hydrographic Office, Suitland, Md.[3]	Yard frigate	1944		132	30	6	10		
SAN PABLO		AGS (Ex-AVP)	1943	2,700	310	41	8	200	3,200	10,000
REHOBOTH		AGS(Ex-AVP)	1944	2,700	310	41	8	200	3,200	10,000
ALBATROSS III	U.S. Fish and Wildlife Service, Washington, D. C.	Rebuilt trawler	1926[4]	340	179	24	6	21	650	4,500
BLACK DOUGLAS		M. schooner	1930	371	152	32	5	11	600	4,000
H.M. SMITH		Tuna clipper	1945	600	128	29	6	12	625	6,000
EVERGREEN	U.S. Coast Guard Washington, D. C.	Cutter	1943	1,025	180	37	2	53		15,000
	U.S. Coast and Geodetic Survey, Washington, D. C.	Employs several ships for coastal surveys								

[1]From William V. Kielhorn, Oceanographic Vessels in the United States (Office of Naval Research, 1953).

[2]Manages ONR's Laboratory of Oceanography.

[3]Operates other ships, but these three do most of deep-sea oceanography.

[4]Rebuilt in 1941.

equipping themselves for oceanographic research to get an idea. (Sizes of selected U. S. and foreign research ships are given in the table below.) Particularly noteworthy is the fact that both Russia and Japan are continually building new research ships. The Russians started with conversions and have graduated to specially constructed research ships such as the MIKHAIL LOMONOSOV. The Japanese have one of the finest research fleets in the world, theirs having been built largely for research in connection with their fisheries. These nations are conducting much the same type of research at sea as we are, but they have better ships with which to do it. We may assume, further, that nations which are willing to invest large sums of money in research ships also have the skilled scientists necessary to use them properly.

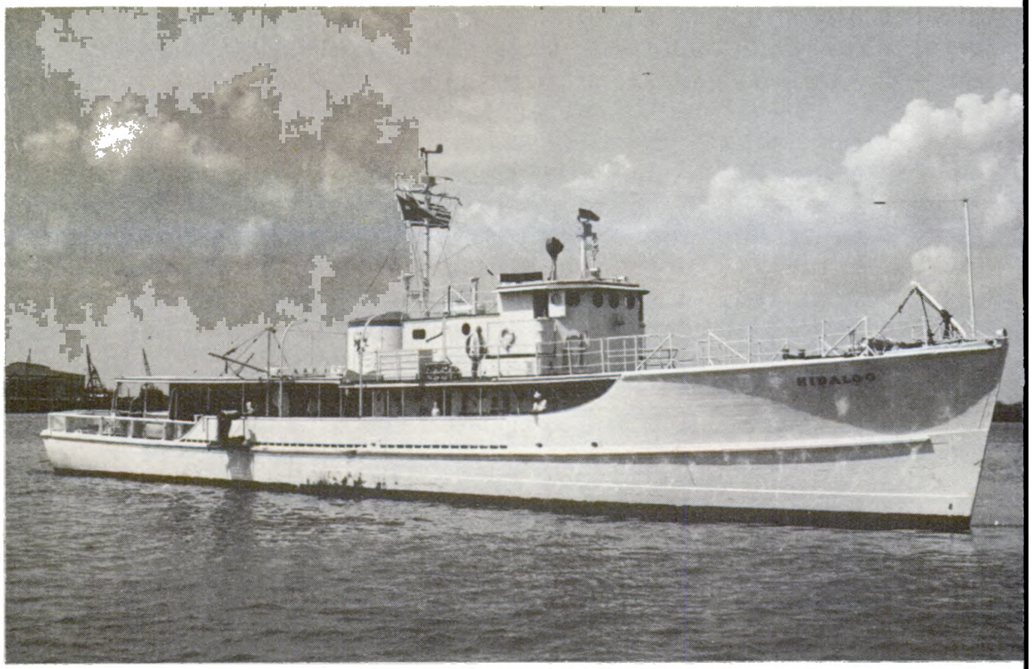
Tonnage comparison of selected research ships.

Ship	Displacement (tons)	Ship	Displacement (tons)
United States		USSR	
SPENCER F BAIRD	505	MIKHAIL LOMONOSOV	5,960
HORIZON	505	VITYAZ	5,546
VEMA	533	POLE	5,000
ATLANTIS	298	SEVASTAPOL	3,000
CRAWFORD	295	DIAMOND	1,500
BROWN BEAR	270	EQUATOR	1,500
HIDALGO	243	LENA (Icebreaker)	12,000
PAOLINA T	111	OB (Icebreaker)	12,000
		OKEAN	3,000
Japan		Great Britain	
UMITAKA MARU	1,387	JOHN BISCOE	2,250
RYOHO MARU	1,100	DISCOVERY II	1,736
TUGARU	1,050	SIR WM HARDY	418
OSHORO MARU	618	SARSIA	250-300
SHINYO MARU	260		

In spite of these facts, the oceanographic picture in the United States, for the present at least, is not bleak. Actually, this country has accumulated a more impressive store of knowledge in the field than any other nation. This is owing primarily to the high caliber of its oceanographic institutions and the keen interest of the Navy in the field. Thus a large amount of work has already been done. The problem is simply this: How long can the United States expect to keep the scales weighed in its favor when its two chief competitors are now exerting greater efforts for new knowledge on the seas than it is?

Granted that the United States needs more specially designed research ships, what should be the nature of the new construction? Here are a few guidelines suggested by ONR's ship-design advisory group.

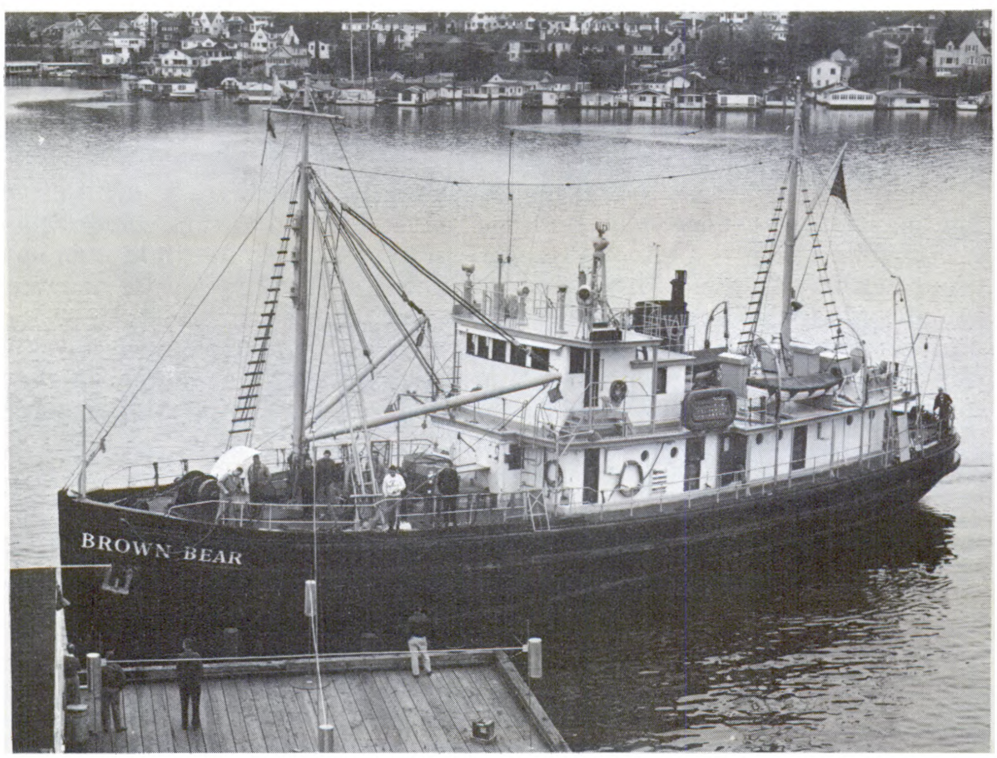
● The research ship must be quieted for acoustic work. For example, for acoustic experiments at 10 kilocycles, the auxiliary equipment of the ship must be at least as quiet as the ambient noise of a sea state 1.



The HIDALGO of the Department of Oceanography and Meteorology, Te
A&M Research Foundation.

FOUR UNITED STATES SHIPS ADAPTED F

The BROWN BEAR of the Oceanographic Laboratories, University of
Washington.



SEARCH AT SEA

The VEMA of Lamont Geological Observatory, Columbia University.

The SPENCER F. BAIRD of the Scripps Institution of Oceanography.

- The ship must have an efficient scientist-to-crew ratio, or a ratio of about 1 to 1.

- The ship must be able to maintain heading at very low speeds; this requires a carefully considered main propulsion plant, propellers, and perhaps some type of bow propulsion.

- The ship must have adequate deck, laboratory, office, berthing, messing, helicopter, and sonar spaces. The need for a center well has not been accepted by all oceanographers, but there are many reasons why one should be included, perhaps the most important of which is to allow work in rough seas.

- The ship must be designed so that work can be performed in a normal manner in a sea state 5. It must be stabilized with antiroll tanks and have proper lines to minimize pitch.

As a first step toward building a fleet of new research ships, ONR contracted with the Woods Hole Oceanographic Institution several years ago for a study of modern research-ship designs (see Research Reviews, December 1956). As a result, a list of specifications was drawn up and the Bureau of Ships, with the aid of the ship-design advisory group of ONR, began converting the ideas into blueprints. One such ship is now scheduled for construction in the 1960 shipbuilding program. Her principal characteristics are—

Length over-all	209 feet
Length between perpendiculars	188
Beam, molded	37
Depth, to main deck amidship at side	21
Draft, full load	15
Displacement, full load	1200 tons
Speed, sustained	13 knots
Endurance at 12 knots	12,000 miles
Propulsion plant: single screw (diesel electric)	
Accommodations:	
Officers	8
Crew	14
Scientists	15
Total	37

The ship is expected to provide enough space to house personnel and equipment for several fields of scientific investigation, yet to be modest, thereby limiting building, maintenance, and operating costs. In so far as possible in a ship of this size, it is planned to include the concept of independence at sea, so that as much data as possible can be worked up on board ship before return to the laboratory.

Unfortunately, the construction of one new ship will not place us ahead of Russia and Japan in research capability at sea. It will simply help us to hold our own. So, until more ships are built specially for research, we must continue to rely heavily on conversions. In this connection, two important events occurred during the past two months. In

November, the USNS CHAIN, a converted Navy salvage vessel, was put in research service, and in December, the USNS GIBBS, a former seaplane tender, joined the research fleet. A third Navy ship—another salvage vessel—is scheduled to undergo alterations for conversion to a research vessel during 1959. Although not the ultimate in ocean platforms, these vessels have a lot to offer the oceanographer.

As has been pointed out, the final answer to the problem is new construction. Only such modern vessels permit the oceanographer to conduct the variety of studies he envisions with the efficiency and thoroughness that satisfy him. When one considers that there are many important features of the oceans that we know little or nothing about, the urgent need for these ships becomes clear. For example, we have yet to determine the current structure at all depths, bottom topography and sediments, the nature of the bedrock below the ocean floor, chemical constituents of sea water and how they influence life in the seas, the interchange between ocean and atmosphere, the productivity of life in the oceans, and many other features of this vast frontier.

Waiting to be carried out in addition to these basic studies are investigations having significant Navy applications. Submarines, for example, cannot function properly in strategic areas without adequate knowledge of currents, bottom topography, the velocity of sound in seawater, ocean temperatures, and weather. Thus, the successful polar journeys of the NAUTILUS and SKATE were facilitated by data previously obtained from oceanographic research.

Over the past six years, ONR has suggested a program whereby the obsolete research ships will eventually be replaced by new construction. Although much has been accomplished during this period, the U. S. Navy and its contracting oceanographic institutions are still without ships designed for research. In view of the accelerated oceanographic programs in other countries, time is now a critical factor. If new research ships are not forthcoming in the immediate future, the United States' lead in the field of oceanography is sure to be overtaken by both Russia and Japan.

Interdisciplinary Conference on Self-Organizing Systems

An Interdisciplinary Conference on Self-Organizing Systems will be held on May 5th and 6th, 1959, at the Museum of Science and Industry, Chicago, Illinois. The conference is to be co-sponsored by the Information Systems Branch of the Office of Naval Research and the Armour Research Foundation. Its purpose is to bring together research workers in all fields of science who are concerned either with the development of self-adaptive information systems or with the conduct of research which may contribute to an improved understanding of cognitive, learning, and growth processes. Particular emphasis will be placed on theoretical models of systems which are capable of spontaneous classification, identification, and symbolization of their inputs.

Further information concerning the conference may be obtained by writing to Mr. Scott Cameron, ICSOS Conference Secretary, Armour Research Foundation, 10 West 35th Street, Chicago 16, Illinois.

Information Theory and Radar

Stanford Goldman
Department of Electrical Engineering
Syracuse University

Since 1948, when Claude Shannan published the first of his famous papers on information theory, the ideas and the language of this new discipline have permeated electronics and various other fields. The practical value of this theory is somewhat elusive. It is hard to say that any particular new equipment owes its existence to information theory. Nevertheless, many engineers feel that they understand what they are doing much better because of it. Because of these practical consequence, The Information Systems Branch of the Office of Naval Research is supporting investigations in information theory at Syracuse University.

One of the more valuable results of information theory has been the light which it has shed on the understanding of radar.* As is well known, the purpose of radar is to detect the presence of distant objects, to give their location, and sometimes their speed and composition. Locating an object by means of radar is accomplished by sending out a radio signal and observing its echo. The direction from which the echo comes gives the direction of the object, and the time required for the echo to return gives its distance (range). A change in frequency or pitch of the echo gives information concerning the speed of the object.

A tremendous amount of effort and expense is applied every year to the problem of improving radar, so that it will detect objects at greater distances and give their locations and speeds with greater accuracy. The technology of radar is now sufficiently advanced so that the more obvious directions of progress have been pushed to the point of diminishing returns. In such a case it would appear that important further progress, other than taking advantage of new developments in components, is likely to depend upon a sophisticated analysis of the problem. Such an analysis is given by information theory. It is a problem in information theory to look at the operation of a radar system from the point of view of what happens to the information the system provides. This is the rock-bottom analysis.

A radar signal gives information concerning a situation (or event) in the physical world. The measure of the information in this signal is the extent to which its reception causes a change in the probability of the event as estimated at the receiver. More precisely,

$$\text{Information in radar signal} = \text{logarithm}\left\{\frac{\text{probability of event on the basis of knowledge at the receiver after the signal is received.}}{\text{probability of event on the basis of knowledge at the receiver before the signal is received.}}\right.$$

*This subject has been discussed at length in a book entitled "Probability and Information Theory with Applications to Radar," by P. M. Woodward (McGraw-Hill, New York, 1953). Woodward was responsible for much of the original analysis in this field.

Let us see what this equation means in the particular case shown in Figure 1. This figure shows a display on a cathode ray tube screen of a radar receiver. It is the familiar "A-scope" display. In the absence of a radar echo, this shows merely an output of receiver "noise," which

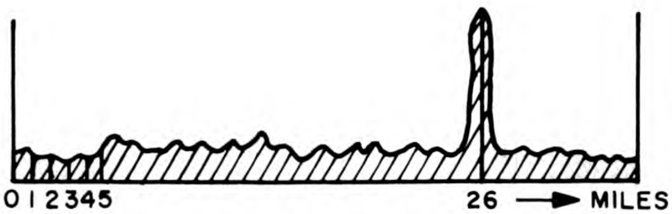
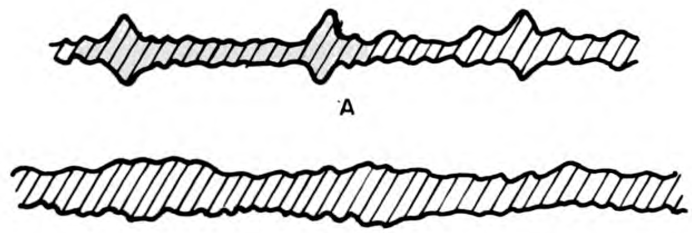


Figure 1 - A display on a cathode ray tube of a radar receiver.

causes random fluctuations in the base line. However, when an echo is present, the echo is shown superimposed on the noise background. In Figure 1 there is evidence of an echo at a range of 26 miles.

Let us suppose that this radar signal has a range resolution of one mile. By this we mean that echoes from objects one mile or more apart will be separated clearly, whereas echoes from objects less than one mile apart will not be distinct. The display shown in Figure 1 can give information concerning at most 30 independent events, since this is the maximum number of objects separated by at least one mile which can be placed in a 30 mile interval. Prior to receiving the radar signal, the probability that there is an object which would give rise to an echo at any particular one-mile range is small. This is equivalent to saying that the probability that there is no object is nearly 100 percent. After receiving the signal, this probability is even closer to 100 percent at all ranges except 26 miles. At 26 miles, on the other hand, the probability that there is a target is almost 100 percent after receiving the signal. The relative values of these probabilities are known, because the probability that a signal of any particular size is just a fluctuation in the background noise is known. Keeping in mind that the logarithm of the number 1 (one) is zero, our equation tells us that the radar signal contributes a very small amount of information about the absence of objects at those ranges from which signals are not received, but a relatively large amount of information about the presence of an object at a range of 26 miles.

By the time a radar signal has gotten to the display stage shown in Figure 1, many of the most significant operations on its information content have already taken place. This same signal at an earlier stage in the receiver, for example in the radio-frequency amplifier, may have the waveform shown in Figure 2A or 2B. Since the receiver itself cannot add information to a signal, but in the most favorable case will just lose as little information as possible, it follows that the signals in Figure 2 have all the information contained in the signal in Figure 1, and probably more. It would be very difficult for a human observer to extract the desired information from a display of the signal in Figure 2B. The reason for this is intimately tied up with the characteristics of the human perception mechanism in dealing with information.



A

B

Figure 2 - Signal displayed in Figure 1 as it might appear at an earlier stage in the radar receiver (for example in the radio-frequency amplifier.

The human perception mechanism apparently has certain "thresholds" of detection which correspond to the "improvement thresholds" in noise reduction systems.* These thresholds tend to make the perception mechanism give a "yes" or "no" answer to the question of whether a signal is present or not. This type of operation causes a loss of the information in signals whose strength is below the threshold value. For complicated signals (corresponding to wide bandwidth signals in noise-reduction systems) the threshold value is high, so that a strong signal is required in order to exceed the threshold. The threshold can often be reduced by learning processes. The perception mechanism has a tendency to deal only with a few simple elements of a signal and to treat most of the elements of a complicated signal as noise. Therefore, when faced with a signal such as that in Figure 2B, it finds the desired signal below threshold, and the information in it is lost.

In order to present the perception mechanism with a signal which it can handle, it is necessary to eliminate certain secondary information from the signal in Figure 2B, while losing as little as possible of the primary information. The primary information in this case is the information concerning the presence and location of a reflecting object. The secondary information is carrier-frequency and perhaps carrier-phase information, pulse-repetition-rate and synchronization information, and pulse-wave-shape information. In practice, the pulse-wave-shape information is eliminated by using a matched filter, the carrier-frequency and phase information is eliminated by linear detection, and the pulse-repetition-rate and synchronization information is eliminated by synchronized sweep in the display. These information-elimination processes effectively reduce the amount of noise put out by the system, but care must be taken that they don't destroy any of the primary information.

In the foregoing paragraph we have mentioned matched filters. These have come into special prominence since the information-theory analysis has been applied to radar. A matched filter is specifically designed to deal with signals of a particular waveshape. For an input signal of this waveshape, even though the latter may be quite long, the output of the filter is usually sharply peaked and is thus ideal for

*Discussed in the book "Information Theory," by Stanford Goldman (Prentice-Hall, New York, 1953).

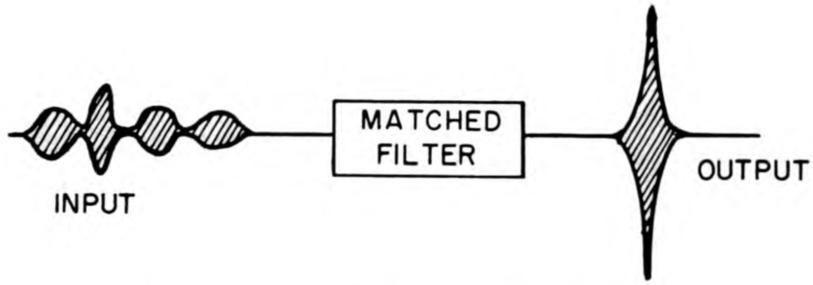


Figure 3 - Output of a matched filter.

echo-location purposes. The action of a matched filter is shown diagrammatically in Figure 3.

Theoretical investigations made during World War II showed that a matched filter gives the maximum ratio of peak signal to root-mean-square noise in radar reception. This is obviously a desirable property, but one may ask whether there is something better. Information theory shows that the output of a matched filter most clearly expresses the probability of the presence of an echo on the basis of the received signal. As the received signal represents the most information we can possibly get about the presence of an echo, we know that the matched filter is theoretically ideal.

Information analysis finds that the true measure of radar-signal quality from a noise point-of-view is a number determined by the ratio of two times the total signal energy to the noise power per unit bandwidth. Thus it can be seen that it is the total energy of the signal that counts and not its peak value in determining the detectability of an echo. Therefore, if a radar transmitter is limited by peak power, it is desirable to have a long waveshape for the transmitted signal in order to have as much energy content as possible. A matched filter can then be used in the receiver to bring out the intrinsic quality of the signal. Information theory also shows that the longer the waveshape and the wider the bandwidth of the radar signal, the more information it will have for position and velocity determinations.

The application of information theory to the analysis of the radar problem showed that practical radar-design methods already approached the theoretical ideal in many respects such as in the use of matched filters. A valuable practical consequence of information analysis has been the support it has given to the use of long radar-transmitted signal waveshapes in place of the short pulses previously used. The most important result of the use of information theory in the radar field is that it has put radar theory on a sound basis.

ONR Contractor Wins Chemistry Award

Dr. Herman I. Schlesinger, Professor Emeritus of Chemistry at the University of Chicago has been named winner of the 1959 Willard Gibbs Medal of the Chicago Section of the American Chemical Society. Before he retired recently, Dr. Schlesinger directed an ONR project entitled, "The Chemistry of Boron Hydrides."

Animal Sounds from the Sea

Richard H. Backus
Woods Hole Oceanographic Institution

Most people do not think of fishes and other marine animals as having voices, and of those who are aware of the fact that many of them can "speak," few understand that these "conversations" have significance. Actually, their talk may be as meaningful as much of our own. For example, some sea animals use their "voices" to locate their food in the ocean expanses; others, to let their fellows know of their whereabouts; and still others, as a means of obtaining mates. Sometimes, "speaking" may even mean the difference between life and death to a marine animal. It appears in some cases that when a predator approaches, the prey depends on no more than the sounds it makes to escape.

Fish sounds are important to man, also. By listening to them he can learn a great deal about the habits of the creatures that make them, the size of the schools they form, the patterns of their migrations, and the nature of the environments in which they live. He can also apply this information to the more effective utilization of the listening posts he has set up to detect enemy submarines. A knowledge of fish sounds can avoid confusion and unneeded effort when a "new" sound is picked up and the sound sentry must decide whether or not to call an alert.

DISTINGUISHING BETWEEN SOUNDS

Of the many strange animal sounds that have been heard in the sea, only a very few, produced by three groups of marine animals (crustaceans, fishes, and cetaceans), have as yet been identified. Because sounds travel great distances underwater as compared with light, the animals producing the sounds are usually so far from the observer they can't be seen. But even if they can be seen, the observer may not be able to single them out from their quiet neighbors, because often there are no conspicuous visible manifestations of sound production.

Most of the better known sound-makers have been identified with their characteristic sounds because they make them while being removed from a hook or a net. Sometimes, the sound is matched to its source by an often lengthy correlative process (presence of animal, presence of sound; absence of animal, absence of sound). If the animal is adaptable to an aquarium, this correlation may be tested there, although normally noisy species may utter fewer sounds or even "hold their tongues" when in confinement. Marie P. Fish, of the Narragansett Marine Laboratory, has placed animals that are not voluntarily noisy in aquaria and stimulated them artificially to "speak" if they are capable of it. When this is done, of course, the sounds made may not be much like those produced under normal conditions in the natural environment.

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*Shortened version of an article published in The Journal of Underwater Acoustics (Office of Naval Research), April 1958.

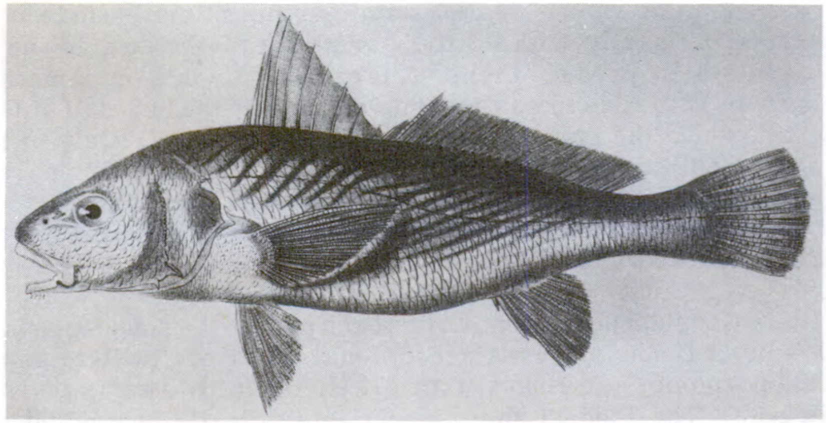
The literature dealing with marine animal sounds has been concerned primarily with word descriptions of the sounds and the mechanisms which produce them. A large part of this information (pertaining mostly to fishes) was accumulated during the last half of the nineteenth century and the early decades of the present one. Only in recent years have quantitative data been collected, such as on principal frequencies, sound spectra, and measurements of time relationships.

SOUND-PRODUCING MECHANISMS

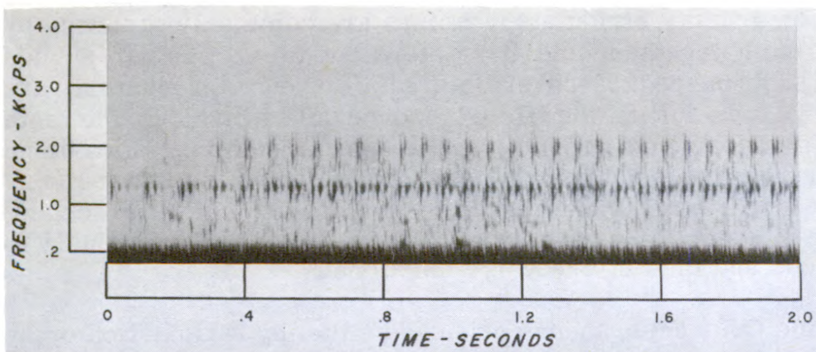
Considerable attention has been paid to the sound-producing mechanisms of fishes and crustaceans, and relatively little to those of whales and porpoises. In fishes, they are of one of two sorts or a combination of both. The loudest sounds originate with the swimbladder, which is made to resonate, the process being somewhat analogous to drum-beating. (The noisiest family of fishes, the Sciaenidae, are called the drums.) Stridulatory sounds are made by rubbing one hard part against another, as in the drawing of the thumb along the teeth of a comb. In some cases, stridulatory sounds are amplified by the resonant swimbladder, as in the Haemulidae, or grunts. Stridulatory noises are commonly produced by grinding the teeth together, and it is often not clear whether sounds produced by such unspecialized structures (for sound-production) are accidental or purposeful. In the filefish, Monocanthus hispidus, the teeth are well adapted for sound production, the upper median incisors being provided with transverse ridges against which the lower median incisors are rubbed. In the swellfish, Spheroides maculatus, chewing sounds, which certainly seem to be adventitious, do attract other individuals to a source of food and thus in a way are functional.

In marine Crustacea, sounds are made either by stridulation or by rapping one hard part against another. In the spiny lobster (Panulirus argus) a very elaborate stridulatory mechanism has evolved. This includes a ridged membrane on the basal portion of the antenna and a toothed surface on the carapace of the head near the base of the antenna. There are mechanisms for engaging and keeping engaged the two rough surfaces as the antenna is raised. In the so-called snapping shrimps (family Alpheidae), well known as noise makers, the sound is produced as the movable "finger" of the enlarged claw is brought down against the immovable "thumb." This ostensibly simple arrangement is actually quite elaborate. The finger is fitted with a knob which fits into a groove on the thumb. The base of the finger is provided with a small suction cup, which, when the finger is raised, meets another suction cup on an immovable portion of the claw. Considerable muscular force is required to break this connection, so that the mechanism is, in effect, spring-loaded. It is thought by some investigators that the function of the mechanism is to produce a water-jet which frightens enemies away, the accompanying sound being incidental. However, both sound and a water-jet would seem to be inevitable consequences of this action, and the construction of the mechanism itself does not clearly show to what end it is an adaptation.

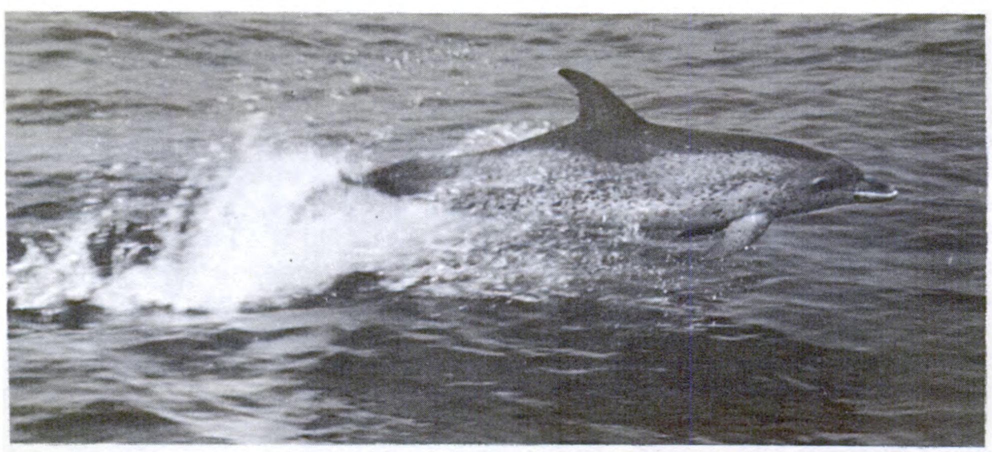
Although vocal cords are lacking in cetaceans, phonation is undoubtedly centered in the larynx. W. E. Schevill of the Woods Hole Oceanographic Institution has connected a tire pump to the larynx of



The croaker, Micropogon undulatus. A reproduction of a plate printed in "Natural History of New York" (1842) in the section entitled "Reptiles and Fishes," by James E. DeKay.



A sound spectrogram of the staccato call of a sea robin (Prionotus sp.). Note that pairs of 2-kc pulses alternate with pulses at 1.3 kc. It has been suggested that each series of pulses corresponds to vibrations of one of the two lobes of the swimbladder. Courtesy of J. M. Moulton.



A porpoise of the genus Stenella. Photo courtesy of Jan Hahn, Woods Hole Oceanographic Institution.

freshly-killed porpoises. When air is thus pushed through this organ, sounds are indeed produced, but they do not exactly resemble those heard from the living animal. Schevill's retort to criticisms of this observation has been, "Under the same conditions would you expect Chinese from a Chinaman?"

The toothed whales, or odontocetes (sperm whale and porpoises), are much more vociferous than the whalebone whales, or mysticetes. In this country observers have recorded only occasional sounds from two species of mysticetes (the humpback and right whale). The Russian cetologist, A. G. Tomilin, however, reports hearing sounds from at least five species of whalebone whales but gives us no details of the circumstances or descriptions of the sounds themselves. Although comparison of the sound-producing apparatus in the two whale groups cannot yet be made, it is interesting to note that the auditory centers of the brain are much more highly developed in the odontocetes than in the mysticetes, in fact, to a degree unsurpassed by any other mammalian group.

PURPOSES OF THE SOUNDS

One of the most interesting directions in which the study of marine animal sounds leads us is toward understanding how the sounds are used in regulating the lives of the animals that make them. What are the things that the "talkative" animals accomplish with their "voices" that silent animals necessarily do by other means? Our knowledge on this question is still very slight, and the examples that follow are fragmentary, in part speculative, and can suggest little more than what remains to be learned.

In Sexual Activity. In many species, sound production is believed to be closely related to sexual activity. This is presumably true of species in which sound production is limited to a single sex, as it is to the males of most species of drums and croakers. The value of sounds in leading a female to a male is obvious in an environment in which olfactory and visual signals are generally useless at ranges of more than a few feet. Such orientation, however, has not been demonstrated definitely for fishes, although it has been in certain terrestrial animals (insects, toads, and birds). The loud boatwhistle-like sound of Opsanus tau, the toad fish, may serve in such a way. Males establish a territory and guard the nest, in which successive females spawn. The male calls until his milt is spent. It is also believed that sound assists in bringing together sea robins (Prionotus spp.) for sexual purposes.

Moreover, sound may play a part in the actual acts of courtship and mating in some fishes. During courtship (but at no other time) the male of a certain goby (Bathygobius soporator) emits low grunts which elicit a characteristic response from the female. In the so-called purring gourami (Trichopsis vittatus), both sexes make noises during prespawning activity. Clicking sounds are produced by both male and female sea horses (Hippocampus spp.) during the preliminaries to spawning and especially during the act itself, when loud and continuous sounds are made as the female deposits eggs in the brood pouch of the male. In the filefishes Cantherines pulles and Alutera punctata, the large dorsal spine of the male is moved rapidly back and forth as he displays before the female. In closely related species, at least, this movement produces sound.

In the cetaceans, some sounds may well have a sexual significance. For example, during mating season, a captive adult male of the porpoise Tursiops truncatus made peculiar yelping sounds which attracted females.

Sexual motives have not yet been attributed to the sound production of strictly marine crustaceans, so far as I am aware, but in the littoral Uca pugilator, a fiddler crab, low-frequency drumming is associated with a sort of dance, called "beckoning," which the male performs upon the appearance of the female.

For Orientation. The only marine animal that is known to echo-locate is the porpoise Tursiops truncatus, but other odontocetes probably do so too. Moreover, in a recent paper, the well-known student of animal orientation, D. R. Griffin, discusses a sound and its echoes which emanated from an animal, in all likelihood a fish, deep in the ocean. Knowing the water depth and the time difference between the arrival of the original sound and its echo, Griffin computed the possible locations of the sound source—a shallow, saucer-like surface whose deepest point is 3,900 meters below the sea surface. Griffin argues that if this animal can hear as well as many fishes can, it could easily detect the echoes of its own sounds and might, by means of them, orient itself in the black waters at that depth.

In a discussion of the lateral-line organ of fishes, O. Lowenstein, the British sensory physiologist, has this to say of its function (a matter about which there is still much dispute): ". . . .the lateral line organs in fishes are chiefly concerned with what Dijkgraaf* calls 'distant touch'. . .objects may either be moving (prey, enemies) and thus constitute the focal point of a mechanical disturbance, or their presence and localization may be perceived and accurately computed from the time relations of reflected water waves set up by the swimming movements of the fish itself. The latter case would fundamentally conform with the principle of echo-location." The water wave to which Lowenstein refers in the latter instance would presumably be a pressure wave (a sound wave of very low frequency) or perhaps a vortex which, upon reflection, would deform the streamlines around the fish. These changes in flow would be detected by the lateral-line organs. However, such a system would be operative only at relatively short ranges.

If sound-ranging systems exist in fishes, either the "conventional" type which Griffin suggests or the lateral-line type which Lowenstein suggests, we might expect to find them especially well developed in blind fishes. In this connection, I offer two excerpts from the literature concerning cave fishes (both written before the discovery of echo-locational systems in animals).

The brotulid fish, Stygicola dentatus, lives in the limestone caverns of western Cuba together with its blind relative Lucifuga subterranea.

*Of the University of Utrecht.

C. H. Eigenmann, in his fascinating book "Cave Vertebrates of America," says about Stygicola: "Two instances that seem to indicate that fishes 'remember' localities must be put on record for what they are worth. . . In the 'M' Cave the same fish, three times within an hour and a half, apparently made straight for an opening under the wall of the cave and escaped. In the Donkey Cave the same thing happened about a big stalagmite that rises out of the water. Several times within half an hour the fish came out, but each time it darted back among the nooks in the stalagmites with apparently as much decision as a mouse in seeking its hole. Perhaps in both cases the action was a reaction merely to the vibrations set up by my net. Perhaps the location of the solid stalagmite and the wall were perceived by the approaching fish, and the escapes into nooks below the wall were simply necessary sequences in following along the solid wall until an opening was reached. Whatever it was, the repeated escape of the two fishes was as interesting as it was aggravating."

Amblyopsis spelaea belongs to a small family of North American fishes, most of which are blind and inhabit caves in limestone regions of the Mississippi drainage basin. John Sloan, a 19th century American naturalist, says the following about Amblyopsis: "In their native pools and in the aquarium when disturbed, they do not strike the bottom and sides of their surroundings, but seem to have a sense of resistance (if the term is pardonable) which protects them."

Nothing in these accounts suggests which, if either, of the two types of echo-locational systems is in use. It is interesting, however, that Lucifuga and Amblyopsis possess swimbladders which are modified for sound production and Amblyopsis has a particularly well developed lateral-line system.

In Defense.—Many marine animals produce sounds when caught, roughly handled, or otherwise disturbed. Largely on the basis of this behavior, it is supposed that some sounds are defensive in nature. In the burrfish, Chilomycterus spinosus, and in the swellfish, Spheroides nephelus, a "whining scrape" is made by grinding the incisors together during or after inflation. In sculpins of the genus Myoxocephalus and in the flying gurnard, Dactylopterus volitans, drumming noises are made as the fish spreads its spiny gill covers. In the sea robin (Prionotus sp.) a low grunt accompanies the erection of the spiny fins; observations of similar activity have been made of the toadfish, Opsanus tau. In the spiny lobster, Panulirus argus, sound production accompanies the violent abdominal contractions of a restrained animal. These contractions bring into play the various spines and sharp edges of the exoskeleton. Supposedly, the sudden sound so startles the predator that he momentarily hesitates or relaxes his hold, whereupon the prey escapes. (This, of course, presumes the predator is capable of hearing the particular sound). It also seems possible that the tactile sensation that the sound-producing structure causes when constrained might have the same effect. Those who have snatched up certain crickets or grasshoppers will understand this.

For Simple Communicative Purposes.—There are clear-cut instances of the use of sound in coordinating the behavior of certain cetaceans. Sounds are used by both the mother and the young of captive bottlenose porpoises (Tursiops) to keep the family together. In an experiment conducted at Marine Studios, a mother and her young, separated by all but an acoustic connection, frantically called back and forth and made attempts to reunite. But when the acoustic link was broken, the mother swam peacefully off to feed. Captive porpoises react characteristically when strange objects are introduced to their tanks. According to A. F. McBride and D. O. Hebb, who made observations at Marine Studios, they "gather in a tight school. . . .and swim in unison. . . . If one animal becomes separated, it will attempt to rejoin the group as quickly as possible. . . . Whistling is frequent and loud during such a period." F. G. Wood, Jr., of Marine Studios, reports that when food is presented to captive porpoises, they make "mewing and rasping" sounds not heard at other times. Presumably, such sounds serve to attract others of the species to the sound (and food) source.

Special feeding noises are produced by certain damselfishes. These have been interpreted as "competition" noises, but they might well serve the opposite purpose, such as that suggested for the porpoise.

Finally, J. M. Moulton of Bowdoin College and the Woods Hole Oceanographic Institution has observed the squirrelfish, Holocentrus ascensionis, making barking sounds as it withdrew to its retreat at the approach of a strange object (Moulton's hydrophone). This might be interpreted as a warning to others of its kind.

To Intimidate.—Some sounds seem to be used within the species to establish certain social relationships. Thus, in a group of captive bottlenose porpoises, the strongest male was seen to clap his jaws at other individuals. This was interpreted as an expression of his dominance. In the spiny lobster (Panulirus interruptus) stridulatory sounds are made at the time of impending conflict and are sometimes accompanied by withdrawal. In this case the sounds might be interpreted as a substitute for fighting, as is sometimes noted in birds.

HOW THE SOUNDS ARE USED BY MAN

Where do studies of marine animal sounds lead the investigator? A simple example of the type of problem that can be solved once a sound is linked with its source is the local distribution of the sound-producing animal. Thus, through sound-surveying, M. W. Johnson and co-workers of the Scripps Institution of Oceanography and the Navy Electronics Laboratory were able to determine the disposition of snapping shrimp in the Point Loma area of southern California. Such a study can lead to other discoveries, too. For example, once one learns the disposition of the soniferous species, he may be able to use that information to determine the distribution of silent species living in the same habitat or even certain physical parameters of which the habitat is composed. Thus, from the distribution of snapping-shrimp noise, Johnson's group learned the distribution of certain commercial sponges. Furthermore, their survey showed that maxima of sound pressure due to the shrimp fairly represented the distribution of hard bottom in the study area.

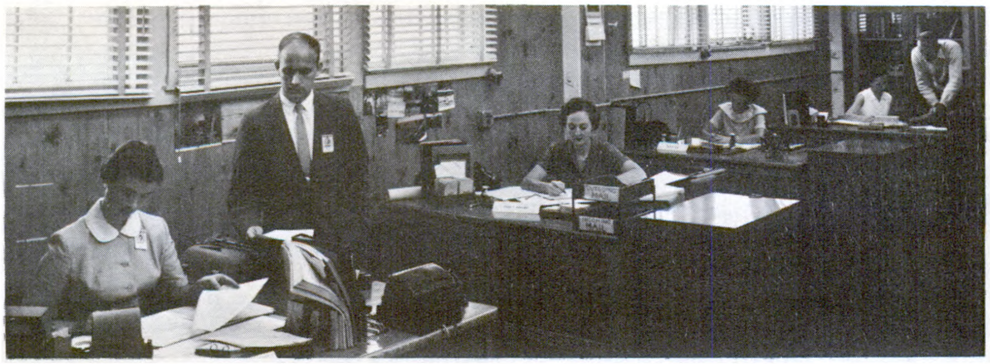
The more one learns about a certain sound, the grander the investigation that he can pursue through it. During warm months in certain areas along the coast of the mid-Atlantic states, loud choruses of sounds are observed which have been attributed to the croaker, Micropogon undulatus, a species of drum in which both sexes are soniferous. Both annual and diurnal fluctuations in the sound have been noted. Moreover, a comparison of May and July measurements made in 1942 in the Chesapeake Bay area showed a drop in peak frequency of the choruses from about 700 cps to about 225 cps. It was suggested that this change was caused by fish growth and the resultant decrease in resonant frequency of the then larger swimbladder (the sound source in this species). Such a frequency shift, however, would necessitate a doubling in the fish's size, and, since this does not occur, changes in the composition of the croaker population through migration is probably the correct explanation. In this connection, observations made by the fishery biologist D. H. Wallace are of great interest. He finds that male croakers become sexually mature at a smaller size than the females do and, on maturing, leave the Bay. Thus, he observed a 50:50 sex ratio in June, but a proportion of males to females of 35:65 in August. If the significance of the croaker sound and the physical factors determining its spectrum were understood, much could be learned of the population dynamics of this important fish.

As has been pointed out, the naturalist is not alone in his interest in marine-animal sounds; the Navy is also "listening in." A classic example of applications it has made of investigations of such sounds concerns—once again—the croakers of Chesapeake Bay. Because croaker choruses greatly interfere with the performance of the underwater listening system at the approaches to the Bay, a means was sought for eliminating them. After a study was made of sound production in fish, filters were installed to block out the unwanted noises. Such problems are rarely so straightforward, however. More often than not the noise is in the same frequency band as the signal. In any event, some knowledge about the source and its comings and goings can be of considerable value.

Looking ahead, marine biologists and acousticians can be expected to continue and perhaps increase their efforts in this field. Of course, the research will be primarily basic in nature, the aim being to learn more about marine organisms and the realm in which they live. But the Navy will undoubtedly remain an interested onlooker and contributor, seeking opportunities to use knowledge concerning these curious "voices" to improve its operations on and under the sea.

A Look into the World of Microorganisms

Dr. Roger D. Reid, Director, Biological Sciences Division, ONR, is co-author of an outstanding new text, "Microbiology," published by McGraw-Hill. The book, written in collaboration with Professor Michael J. Pelczar, Jr., of the University of Maryland, is described as an introduction to the world of microorganisms, offering both background coverage and the latest concepts in this rapidly growing field. It is particularly strong on the applied phases of microbiology.



Infrared Information and Analysis

William Wolfe
Group Supervisor, IRIA
Willow Run Laboratories
The University of Michigan

Recent significant improvements in infrared techniques and wider application of infrared technology in both civilian and military life have generated a tremendous increase of interest in this field of physics and engineering in recent years. Better knowledge of radiation sources and atmospheric transmission characteristics, and improved devices, particularly detectors, have made possible the use of infrared techniques in applications heretofore unforeseen. But to facilitate new discoveries, scientists must have access to the data obtained through previous research. The need for a central information agency to assist in these problems is particularly acute in classified military work. Several attempts in the past were made to fulfill this need, but it was not until almost four years ago that an adequate facility was established. This organization, called the Infrared Information and Analysis Center (IRIA) was instituted at the Infrared Laboratory of the Willow Run Laboratories, The University of Michigan, under the sponsorship of the Office of Naval Research.

Actually, the history of organized efforts to gather and exchange information in the field of infrared technology goes back to World War II, when the Office of Scientific Research and Development and the National Defense Research Council recognized such a need. To meet it, they let contracts for the study and summary of accomplishments in the field. However, the functions were not carried out on a continuing basis. Not until 1946, when the Joint Research and Development Board was established, was the work resumed—through a Panel on Infrared. Two years later, when that organization was replaced by the Department of Defense Research and Development Board (RDB), the Panel was made a part of RDB's Committee on Electronics. As such, it served partly as a center of information. Realizing, however, that it could not handle the task alone, it strongly recommended, in 1952, that an infrared information center be established under government contract. In the same year, the Metcalf Committee, under ONR sponsorship, undertook a survey of infrared research in the Department of the Navy, and its final report, among other things, urged the establishment of an infrared information center that would fulfill the ever-increasing need for better exchange of scientific information. The report stated in part, "A central information center is an attractive possibility. . . . [This active center] could be an enormous help in integrating and catalyzing the whole infrared effort."

Accordingly, ONR arranged a series of informal conferences, with representatives from each of the military departments, to discuss the possibility of establishing such a center. The suggestion for this project was greeted with enthusiasm, and plans to establish the center were initiated. As a result, ONR set up IRIA at The University of Michigan on March 1, 1955. Currently, the project receives support from the Army, Navy, and Air Force and is guided by a steering committee composed of representatives of the three services.

THREE FUNCTIONS

The objective of IRIA is the "collection, analysis, and proper dissemination of infrared information."

- "Collection" means the gathering of all infrared information—published and unpublished, classified and unclassified—that will advance military technology. Timely collection is, of course, implied.

- "Analysis" has two distinct meanings: (1) analysis of individual infrared reports for information content and value, and (2) analysis of general fields of infrared research and technology. The purpose of the first function is to ensure that useful reports are readily available to the proper contractors, and the purpose of the second function is to ensure that useful integrated information is available to all who need it.

- "Dissemination" implies active dissemination. It requires a knowledge of the information requirements of the various contractors, and calls for notifying them of the existence of pertinent information. It also involves informing contractors of other workers engaged in similar tasks, when this is not prohibited. In short, it calls for doing all that is possible to help workers keep up-to-date in the areas of infrared technology of interest to them.

As IRIA is part of the Infrared Laboratory of the Willow Run Laboratories, it utilizes the services of the members of the Infrared Laboratory who are performing a variety of research and development tasks. Analyses are accomplished on a broad basis by the IRIA supervisor and full-time assistants, and on a more specific basis by the members of the Infrared Laboratory who participate part time.

The three functions of the IRIA Center are carried out as described below.

COLLECTION

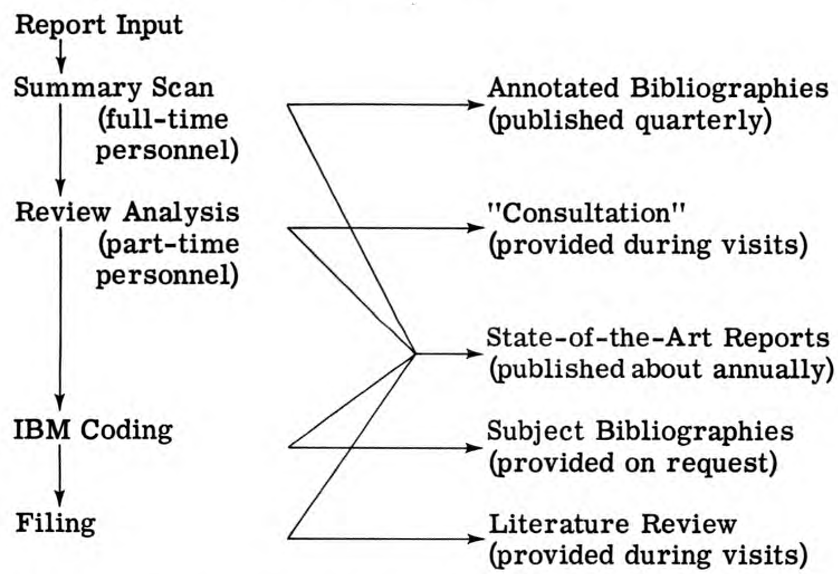
Contract work is continually monitored through project cards, contact with military agencies, and direct association with contractors.

It is noteworthy that through numerous visits and diligent correspondence with contractors and government agencies, most reports are now received by IRIA directly from the originators of the reports. Significant delays are thereby circumvented. The most important aspect of the collection process is learning of new infrared work. Then, by verbal contact, written communication, and receipt of reports, IRIA soon obtains information generated by these research and development efforts. In this way, new data can be supplied to others and the dissemination function can be performed more effectively.

ANALYSIS

The analysis of reports can best be understood by referring to the following diagram of the internal operations of IRIA.

The IRIA Operation



As shown in the diagram, a report is received, scanned by a full-time staff member, and reviewed in greater detail by a reviewer-analyst. The information thus generated is put on library cards and IBM punch cards for easy retrieval, and the report is filed. An explanation of the various procedures is given below.

When a report is first received, it is examined briefly by the supervisor or one of his assistants. This comprises the "Summary Scan." The notes which are generated by this inspection, together with the report title and other pertinent information, are put on library cards, which are filed and used later for the preparation of an Annotated Bibliography.

After this preliminary perusal, the report is screened for assignment to the proper reviewer-analyst. It is the job of the reviewer-analyst to indicate the content of the report by assigning the proper category numbers and code words. He also evaluates the information content of the report and includes a statement as to what sort of report it is, such as experimental, theoretical, or administrative. The IRIA category numbers are part of an information classification system that divides infrared work into some ten groups or categories, each of which is divided into ten subgroups, which in turn are divided into ten sub-subgroups. Thus, there are about 1000 numbers available for the classification of information. Up to three of these three-digit numbers can be used by the reviewer to specify the three main interests of the reports. A large number of four-letter code words are also available to him for further defining the subject matter. These words (for example, SCAN, which represents scanner; ATMO, atmosphere; and IIIV, which stands for three-five compounds) are used independently for identifying specific data. An evaluation of the report is made by using a scale of 1 to 5 (representing a range from "valuable new contribution" to "marginal reading for a few researchers"), and one of several "report-type numbers" is assigned. This information, together with the title-page information, is punched on an IBM card. The title-page information, which includes date, author, corporate author, contract, cognizant agency, and other such data, is tabulated by one of the IRIA file clerks.

The analysis procedure facilitates the preparation of Annotated Bibliographies, Subject Bibliographies, State-of-the-Art Reports, and library and "consultation" services.

The Annotated Bibliography is a compilation of the data contained on the library cards, organized according to the IRIA cataloging system. It is issued quarterly and includes information about the reports received during the most recent quarter.

Subject Bibliographies are prepared on special request. They contain a list of reports pertinent to a contractor's request. The entries are arranged according to subject matter and include such information as title, corporate author, report number, IRIA evaluation, and date of publication. The list is obtained from an IBM card sort. The Subject Bibliography is prepared from these cards and is sent to the requesting contractor.

If for some reason a Subject Bibliography does not provide the information a contractor needs—perhaps because of the delay in obtaining reports or because active discussion is desired—the contractor may wish to visit the IRIA Center. All proper security measures must be met for this visit. The fields of interest of the contractor are decided by his authorized "need-to-know" and by consultation with the IRIA staff. IBM techniques are used for locating those reports that apply to the particular research or development problem at hand, and the reviewers are available for consultation.

State-of-the-Art Reports are generated through periodic analyses of various fields of infrared. These analyses are made by studying the documents on hand, consulting experts, and conferring with the proper contractors. As the occasion arises, consultants from various fields are invited to participate in these studies.

As need dictates, symposia are sponsored. They are called only when they fulfill a definite need and do not compete with or duplicate other symposia. The signal success of IRIS, The Infrared Information Symposia, also sponsored by ONR, is noted in this context. Active co-operation and administrative assistance is given to organizations like the Working Group on Infrared Backgrounds to assist in establishing units and nomenclature as well as basic concepts in this rapidly expanding field.

DISSEMINATION

The dissemination of IRIA information is intended to be as broad as security restrictions permit. In all cases, requests for information must be authorized by the requester's contracting agency and verified by IRIA's contracting agency, ONR.

Specifically, dissemination is carried out through publication of the Annotated and Subject Bibliographies, discussion during visits, and publication of periodic State-of-the-Art Reports. In addition, the IRIA staff carries out a personal visitation program and discussion sessions at all gatherings of infrared scientists.

In the three and one-half years during which the IRIA Center has been carrying out its program, several hundred scientists have visited the offices to obtain information concerning their particular problems. Also, almost one-hundred Subject Bibliographies have been prepared, and seven Annotated Bibliographies have been published. Recently, the first State-of-the-Art Report, summarizing the properties of optical-mechanical scanning devices, was published (classified secret). The response to this report has been gratifying. It is anticipated that future reports summarizing the properties of optical materials, detectors, and radiation sources will be of further value.

The general problem of information exchange has been extremely popular in the public press recently. The advances made by the Soviet Union have crystallized our thinking in many fields we had not considered before. It is the express purpose of IRIA, an agency established to assist in information exchange, to assist other workers in the field of infrared military technology in solving the problem characterized by the question, "How does one obtain information when he does not know it exists?"

Submariners and Spacemen May be Shocked

Submariners and spacemen may someday receive their exercise through use of electric shock-producing machines, according to the medical officer of the atomic-powered submarine SEAWOLF, LCDR John H. Ebersole, MC, USN, in a speech given before a winter convention of military surgeons. Lack of normal exercise, the doctor said, is markedly obvious in the submariner, who must eat, sleep, bathe, exercise, and work within very limited areas. This problem will be equally or perhaps even more obvious as it concerns the spaceman.

Upon receiving electric shocks, the Navy doctor said, the muscles will be forced to act, and thus will receive exercise that can be gained in no other way aboard these pioneering ships.

Research Notes

Preparing Molybdenum for Use at High Temperatures

To protect molybdenum against high-temperature oxidation, the National Bureau of Standards, in research performed for the Navy Bureau of Aeronautics, has investigated a composite electrodeposited coating of nickel over chromium. Although molybdenum has greater structural strength at high temperatures than steel, it has not thus far been used under such conditions because of its ease of oxidation. With the protective coating, however, high-temperature oxidation of molybdenum is prevented for long periods of time.

A high-temperature coating for molybdenum must have a number of special properties. The coating must, of course, be oxidation-resistant, but it is equally essential that it be non-porous and ductile. Even minute imperfections can allow the molybdenum beneath the coating to oxidize and to disappear completely within a few hours. Studies of the chromium-nickel coating show that if properly applied it satisfies these requirements.

The first step in the plating procedure is to etch the molybdenum with a 1:1 solution of concentrated sulfuric and phosphoric acids. Next, a 1-mil chromium deposit is electroplated on the molybdenum. The newly plated surface is again etched, this time with a 1:1 hydrochloric acid, and finally plated with a deposit of nickel 7 mils thick.

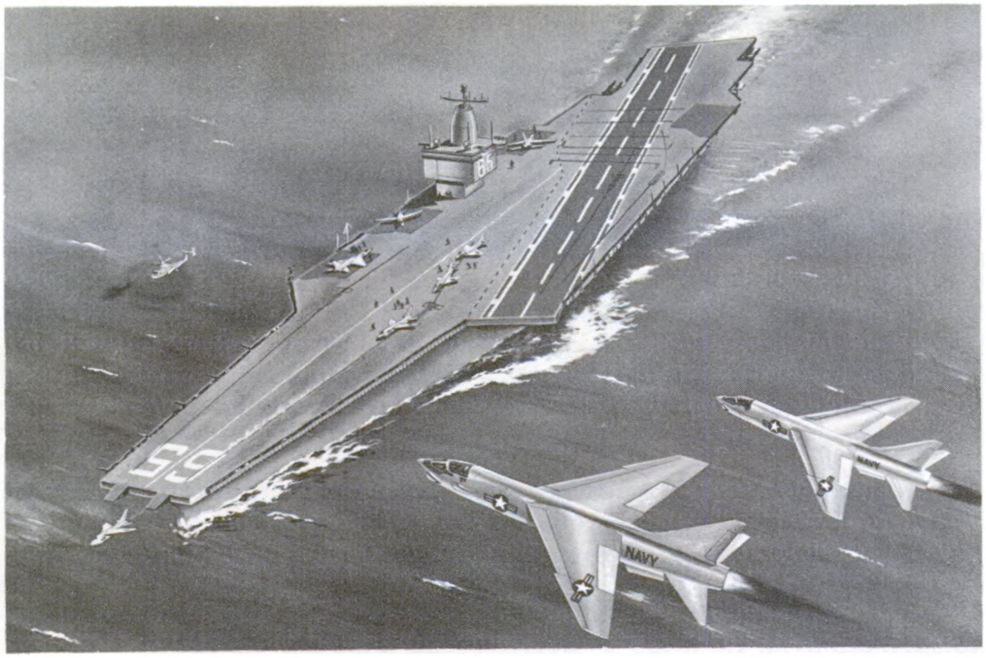
Several types of durability experiments were conducted with the coated samples. To test the adhesion of the coating to the molybdenum, specimens were bent until fractured. The break produced was usually within the molybdenum itself and not between the electrodeposited layers, thus showing excellent adhesion of the plating. To a large extent the soundness of the deposit determines the effectiveness of the protection.

Specimens with the composite coating were exposed to air at 1100°C until the coatings were perforated or until a white smoke of molybdic oxide appeared. At this temperature the coating withstood oxidation for an average of 300 hours. At 1200°C, however, oxidation was greatly accelerated.

Because of these facts, the two-layer coating is considered a promising material for use on turbine blades and similar high-temperature components.

The New Carrier

Navy carriers, as we know them, are on their way out. Just as the sea is ever-changing, the U. S. Navy is continually changing, too. The Nuclear-powered submarine is already a potent missile-carrying strike threat. But this fighting capability is soon to be greatly enlarged, for now on the horizon is the first nuclear powered attack carrier—the ENTERPRISE.



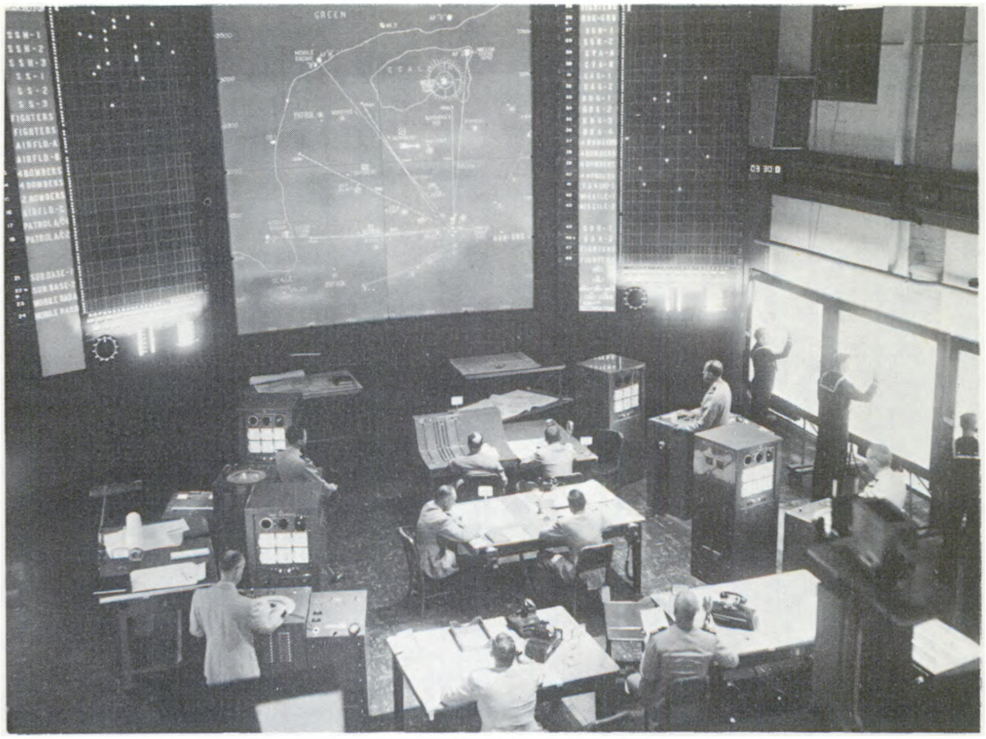
Artist's conception of the Navy's first nuclear-powered aircraft carrier, USS ENTERPRISE. The picture shows the carrier underway as two Navy jet aircraft streak past in the foreground.

As a result of its radical power-plant, the ENTERPRISE will be able to carry appreciably more planes than the conventional, equivalent-sized carrier. It will also be able to carry far more aviation fuel. In addition, owing to its atomic engine, the ship will be able to remain "on the line" almost indefinitely under combat conditions. Furthermore, the ENTERPRISE will be a safer ship for aircraft to land on than today's carriers, other than those of the FORRESTAL class. Although the ENTERPRISE (roughly the same length as the FORRESTAL) is only about 150 feet longer than carriers of the ESSEX class, that 150 feet has already cut the FORRESTAL's accident rate to half that of the smaller carriers.

The new ship is being built at the Newport News Shipyard, Newport News, Virginia. Work on the carrier has reached the stage where shielding for the nuclear reactor, which will drive the propulsion machinery, is now being installed.

NEWS

In a three-story, block-long building at the Naval War College, Newport, Rhode Island, is a massive electronic "brain" which is being used to fight the wars of tomorrow, today. Called the Navy Electronic Warfare Simulator (NEWS), it consists of extensive communication systems, radar units, navigational computers, and other complex equipment. By feeding information into the giant system, simulated naval battles can be fought and their progress and outcome viewed on a 15-



Above, a war game in progress in the NEWS master control room. Left, a Navy technician adjusts complicated electronic mechanism of the "brain." Below, technicians operate the master control board of the simulator.

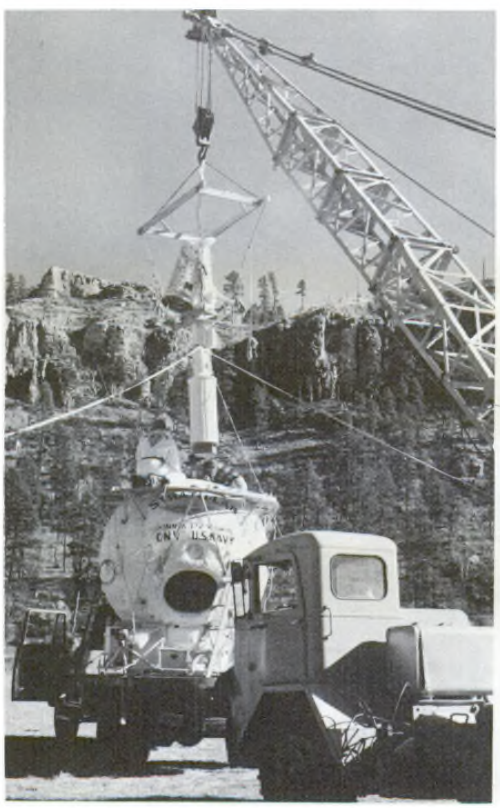
foot plot screen. On the screen, the course and speed of surface units, and the course, speed, and altitude of aircraft and missiles can be indicated. Thus, Naval commanders, sitting in the master control room, can watch their battle plans in action and evaluate their strategy.

The NEWS was planned and designed by the Naval Electronics Laboratory in close cooperation with the Naval War College.

CAPT Norman Barr of the Bureau of Medicine and Surgery adjusts telemetering equipment which was to be worn by Professor Strong during flight. Its purpose was to provide physiological data on the STRATO-LAB scientists while aloft.

Attempts to launch ONR's STRATO-LAB, carrying a 16-inch telescope, on a flight to a high altitude to view Mars were called off late last November at the launching site near Rapid City, South Dakota. First, unfavorable weather caused postponement of the launching, then a tear in the giant polyethylene balloon that was to lift the sealed cabin skyward made it necessary to cancel the flight. CDR Malcolm

High-Altitude Observations of Mars Delayed



The 16-inch Schmidt telescope is lowered over STRATO-LAB in preparation for mounting.

The Schmidt telescope, mounted o Johns Hopkins trailer, is calibrate in preparation for use on STRATO LAB.

Inflation of the polyethylene balloon begins. Gas has filled only a portion of the huge bag, most of which lies on the ground.

Ross of ONR's Air Branch was to be the pilot, and Professor John Strong of Johns Hopkins University, the scientific officer.

If the flight had been made as planned, the STRATO-LAB would have been lifted to an altitude of about 80,000 feet and would have remained overnight at that level while the scientists viewed Mars through the Schmidt telescope mounted on the sealed cabin. The main object of the undertaking was to investigate the water-vapor content of the red planet's atmosphere. By making the observations from such a high altitude—above all but about three percent of the earth's atmosphere—little image-distortion, which the earth's atmosphere causes—would have affected the viewing.

A few photographs showing some of the activities which took place in preparation for the attempted launching are reproduced on these pages.

The Navy expects to make another attempt to launch the telescope-carrying STRATO-LAB in the near future. On this flight, studies will be made of the oxygen content of the Martian atmosphere.

Ground crewmen struggle to weight down partly inflated balloon as wind sweeps launching site.

Conferees at the Oak Ridge seminar

On the Naval Research Reserve

Nuclear Sciences Seminar Held at Oak Ridge

The tenth annual Nuclear Sciences Seminar was held last month at Oak Ridge, Tennessee, with Naval Reserve Research Company 6-3 welcoming the conferees. Eighty-seven Reservists attended, 44 from the Navy, 22 from the Army, 18 from the Air Force, and 3 from the Coast Guard. The seminar, which convened December 1 for a two-week period, was sponsored by the Office of Naval Research in conjunction with the Atomic Energy Commission and the Oak Ridge National Laboratory. LCDR C. O. Smith, USNR, served as Seminar Chairman.

In a message from the Chief of Naval Research to the conferees, RADM Bennett took note of the accomplishments of the nuclear powered submarines during the past several months and then stated, "This revolution in submarine warfare has been made possible by the comparatively simple pressurized water reactor, which ADM Rickover has referred to as the 'Kitty Hawk' model of the nuclear reactor. During this seminar you will understand what he means when you view and hear about the important advances that are taking place in reactor design and theory."

In the course of the seminar the Reservists were presented as complete a discussion of fundamentals of nuclear science in general, isotope production, and the various nuclear research programs now underway as time and security regulations permitted.

The Commanding Officer of the local Research Reserve company, CDR Burl Zimmerman, USNR, opened the seminar and introduced LCDR C. O. Smith, who read a speech forwarded by RADM Bennett, Chief of Naval Research, who was scheduled to speak at that time but who was unavoidably detained in Washington. Other presentations on the opening day were made by CAPT W. I. Bull, USN, Commander, Charleston Naval Shipyard, who represented the Commandant, Sixth Naval District; Mr. S. R. Sapirie, Manager, Oak Ridge Operations Office, Atomic Energy Commission; and Dr. W. G. Pollard, Executive Director, Oak Ridge Institute of Nuclear Studies.

Left, CDR Burl Zimmerman, Commanding Officer of NRRC 6-3, opens the meeting. Right, LCDR C. O. Smith, Seminar Chairman, reads remarks prepared by RADM Rawson Bennett for the Seminar.

In the sessions that followed, talks were given by scientists and engineers attached to the Oak Ridge National Laboratory and the Oak Ridge Institute of Nuclear Studies. Guest speakers from other activities were as follows: CAPT J. P. Aymond, USN, Special Assistant to the Chief of Naval Research for Research Reserve ("The Research Reserve"); CDR R. F. Craig, USN, Armed Forces Special Weapons Project ("Nuclear Weapons"); CDR Edward Biddle, USN, Nuclear Power Section, Technical Assistance Branch, Office of the Chief of Naval Operations ("The Navy's Program for Nuclear Propulsion of Ships"); CAPT E. W. Hribar, USN, Project Director, Naval Aircraft Nuclear Propulsion Program, BuAer, and Deputy Chief, Aircraft Reactor Branch, Division of Reactor Development, AEC ("The Navy's Interest in Nuclear Power for Propulsion of Aircraft"); and CAPT L. P. Crocker, CE, USA, Army Reactors Branch, AEC ("The Army Package Power Reactor Program").

The Reservists visited several activities of interest in the area: American Museum of Atomic Energy, Loudon Dam and the Kingston Steam Plant, Abbott Laboratories, and the Oak Ridge National Laboratory. On the lighter side, a smoker was held on one evening and a dinner dance at the Oak Ridge Golf and Country Club on another.

Seminars Scheduled for Remainder of Fiscal Year 1959

Within the first half of fiscal year 1959, six Research Reserve seminars were held. Before the close of the fiscal year—July 1, 1959—two more seminars, both of which are open to Reservists of other Services, are scheduled to convene. They are the Seminar in Aviation Medicine, to be held at Pensacola, Florida, on March 9, and the Research Reserve Seminar, to be held at ONR, Washington, D. C., on June 1.

Statistics on the Research Reserve

The following figures were compiled from data submitted in the annual reports forwarded by Research Reserve companies for fiscal year 1958:

Companies	110
Panels	8
Members	2,429
Ready Reserves, percent	75
Standby Reserves, percent	25
Attendance at drill meetings, median percent	79
Earned Satisfactory Federal Year	1,879
Selected for promotion	317
Promoted	185
Received Active Duty for Training	690
Captains	33
Commanders	197
Lieutenant Commanders	248
Lieutenants	151
Lieutenants (JG) and below	61
Completed correspondence courses	1,337

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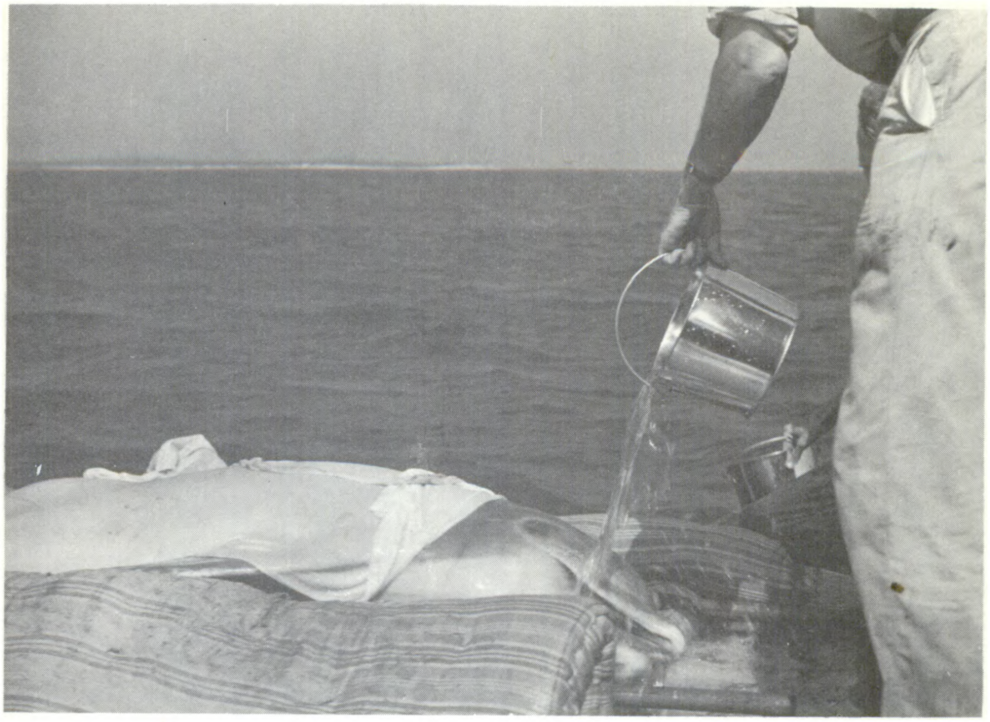
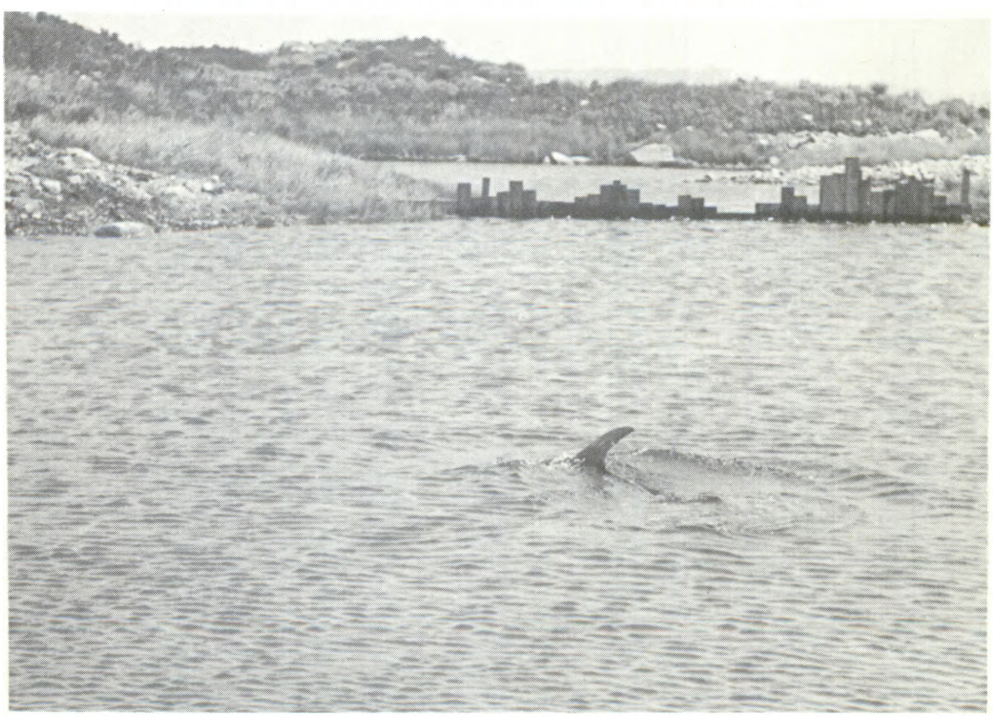


A bucket of water is poured on the porpoise to keep him moist as he is transported from Florida to Woods Hole.

The two pictures on this page show the bottlenose porpoise (Tursiops truncatus) with which echolocation was first demonstrated by W. E. Schevill and B. Lawrence of the Woods Hole (Massachusetts) Oceanographic Institution. See article beginning on page 12.

The captive porpoise investigates his new surroundings--a pond near Woods Hole--shortly after his arrival from Florida.



In This Issue

COVER PHOTO: Porpoises of the genus Stenella, one of the noise-makers of the sea discussed in the article beginning on page 12.

RESEARCH REVIEWS endeavors to report briefly highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C. . . . Research Reviews is listed for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Subscription price: $1.50 per year in U. S. and Canada; $2.00 per year, foreign; $0.15 per individual copy. Use of funds for printing this publication was approved by the Director of the Bureau of the Budget, February 12, 1958.