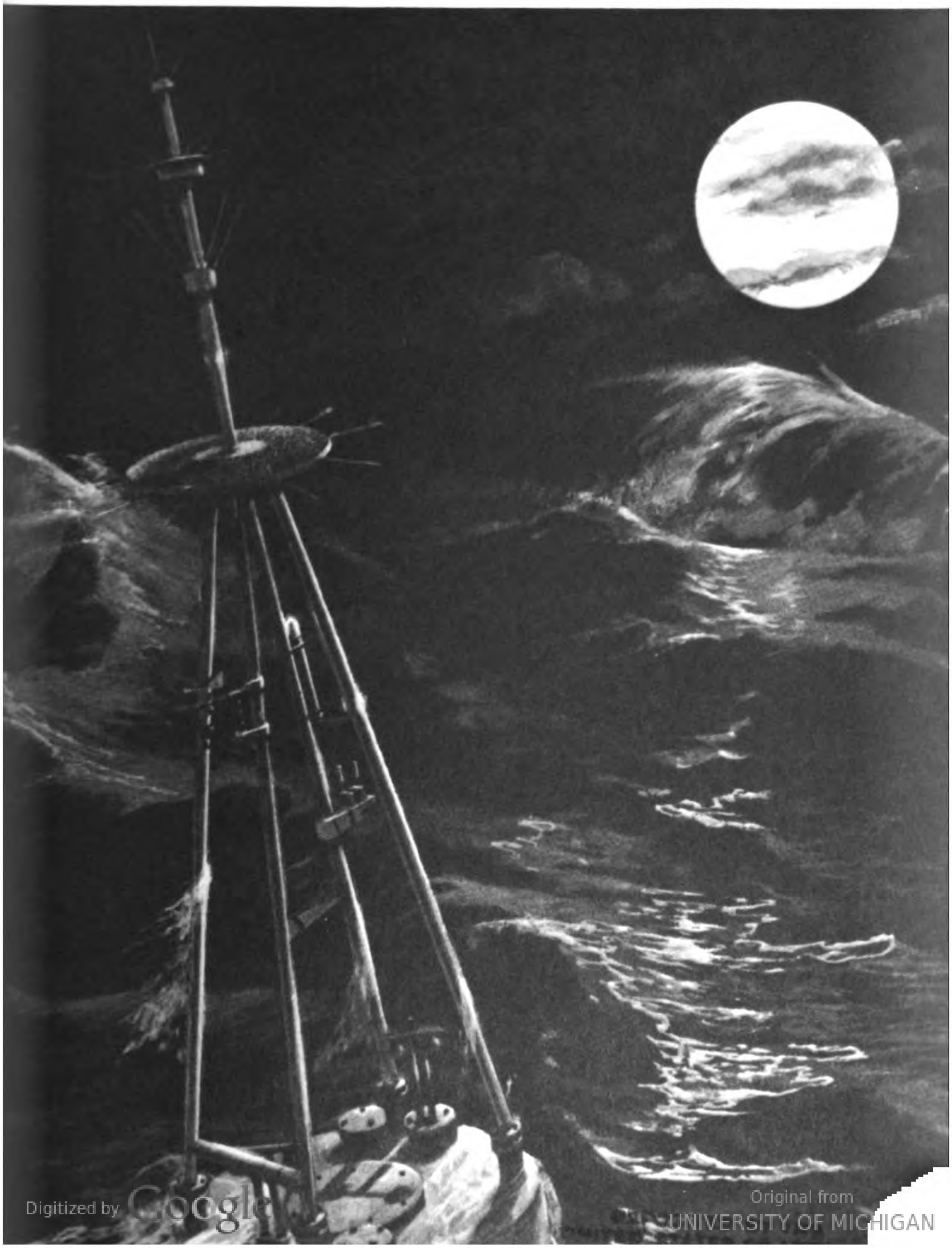
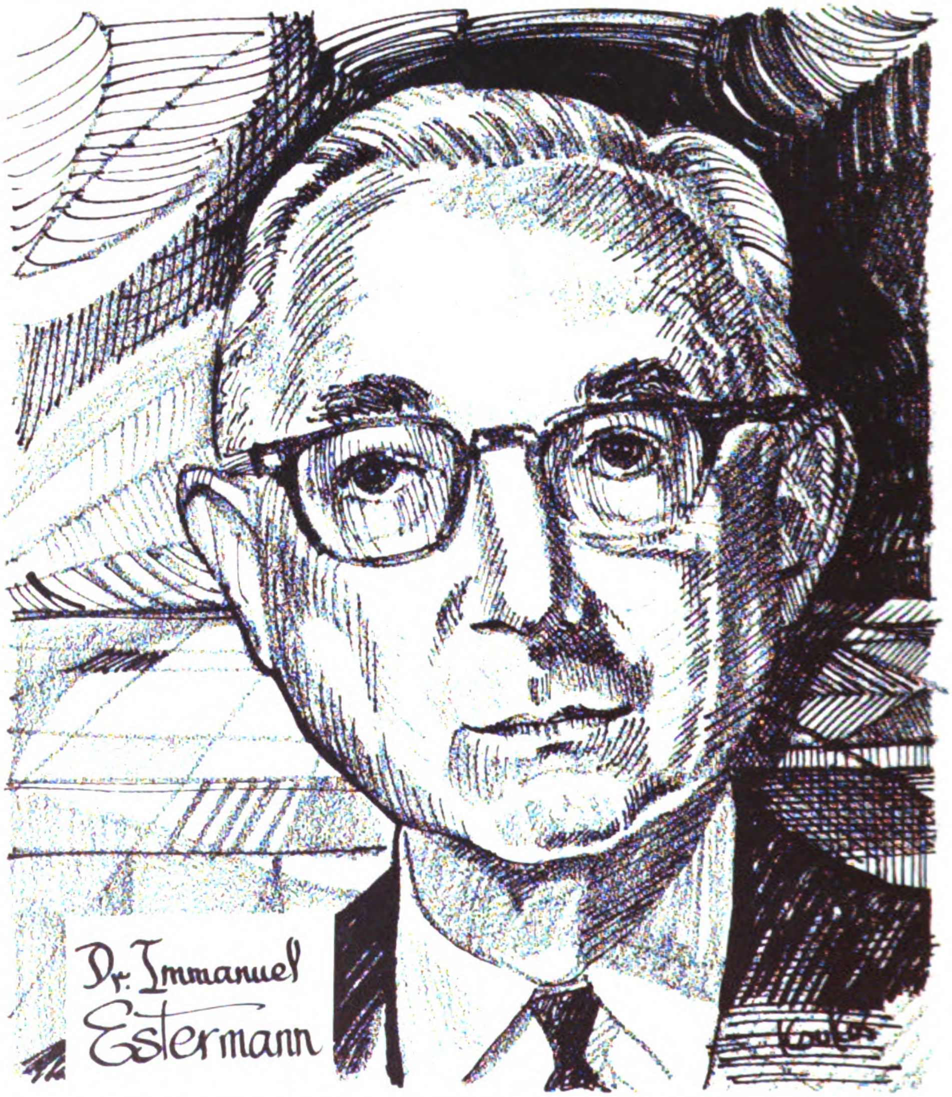
NAVAL RESEARCH

REVIEWS

SEPTEMBER 1969



Portraits in Science



IN 1922 DR. ESTERMANN RECEIVED HIS DOCTORATE FROM THE UNIVERSITY OF HAMBURG; HIS THESIS ON THE MECHANISM OF CRYSTAL GROWTH BECAME A STANDARD REFERENCE. DR. ESTERMANN CONTINUED OUTSTANDING WORK IN HIS FIELD OF PHYSICAL CHEMISTRY AT THE CARNEGIE INSTITUTE WHERE HE EVENTUALLY BECAME AN ONR CONTRACTOR. AT THE UNIVERSITY OF ROSTOCK, DR. ESTERMANN WAS A COLLABORATOR OF DR. OTTO STERN, WINNER OF THE NOBEL PRIZE IN PHYSICS IN 1945. DURING WORLD WAR II DR. ESTERMANN WORKED FOR THE NATIONAL DEFENSE RESEARCH COMMITTEE AND THE MANHATTAN PROJECT. FOR A SHORT TIME DR. ESTERMANN WAS DIRECTOR OF THE MATERIAL SCIENCES DIVISION OF ONR; THEN IN 1954 HE BECAME RESEARCH COORDINATOR FOR ONR; LATER ON HE WENT TO THE LONDON BRANCH OF ONR TO SERVE AS CHIEF SCIENTIST AND SCIENTIFIC DIRECTOR. TODAY DR. ESTERMANN IS PROFESSOR EMERITUS AT THE ISRAEL INSTITUTE OF TECHNOLOGY, HAIFA.

Satellite/Buoy Communications and Position Fixing

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Office of Naval Research

INTRODUCTION

The first communications satellite was launched by the United States in 1958. It had the limited capability of transmitting simple messages placed on tape before launch. Since the first launch, the evolution of communications satellites has led to the most accelerated improvement in communications capability ever experienced by man. Today, through massive joint development programs by the International Telecommunications Satellite Consortium (INTELSAT), National Aeronautics and Space Administration (NASA), and DOD, we have progressed to the point where reliable, high capacity communication *via* synchronous satellites among ground stations, ground vehicles, ships, and airplanes has not only been demonstrated, but is already considered cost-effective for commercial applications and operationally advantageous for military uses. Communications satellites now vary in frequency from VHF (135 MHz) to X band (8 GHz) with bandwidth requirements that correspond to data rates of from 100 bits/sec (teletype) to millions of bits/sec (color TV). Design specifications for one of the most advanced satellites for 1970 range up to 2000 pounds in satellite weight and up to 10,000 two-way telephone circuit capacity.

Along with the activity in oceanography and ASW there has been an increasing interest in the ocean buoy. The ocean buoy, which is used as a sensor platform for data gathering, can communicate data to the user in a timely and synoptic fashion.

In early 1968 the U.S. Coast Guard completed a study of the feasibility of national data buoy systems, examining the national requirements for marine meteorological and oceanographic data and how such requirements could be met by a data buoy system. It was concluded that unmanned buoys are extremely efficient platforms for sampling and collecting meteorological, oceanographic, and geophysical measurements on a world-wide basis.

Technological advances in buoy construction and materials such as reliable and efficient power supplies, extremely sensitive and low-maintenance instrumentation, and microminiaturization of electronics produced two general classes of buoys: (1) the deep-sea, long-lived moored buoy, and (2) the inexpensive, small, lightweight and expandable floating buoy.

The U.S. Navy's air ASW program has long relied on the air-droppable sonobuoy for detecting, tracking, and localizing submarines by acoustic signals, which are processed and transmitted from sonobuoy to the monitoring aircraft. Work on sonobuoys, both free-floating and moored, continues; and the sonobuoy will have a long and useful lifetime for future ASW system concepts.

For any system concept that uses the buoy as a data gathering platform, whether oceanographic, meteorological or acoustic, one of the key problems is transmission of such data to the user. Traditional means in the past have included real time, long range transmission at High Frequencies (HF), 3 to 30 MHz. While transmission distances of around 2500 NM can be achieved, there are two inherent drawbacks to the HF link: (1) poor propagation reliability caused by vagaries of the ionosphere, and (2) the limited bandwidth imposed by the low carrier frequency, resulting in low data-relay rates.

Another commonly used method for data transmission has been aircraft readout of stored sonobuoy data at VHF frequencies, approximately 160 to 170 MHz. This concept lacks the capability for synoptic coverage of buoy fields.

Recent NASA Applications Satellite Programs

The NASA Space Science and Applications Group has supported several space applications satellite programs that are extremely relevant to the requirements for buoy readout. One of the most interesting and successful has been the Applications Technology Satellite (ATS) program, which is for the development and testing of advanced components and techniques for future communications, meteorological, and navigation satellites. The first phase of this program is scheduled to end this year with the launch of ATS-5. ATS-1 was launched into synchronous orbit (24-hour period) over the equator in the Pacific Ocean (152° W longitude) in December 1966. ATS-3 was placed in a synchronous, equatorial orbit over the mouth of the Amazon River (57° W longitude) in November 1967. Both ATS-1 and ATS-3 are still operating successfully. In addition to other equipment, both satellites have VHF transponders aboard that, receive at 149.22 and transmit at 135.6 MHz, with a 40 watt transmitter power output.

The ATS program is being used to test and support two other NASA projects of interest to most buoy users. The OPLE experiment (Omega Position Location Equipment) is demonstrating the feasibility of using the Navy-developed and operated Omega Navigation System with synchronous satellites to establish a global location and data collection system. OPLE receives a VLF (Very Low Frequency) signal from three or more of the Omega long range (up to 7000 NM) ground stations. Similar in concept to LORAN, Omega measures the phase difference in signal from two stations to determine a locus, which is a hyperbolic line-of-position. The intersection of two or more hyperbolas produces a fix. In OPLE, the received signals, on frequencies from 10.2 kHz to 13.6 kHz, are than shifted up in frequency to 149.22 MHz (still preserving phase) and retransmitted to an ATS satellite. The satellite then relays the navigation signals, plus several channels of impressed sensor data, from the interrogated platform to a ground station at NASA Goddard. The actual sequence of events proceeds as follows. The Goddard station interrogates the configured platform first with a unique coded address. The OPLE PEP (Platform Electronic Package), several of which were built by NASA, recognizes its coded address and returns both the VLF navigation signal and sensor data *via* the ATS satellite back to the Goddard station. At the ground station the position of the interrogated platform is then computed, using the phase information that has been preserved throughout transit of the OMEGA signal. The PEP is suitable for testing on such diverse platforms as aircraft, ships, balloons, ground vehicles, and buoys. The OPLE uses a reliable, world-wide ground-based navigation system, OMEGA, for position-fixing and merely uses the satellite for signal relay, as depicted in Figure 1. This feature makes the precise position determination of the satellite unimportant, except in the general sense that it be within the line of sight of the interrogated platforms. This concept requires only one

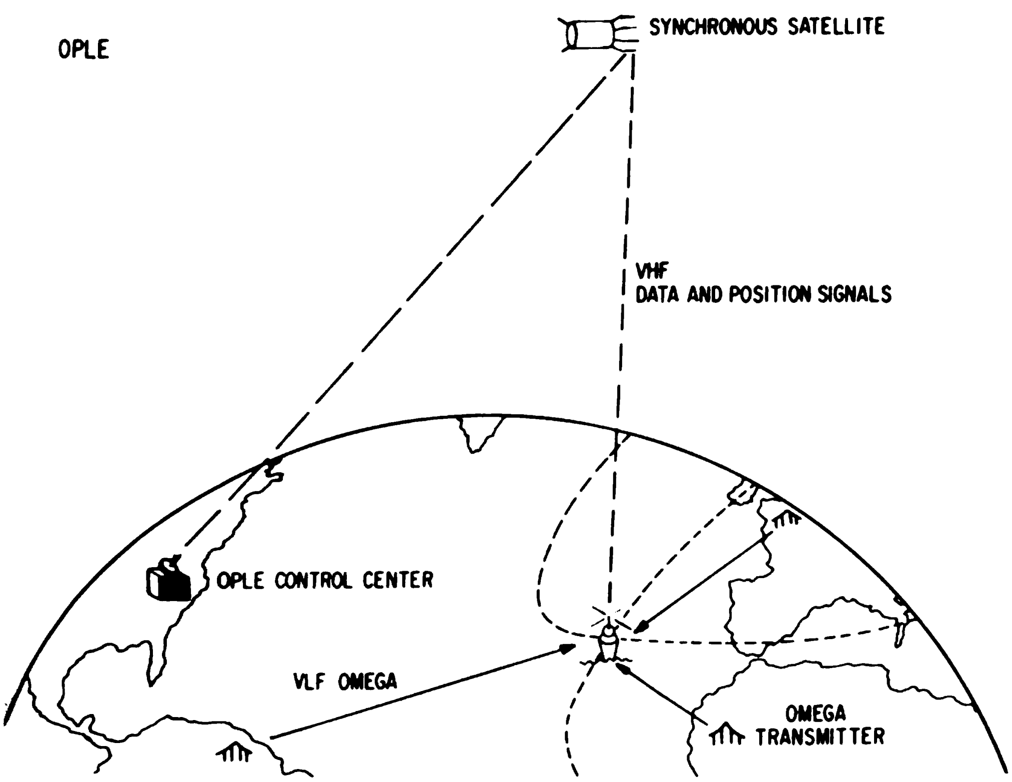

Figure 1 — The Omega Position Location Equipment (OPLE) uses a reliable, world-wide ground-based navigation system, OMEGA, for position-fixing and merely used the satellite for signal relay

properly located synchronous satellite and one interrogation for a positio fix.

Another position-fixing scheme using ATS, now being evaluated b NASA, is the General Electric Company's "Tone Code Ranging technique, which was developed in connection with NASA's Air Traffi Control Satellite program. This technique employs two or more satel lites (like ATS-1 and ATS-3) to determine two or more lines of position whose intersection determines the position or fix. In this scheme th precise position of the satellite is required since the lines-of-positio are range locii, which are determined by transit time of signal fron ground site to satellite, to interrogated platforms, and return. Severa channels of data can be sent as part of the ranging signal.

The recent launch of the NASA Nimbus 3 satellite in April 1969 i also of interest in that it carries another pertinent NASA experimen called IRLS (Interrogation, Recording, and Location Subsystem) IRLS interrogates sensor platforms and then records the stored data collected by such platforms. It also records ranging data. As shown by Figure 2, the Nimbus satellite then dumps the collected data and ranging signals at the Command and Data Acquisition Station, where the data is reduced and the fix is computed. The nimbus meteorological Satellite is in a low altitude retrograde orbit (approximately 600 NM), at, 80° inclination. The orbit is sun synchronous, which means that the orbita plane processes at the exact rate as the earth-sun line so that the space- craft will always pass overhead at approximately local noon or midnight. The IRLS packages on the interrogated sensor platforms operate at UHF (401.5 MHz receiver and 466 MHz transmitter) with a nominal power output of 25 watts.

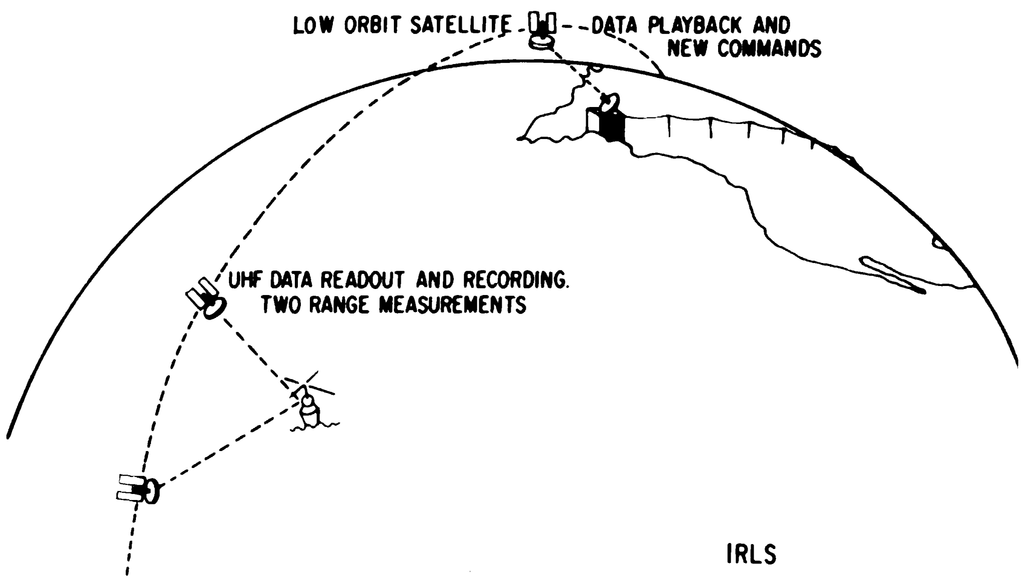

Figure 2 — Interrogation, Recording, and Location Subsystem (IRLS) interrogates sensor platforms and then records the stored data collected by such platforms. It also records ranging data.

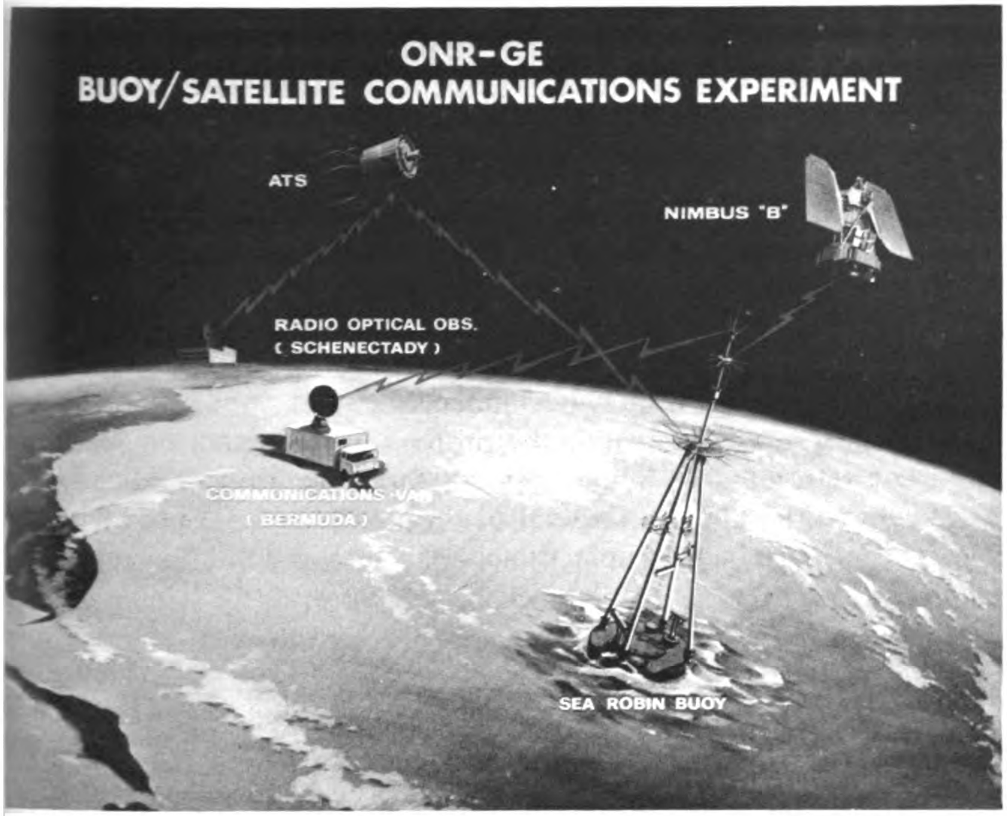

Figure 3 – ONR and the General Electric Company designed an experiment that would investigate the special communications problems between a satellite and a buoy

Sea Robin Buoy/Satellite Experiment

Pertaining to the question of satellite/buoy readout there are several experiments either planned or already underway for testing the NASA packages (OPLE and IRLS) on ocean buoys. The Office of Naval Research and the General Electric Company agreed in early 1968 to design an experiment that would investigate the special communications problems that exist in communicating in both directions between a satellite and a buoy (Figure 3). The Naval Oceanographic Office also provided some support. The main objective was to use as much existing equipment as possible – to accumulate enough experimental data in a realistic test environment and thereby be able to identify problem areas and to supply data for parametric trade-offs in buoy design, satellite concept, and in both buoy and satellite electronics and antenna design characteristics. It soon became evident that the project could be expanded to include the test and evaluation of several proposed position-fixing schemes in a common test environment.

In order to use buoys as sensor platforms, which can be read out by satellites, the system specifications for the buoy and its equipment will have to be determined. The specifications will include such equipment characteristics as: frequency, bandwidth and data rates, encoding technique, power requirements, antenna design, on-board processing and storage; and such buoy characteristics as size, shape, and stability. These specifications will be dependent on such satellite design characteristics as ERP (Effective Radiated Power), polarization, orbital characteristics, satellite stablization and pointing capability. Finally, the propagation characteristics between buoy and satellite will be a major influence on any final system specifications. The effects of the ionosphere, the atmosphere, and sea reflection are some of the major problem areas that must be better understood.

In planning and coordinating the proposed field tests, the Sea Robin buoy was selected as the buoy test platform. This buoy was designed and developed in 1966 by General Electric, Missile and Space Division. It was designed as an experimental oceanographic/meteorological

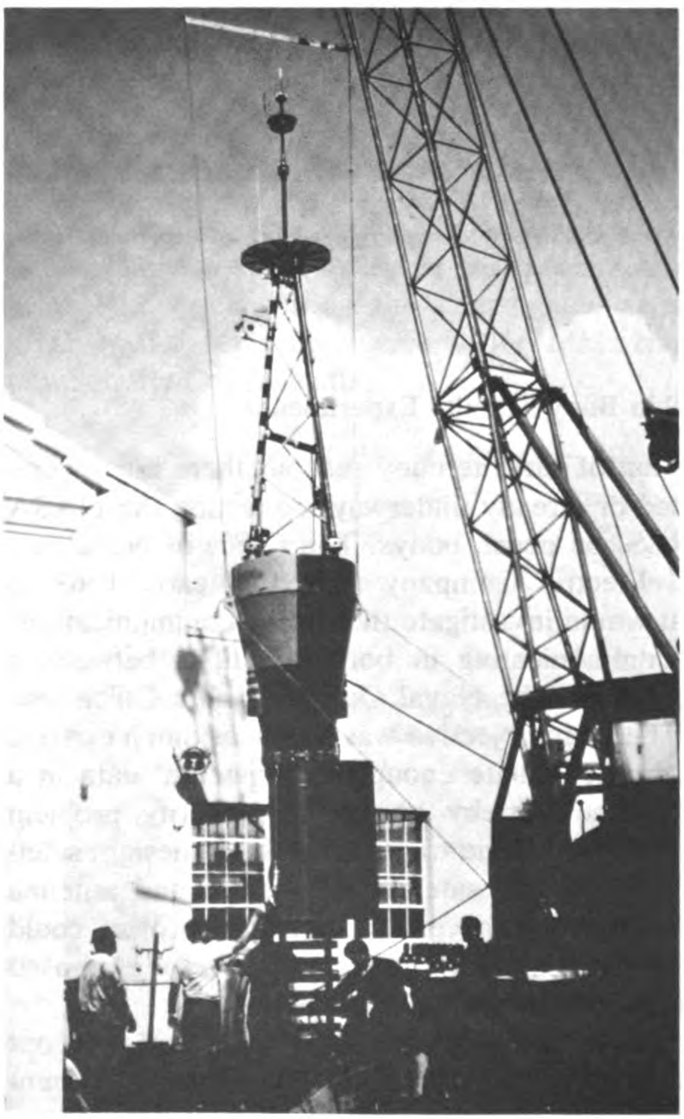

Figure 4 — Shown here is a Sea Robin Buoy that is 14 feet long, 4 feet in diameter at the top, sloping to 2 feet in diameter at the mid section. The buoy in its initial configuration weighed approximately 1500 pounds.

buoy that would be suitable for satellite communications. A modified spar buoy evolved, shown in Figure 4, that was 14 feet long, 4 feet in diameter at the top sloping to 2 feet in diameter at the mid section. The buoy, in its initial configuration, weighed approximately 1500 pounds. A mooring in 10,000-foot depth was successfully tested in 1967. This three part mooring design, with a 1.02 scope, utilized a clam shell anchor.

During the first steps in this phased project ONR and its investigators had to define the experimental program, specify the preliminary design of the buoy electronics to carry out the program, and to configure the buoy. Coordination with NASA Headquarters and NASA Goddard Space Flight Center resulted in the assignment of satellite time on ATS-3, use of a NASA OPLE package, and use of the "tone data ranging" technique for the Sea Robin experiment. The buoy was configured for data transmission by HF link over long ranges (in excess of 1000 miles), so as to be able to compare direct HF communications with satellite communications in a common environment. General Electric, Missile and Space Division planned and conducted the described experimental program under ONR contract.

Figure 5 is a line drawing of the Sea Robin Buoy. In this configuration, the total buoy weighs 2600 pounds. Nineteen oceanographic, meteorological, and house keeping sensors are included on the buoy for telemetry read out. These sensor read outs are also transmitted *via* UHF link to the GE developed van, pictured in Figure 6. These same data are transmitted to the satellite ground station in Schenectady, New York, *via* satellite and to the HF receiving site at Rome Air Development Center in New York. The van is a command station to control the switching on/off of the buoy electronics equipment. The van also monitors the buoy equipment, receives signals from the satellite for reference and comparison with signals received by the buoy, and records selected data on magnetic tape for eventual reduction and analysis.

Figure 5 shows the buoy configured to communicate *via* UHF, VHF, HF and VLF. The original design shows a power configuration, with two propane-fueled thermoelectric generators for use in charging the secondary batteries (nickel-cadmium). Average power output was designed for approximately 100 watts.

Phase two of the experiment was a thirty-day moored test in approximately 4200 feet of water 7 miles south of Bermuda. A good range of sea, atmospheric, and ionospheric conditions was encountered, as expected. This provided a broad enough range of data to permit the assessment of the effects of buoy motion, sea reflection, ionospheric Faraday rotation, and other environmental variables on communications reliability between buoys and satellite. It should allow a first order analysis of effective radiated power requirements for buoy/satellite communications for well defined conditions.

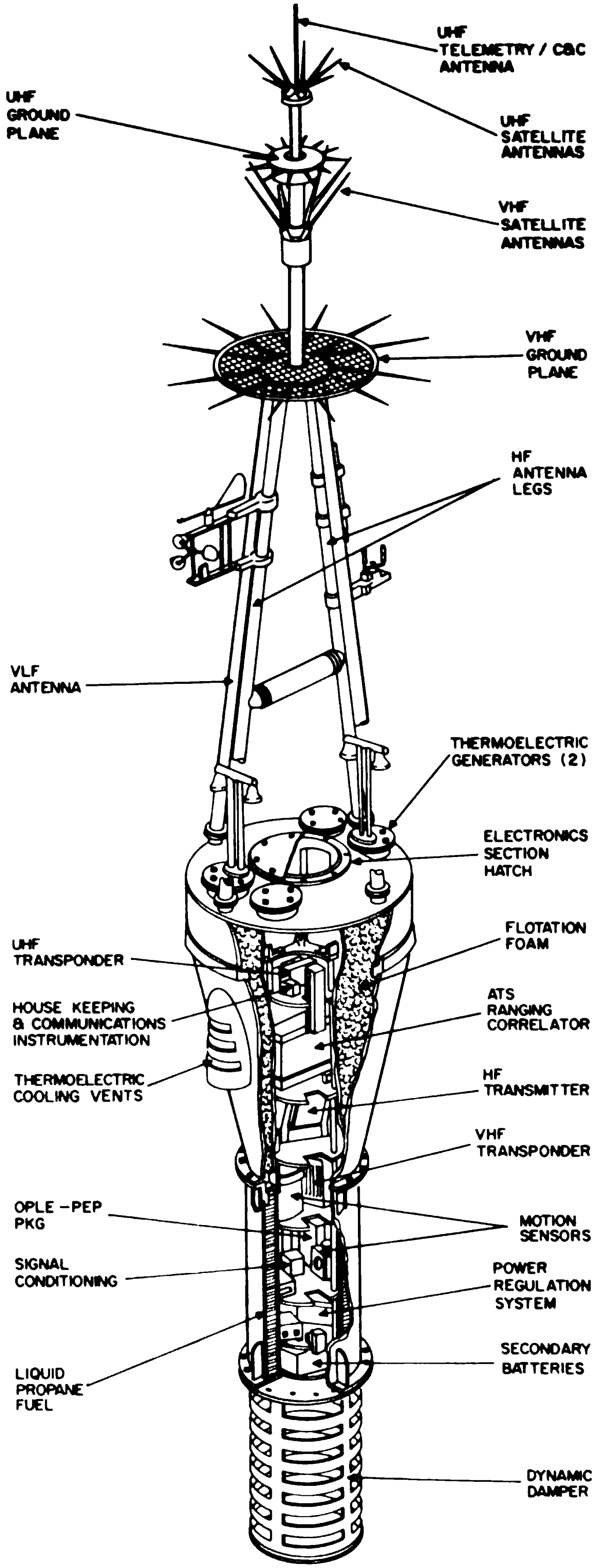

Figure 5 – A line drawing of the Sea Robin Buoy which weighs 2600 pounds in the test configuration. Nineteen oceanographic, meteorological, and house keeping sensors are included on the buoy for telemetry read out.

Figure 6 – The sensor read outs of the Sea Robin are transmitted via UHF link to the General Electric developed van seen here

The following tests were conducted during the thirty-day moored period in the months of April and May 1969:

(1) *ATS Ranging and Position-Fixing or "Tone Code Ranging."* As shown by Figure 7, a VHF signal (149.22 MHz) is sent from the GE Schenectady Radio—Optical Observatory to the ATS-3 satellite, which then transponds the signal at 135.6 MHz to the Sea Robin Buoy. The carrier is frequency modulated with an audio frequency tone code at 2.4414 kHz, as shown in Figure 8. The ranging signal is a pulse train of approximately 1000 cycles followed by a 32 cycle digital address code, with the cycles inhibited for zeros and transmitted for ones. Upon receipt, the signal is applied to a phase matching circuit on the buoy which matches the phase of a local oscillator to that of the incoming signal. When a prewired address recognizer in the buoy sees its 32 bit digital address code, this is the signal to switch to the buoy transmitter. The address code, followed by digitized sensor information, is then sent back from buoy to ATS-3 satellite at 149.22 MHz. Data can be transmitted at two rates: 305 bits/sec and 2400 bits/sec. The buoy electronics package also contains a PCM (Pulse Code Modulated) multicoder which can convert 35 parallel analog input channels of sensor data to a binary serial output sequency for transmission over the ATS subsystem and the buoy TLM subsystem. Upon receipt of the signal back at the GE Schenectady observatory, it is then possible to determine time of transit of the signal and relate this time to a range locus with respect to the satellite. The digitized sensor data can be converted and printed out in a readable format. Two or more satellites will produce two or more lines of position, whose intersection will fix the buoy's

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Antenna Gain:	+3 db
Transmitter Frequency:	149.22 MHz
Modulation Format:	PCM/AM/FM
Transmitter Power:	120 watts
Frequency Deviation:	5 KHz
Satellite Range:	22,300 miles
Receiver Frequency:	135.6 MHz
Modulation Format:	PCM/AM/FM
Receiver Sensitivity:	−146 dbw

ATS EXPERIMENT

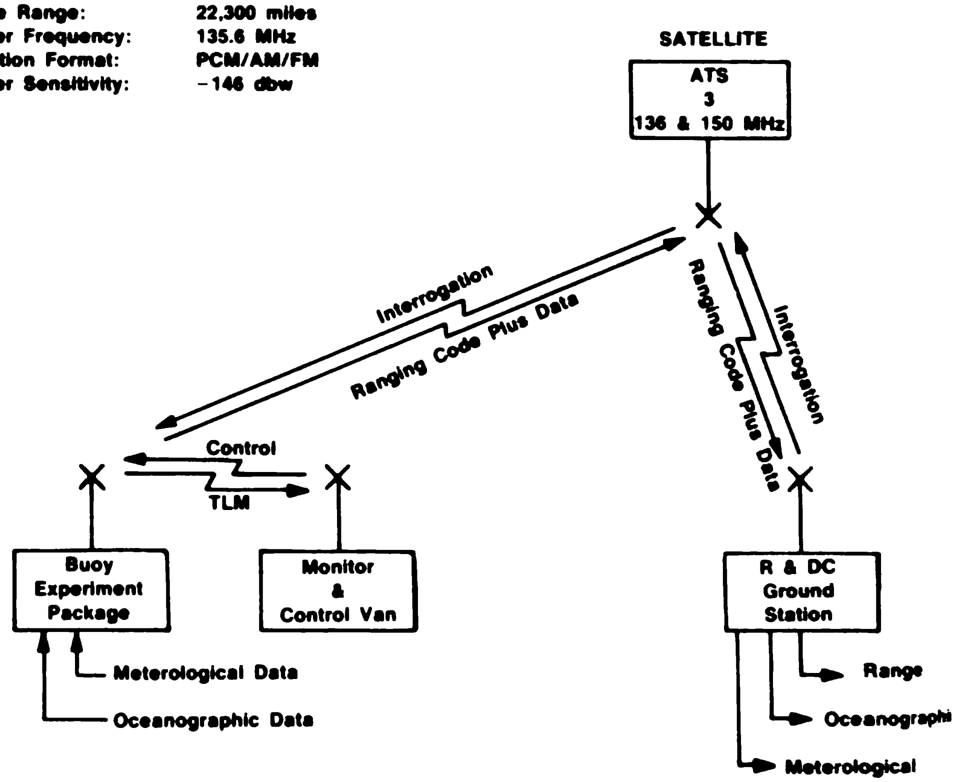


Figure 7 — ATS Ranging and Position-Fixing or "Tone Code Ranging" test was conducted for Sea Robin. A VHF signal (149.22 MHz) is sent from the GE Schenectady Radio Optical Observatiory to the ATS-3 satellite, which then transponds the signal at 135.6 MHz to the Sea Robin Buoy.

TONE CODE RANGING WAVEFORM

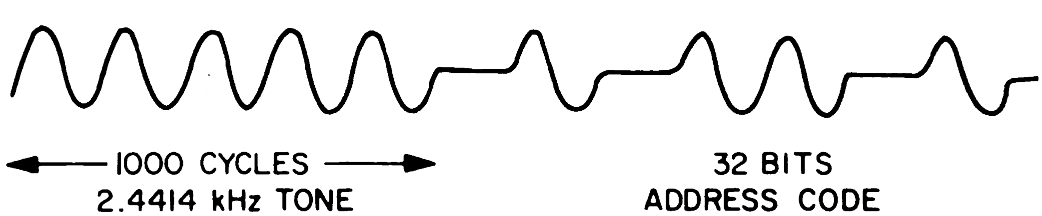


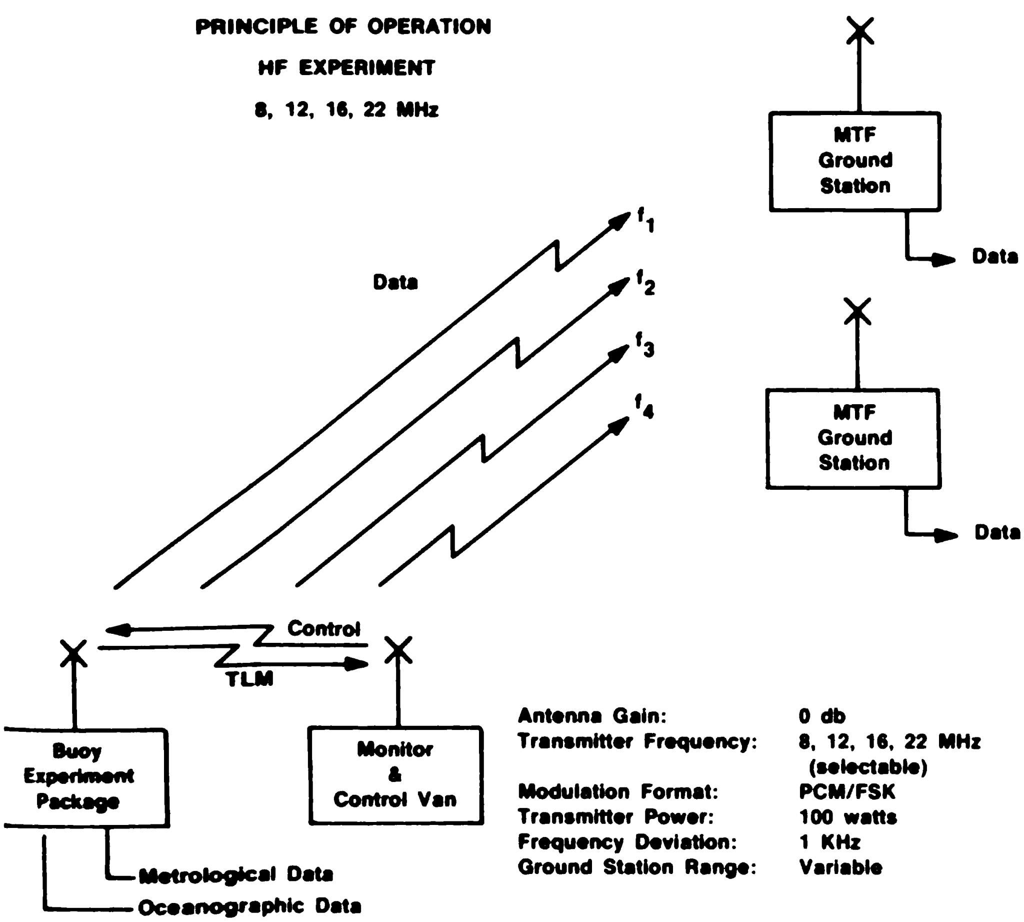
Figure 8 — During the test the carrier is frequency modulated with an audio frequency tone code at 2.4414 kHz

position in a similar manner as with star line-of-positions in celestial navigation.

(2) *OPLE (Omega Position and Location Equipment).* The buoy is also configured with an OPLE package which was discussed before. The OPLE navigation signal is relayed by ATS-3 back to the OPLE Control Center at Goddard.

(3) *HF Data Transmission.* Four frequencies (8, 12, 16, and 22 MHz) are used to send data *via* HF link from the buoy to a ground station receiver site, located at Syracuse, New York. This experiment will permit direct comparison of error rates of transmitted data between HF long range links and satellite VHF links. A block diagram of the HF subsystem is shown in Figure 9.

(4) *UHF Telemetry.* A UHF telemetry transmitter/receiver at 234 and 251.5 MHz on the buoy permits control and monitoring of the buoy by the mobile van. The van maintains line-of-sight communications with the buoy and is located near the Navy's Tudor Hill Laboratory in Bermuda, which is providing operational support for the experiment.



Antenna Gain:	**0 db**
Transmitter Frequency:	**8, 12, 16, 22 MHz (selectable)**
Modulation Format:	**PCM/FSK**
Transmitter Power:	**100 watts**
Frequency Deviation:	**1 KHz**
Ground Station Range:	**Variable**

Figure 9 — A block diagram depicting the four frequencies (8, 12, 16, and 22 MHz) used to send data via HF link from the buoy to a ground station receiver site

The van is approximately 12 feet high, 8 feet wide, 27 feet long and weighs 15,000 pounds. It has mounted an X-band radar at 9.37 GHz for tracking the buoy.

Reduction and analysis of data for the 30-day moored tests is now in progress and is expected to shed considerable light on the special communications problems of a bobbing ocean buoy communicating with a satellite.

Several problems were encountered during check out prior to the thirty-day tests. A critical problem involved the failure of the buoy power supply, because of difficulties with the propane-fueled thermoelectric generators. It finally became necessary to replace the secondary nickel-cadmium batteries with a primary silver-zinc battery, rated at 440 ampere-hours.

While it is too early to draw any firm conclusions from any part of the buoy tests, preliminary data for the "tone code ranging" system indicated a ranging accuracy of ± 2.0 microseconds, rms (± 1000 feet). Fades of the satellite signals were experienced at the buoy from time to time. Of particular interest will be the attempt to determine the causes of such fades—whether from buoy motion, sea reflection effects, atmospheric scintillation, or ionospheric Faraday rotation.

It is hoped that a follow-on test can be run with the Sea Robin Buoy. One plan calls for a ten-day floating test where, in addition to communicating with and tracking the buoy using its present electronics equipment, an IRLS package would be added. This would permit comparative evaluation of another satellite position-fixing scheme. It would also expand the communications parametric analysis by providing data for a satellite orbit at low altitude and for a buoy/satellite communications frequency in the UHF range (401.5 and 466 MHz). A location for the floating tests would be desirable that could also make use of two ATS satellites.

There are many concepts for using a satellite to interrogate, position-fix, and read out the data from a buoy. The type of buoy will be a major influence on the selected optimum system characteristics: frequency, coding scheme, orbital altitude, radiated power requirements, *etc.* However, there will also be the case where the satellite characteristics are given conditions and the buoy design must then be tailored to interface with the satellite in the most efficient manner.

Information provided by this experiment should begin to build a data base to help answer preliminary design questions of buoy/satellite systems in general. Buoy types vary widely: oceanography, meteorology, ASW, emergency distress, search and rescue. An interesting future project will be designing the expendable, floating buoy capable of satellite read out. This buoy will be an inexpensive, small, light weight buoy that has both sufficient receiver sensitivity and transmitter ERP in severe sea conditions to permit satellite interrogation, sensor read out, and position-fixing.

This experiment should also be the start of a data base and a natural lead-in to the concept of a small, long-lived, reliable, cheap, and automatic IFF/beacon system for shipboard use. Properly designed equipment would permit ships to be interrogated, identified, and located in one easy operation, using a synchronous satellite, from a central command station. Such a shipboard system could also incorporate features for environmental sensor read outs, distress alarm, and emergency communications. Plans are underway to investigate this particular concept further by performing a preliminary design analysis and breadboard experiment.

The communications satellite is here. The navigation and position-fixing satellite is here. The interest in and requirement for ocean buoys is increasing. A combination of these ingredients is a natural fallout for many ocean applications of the 1970's. An experiment that brings together the diverse areas of space, the ocean, satellites, buoys, communications, position-fixing or navigation, oceanography and meteorology, ASW, and ocean surveillance is not only extremely applicable but is a prerequisite for sound planning of the many possible ocean-related systems concepts.

Dr. Irwin Receives Award

Dr. George R. Irwin, Boeing Professor of Mechanics at Lehigh University, recently received the Captain Robert Dexter Conrad Award—the Navy's highest award for scientific achievement. The award was given to him at a banquet marking the first day of the Third National Symposium on Fracture Mechanics held at Bethlehem, Pennsylvania, and sponsored by the Office of Naval Research, the Naval Research Laboratory, and Lehigh University. The Navy honored Dr. Irwin for his outstanding work in fracture mechanics performed during his 30 years as an employee of the Naval Research Laboratory in Washington, D.C., which ended in 1967 when he joined the Lehigh faculty. Fracture mechanics is the study of flaws and cracks in material and structures.

The methods of fracture analysis conceived by Dr. Irwin opened the way to the development of new high-strength alloys to achieve structural reliability. This has led to desirable, fracture-tough materials which have been employed in structures of interest to the Navy, including Deep Submergence Rescue Vehicles and Deep Submergence Search Vehicles.

His work has also been applied in the development of high-speed aircraft and Minuteman missile for the Air Force, in the development of rocket weapons for the Army, and in NASA's efforts to develop large boosters and lightweight upper stage rockets.

His earlier work in ballistics led to many improvements in armor for both the Army and the Navy during World War II. Non-metallic personnel armor used extensively in the Korean and Vietnam conflicts was developed by a group of engineers working under Dr. Irwin at the Naval Research Laboratory.

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Techniques for Ocean Floor Search

J. J. Gennari
Naval Research Laboratory

There have been numerous incidents in recent years, both in our Navy and in general maritime operations, which point to the need for search and recovery capability in the deep ocean. This paper shall confine itself to a discussion of techniques developed at NRL for searching for objects on the ocean floor in deep water not recovery methods. The principal topics are equipment requirements, search procedures, problem areas, and a presentation of the results of the SCORPION search.

The development of technology and perfection of techniques required in deep ocean search is the responsibility of the Ocean Engineering Branch at Naval Research Laboratory. The research background of the Ocean Engineering Branch is in the fields of underwater acoustics and optics, the dynamics of deep-towed systems, and the real-time acquisition of information near the ocean-ocean floor interface. Equipment and techniques developed in these research programs have led to our present deep ocean search capability. The Branch has located and photographed the THRESHER and SCORPION and ALVIN hulks and has participated in the search for and recovery of the H-bomb off Spain. Our primary method of search is to scan the ocean floor from an unmanned instrument platform, towed near the bottom by a surface ship.

Figure 1 — The surface platform used during the THRESHER, H-Bomb, and SCORPION searches has been NRL's research ship, the USNS MIZAR (T-AGOR-11), operated by the Military Sea Transportation Service

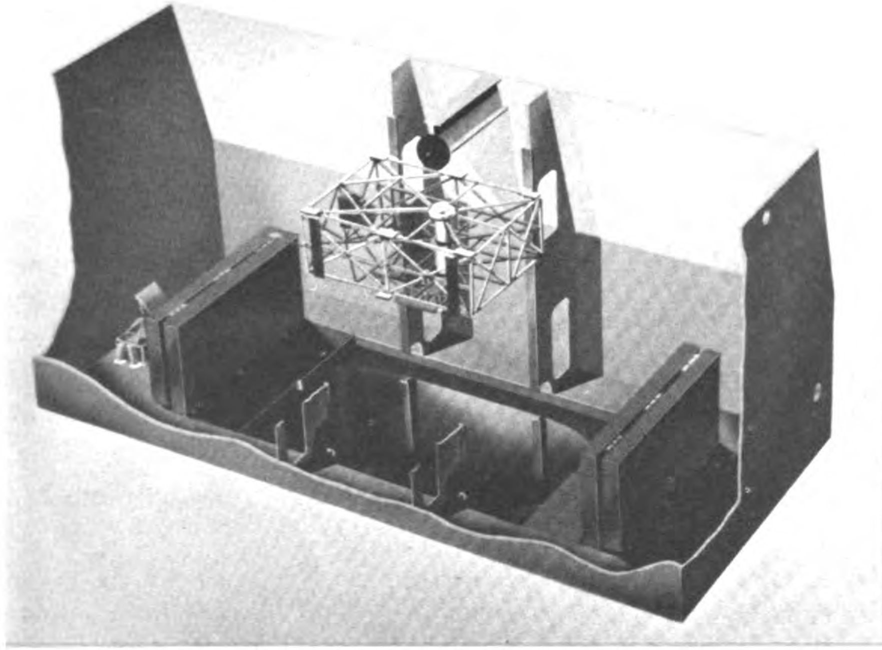

Figure 2 — MIZAR has been modified for ocean search purposes, the most obvious modification being the installation of a 10 foot by 23 foot centerline well. The well is covered over at the main deck with a set of hydraulically-operated, water-tight doors, and a two-level enclosed bridge structure capable of supporting a 100,000-pound payload.

The equipment requirements are a surface platform, an umbilical cord, a towed vehicle, and a group of sensors which provide information to the scientists in charge of the operation. The surface platform used during the THRESHER, H-Bomb, SCORPION and ALVIN searches has been NRL's research ship, the USNS MIZAR (T-AGOR-11), operated by the Military Sea Transportation Service. This ship has been modified for our purposes, the most obvious modification being the installation of a 10-feet × 23-feet centerline well. The well is covered over at the main deck with a set of hydraulically-operated, water-tight doors and a two-level, enclosed bridge structure capable of supporting a 100,000 pound payload.

Within this enclosure and extending down to the keel is a set of rails on which rides an elevator or carriage. The carriage provides a "steady-rest" for the towed vehicle during launch and retrieval. During a towing operation the carriage is locked in the "down" position at keel level. In this position the tow-point for the cable is from a sheave which is attached to the carriage and extends below the keel. With such a towing configuration the ship's maneuvers are not restricted, nor is there fear of fouling the tow cable with the ship's screws. The control center for the search operation is in the laboratory, two levels below the main deck. Almost all activity during a search is here. The height of the towed

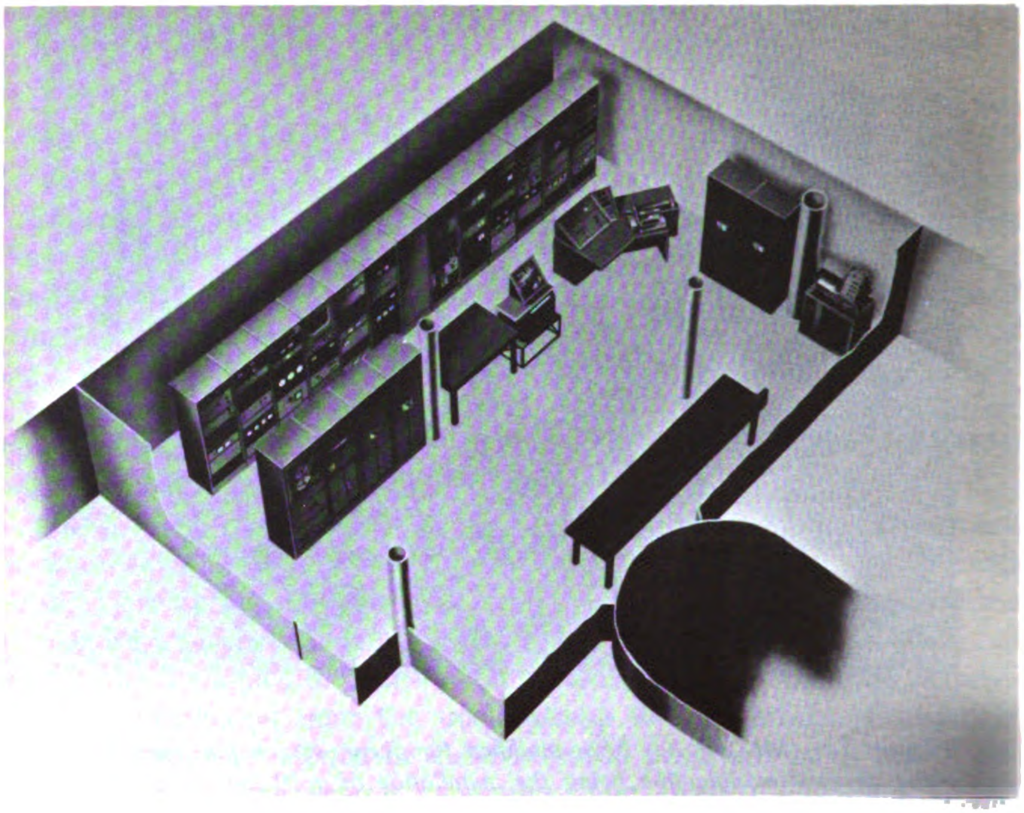

Figure 3 – The control center for the search operation is in the laboratory, two levels below the main deck. Almost all activity during a search is here.

vehicle above the ocean floor is controlled from the winch operator's station in this laboratory. Also at this deck level are a well-equipped photo lab and dark room, a data analysis center, an electronics repair shop, navigating equipment, sensor information processing and display equipment, and the underwater tracking system computer.

The umbilical cord which connects the towed vehicle to the surface platform is a 0.68 inch diameter, double-armored coaxial cable with a breaking strength of 35,000 pounds. The winch can accommodate 22,000 feet of this cable and pay-out or retrieve at a rate of 250 ft/min. The armor is also used as a ground return to provide two independent electrical transmission lines. Commands to the sensors and data from them are transmitted *via* the center conductor-armor circuit. Continuous charging of the sensor's battery supply is accomplished *via* the shield-armor circuit.

The towed vehicle, or fish houses the sensors, the electronics and power supply, and part of the telemetry system. The cones of light in this artist's rendition of the fish are formed by the strobes which provide illumination for the cameras. The fish is normally equipped with three search sensors and two sensors used for fish control. The latter two are a responder, used with the underwater tracking system to determine the

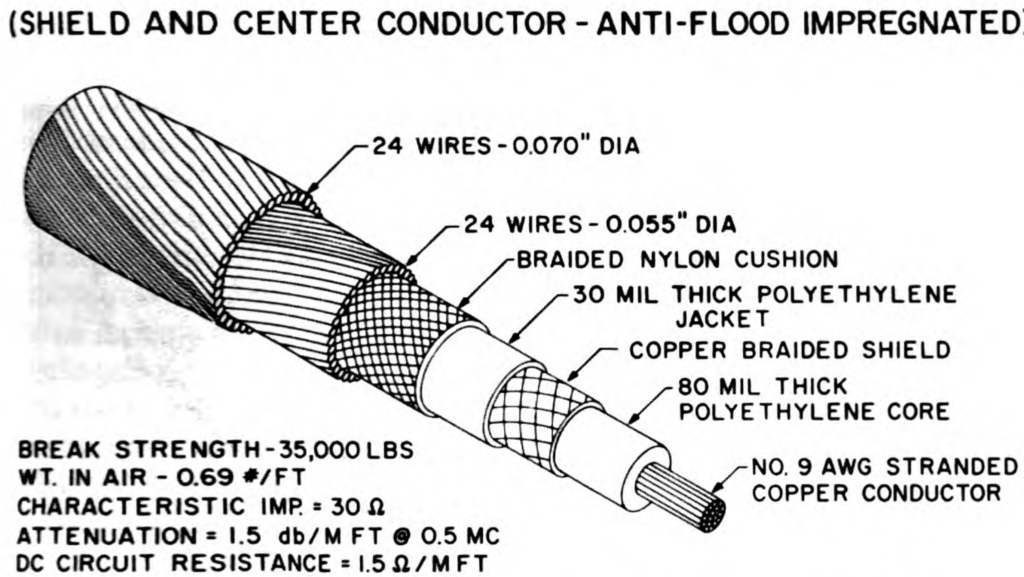

Figure 4 — The umbilical cord which connects the towed vehicle to the surface platform is a 0.68 inch diameter, double-armored coaxial cable with a breaking strength of 35,000 pounds

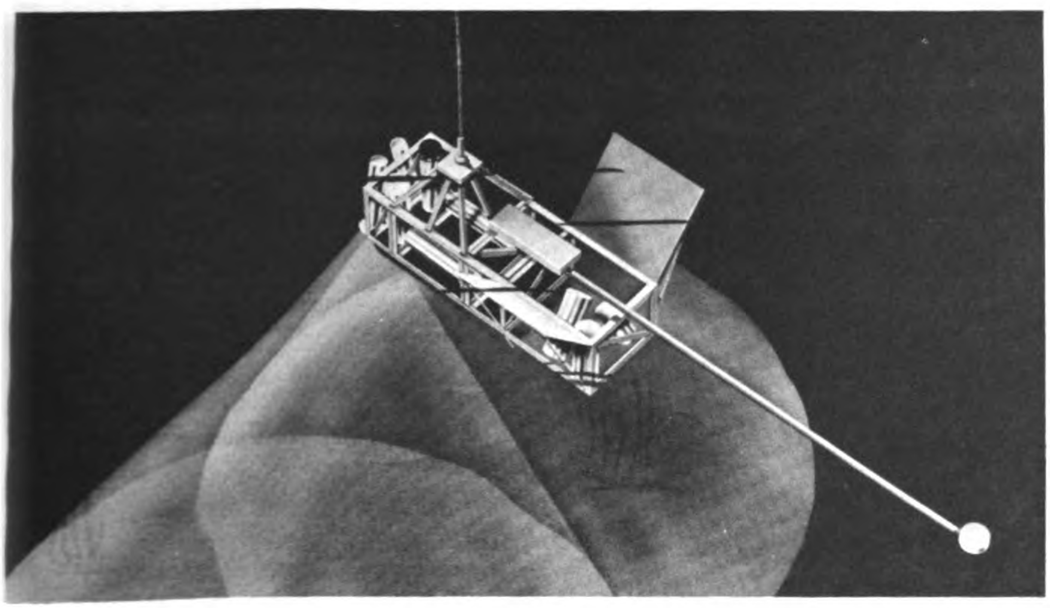

Figure 5 — The towed vehicle, or fish houses the sensors, the electronics and power supply, and part of the telemetry system. The cones of light in this rendition are formed by the strobes which provide illumination for the cameras.

fish location, and a pinger to allow the winch operator to know the fish's height above the ocean floor.

The primary search sensors are 35 mm cameras, a magnetometer, and a side-looking sonar. During the THRESHER search in 1964 standard deep sea cameras had a 57° view angle and a film capacity of 100 feet. A configuration of three of these cameras was used to photograph a 20- by 100-foot rectangle on the bottom. However, camera operating time per roll of film was only two hours when continuous bottom coverage was required. Recently NRL has developed a hemispherical viewing port and a wide-angle lens system which allow coverage of a 100-foot-diameter circle on the bottom with a single camera. When this lens system is used with a new camera having a 450-foot film capacity, we can photograph a 100-foot-wide strip of ocean floor for an uninterrupted period of 34 hours. Our area search rate per day is now about four times as great as it was only four years ago.

The other two search sensors are not as definitive in search as the camera. However, in principle they inspect a larger area. The magnetometer was particularly useful to us in the THRESHER and SCORPION searches. The side-looking sonar is a search sensor of major importance. It has a potential search rate capability much greater than the other two sensors, but this potential has not yet been realized in deep ocean search. Although a number of sonar contacts were made during the SCORPION search, real-time, on-the-spot evaluation of these contacts was not possible. This sensor made not contribution to the success of the search.

Information is transferred between the ship and the fish by means of a frequency division telemetry system which makes use of the large bandwidth inherent in a coaxial transmission line. Up to eleven channels of information are transmitted, with each channel containing a single side band of a modulated carrier. There are two unique features in this system. The first is coherent modulation and demodulation, which

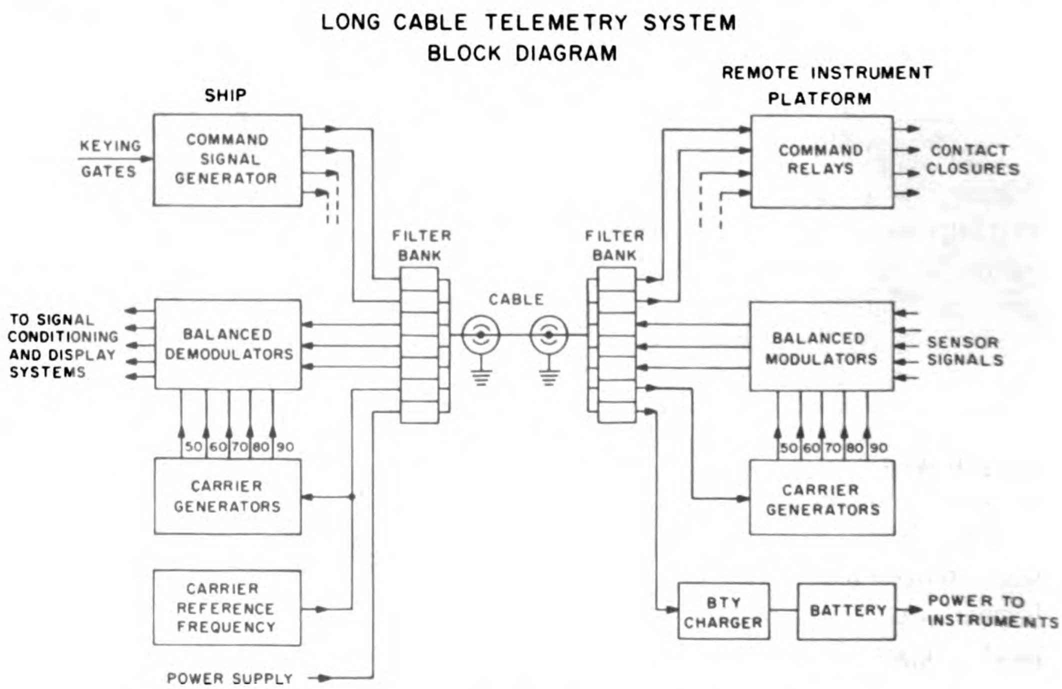

Figure 6 – Information is transferred between the ship and the fish by means of a frequency division telemetry system which makes use of the large bandwidth inherent in a coaxial transmission line

insure faithful reproduction of the original information. The other is a set of specially designed filters, at each end of the cable. Each signal is introduced or extracted through one of these filters. These filters do not load the cable cumulatively. No amplifiers are required on the cable side of these filters; and if desired, power can be sent down the cable at high voltage.

How is the search conducted? Any search in a relatively localized region must begin with a period of area reconnaissance. This "familiarization" process involves determination of surface conditions, such as wind and current, bottom topography and composition, magnetic background, water clarity, and other features of the area which might affect the conduct of the search.

For example in the SCORPION search 400 miles SW of the Azores, preliminary photography showed that the water near the ocean floor was clear and that the cameras could be used as one of the search tools. The northern part of our search area was quite rough and hilly, with numerous magnetic anomalies. The central and southern parts, however, were fairly flat, with only gradual variation in the local magnetic field. Thus the acoustic and magnetic sensors would not be useful search tools in the more rugged northern topography.

After the reconnaissance operation was completed, the next phase was a coarse-grained search in a fairly large area. We started near the center of this area and expanded the search outward, using 35 mm cameras, a magnetometer, and a side-looking sonar. The rationale here is that since you do not know precisely where to look, you are better off making a coarse-grained survey in the hope of finding some clues, such as acoustic or magnetic signatures or photographic evidence of artifacts, which could lead to SCORPION.

Few useful clues were acquired in the first four months of search. There were numerous likely-looking sonar and magnetic contacts, but upon closer examination they all appeared to be geographic or geologic in origin. Very few artifacts were photographed; the only one of real interest was a shiny piece of twisted metal, seen rather early in the search. Because of navigation and sensor problems, the area around this object was not covered at all well at the initial contact, nor was recovery of this contact made until late in October 1968. At that time the SCORPION hulk was photographed remarkably close to this piece of metal.

This brings up an exceedingly important element in a deep ocean search operation: the ability to return the sensors to some predetermined location on the ocean floor. The piece of metal is one illustration of this fact. On run 74 we obtained several magnetometer contacts which were felt to be quite possibly the SCORPION hulk. Some 10 hours after the completion of this 34-hour run the film processing was completed and we were able to view the photographs. There were photographs of debris almost certainly from SCORPION run 75 was already in progress. The problem was to rephotograph the area where contacts were obtained on run 74. This problem is solved by an acoustic positioning system, known as the underwater tracking equipment. It consists of a transponder, which serves as a bench mark on the ocean floor, the responder on the fish, and a triangular array of three hydrophones mounted on the hull of MIZAR. The system is illustrated in Figure 7. The transponder is interrogated from one of the hull hydrophones with a series of acoustic pulses of specific frequency and time spacing. The reply is received by the three hull hydrophones. The time of the interrogation and the time of receipt of replies at the ship hydrophones are processed by a computer in the control center, which takes into account the roll, pitch, and heading of the ship. Interrogation of the transponder results in a print-out of the ship's N/S, E/W, and vertical coordinates relative to the transponder. Similarly, interrogation of the responder results in a print-out of the fish location relative to the ship. Repeated alternate interrogation of the two and coordinate subtraction in the computer result in a print-out of the location, in three dimensions, of the fish, and hence the sensors, relative to the bottom-anchored transponder.

Figure 8 shows the track of the fish on run 75, when photographic contact with the SCORPION hulk was first made, and illustrates our

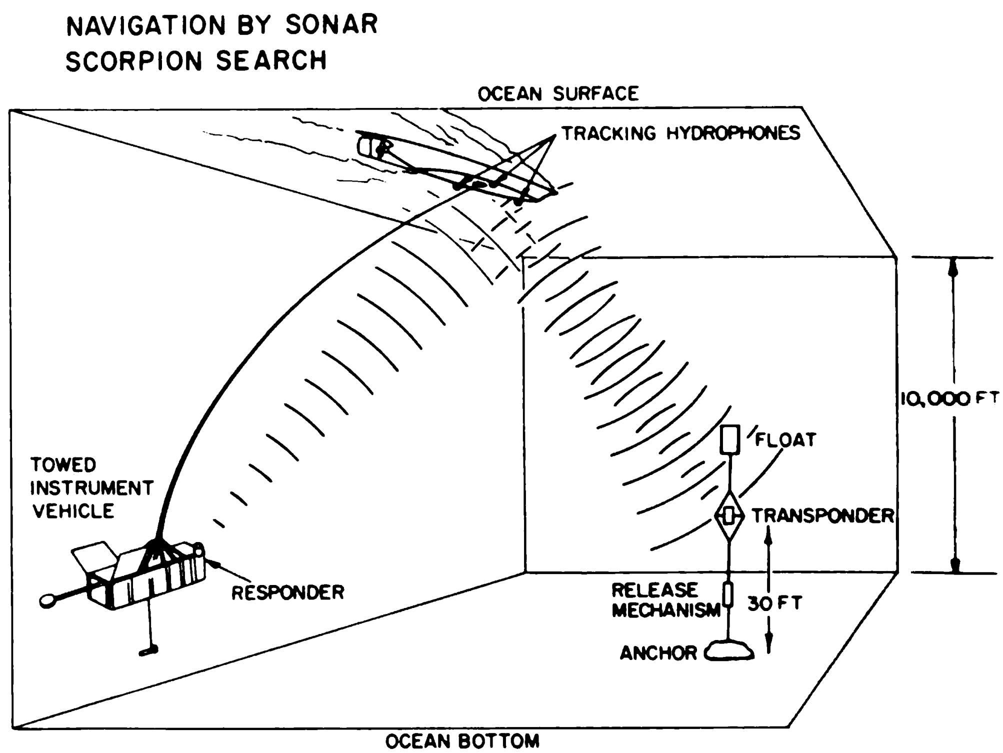

Figure 7 — The problem of rephotographing areas where contacts have been obtained is solved by an acoustic positioning system, known as the underwater tracking equipment

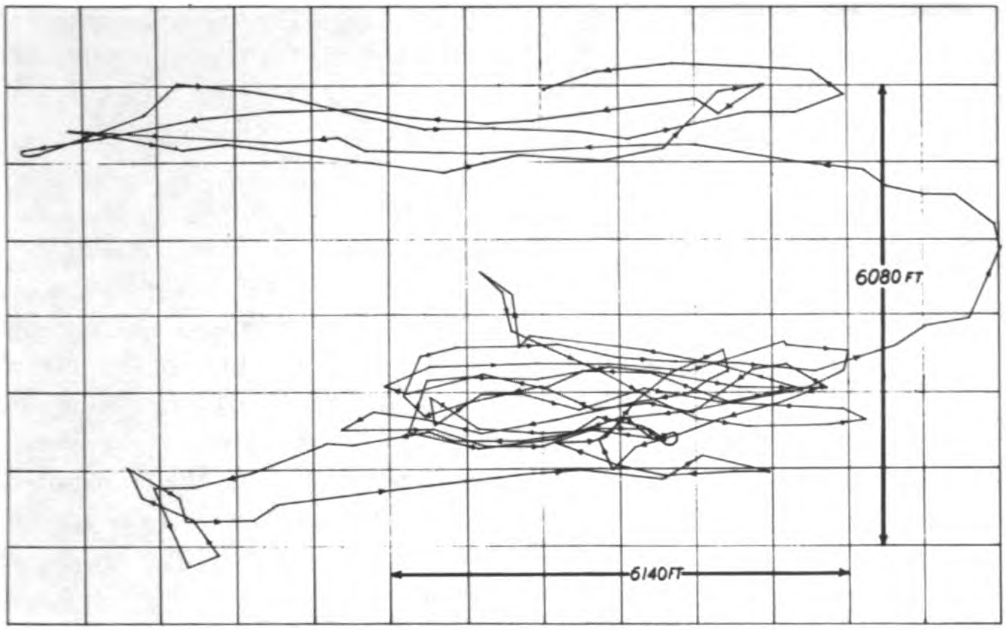

Figure 8 – This chart show the track of the fish on run 75, when photographic contact with the SCORPION hulk was first made

precision search capability when we have good underwater navigation. The transponders we use have a coded interrogation scheme, so that several can be placed on the bottom and selectively queried. This is a very valuable feature and was used to good advantage in the latter part of the search. The transponders are also equipped with a float and an acoustically-controlled release mechanism, so a small number of units can be progressively planted, released, recovered, and replanted to survey a large area.

In contrast to the extended linear runs like run 75, the final four runs were concentrated in a square of limited size, in order to acquire as much photographic information as possible about the wreckage. The ship and fish were turning almost constantly.

The principal surface navigation system used by MIZAR during the search was the Transit Satellite System. This system was used to determine the approximate geographic location of each transponder at the time of placement, and to reacquire the transponder on each return to the area from resupply in the Azores. A more demanding requirement for knowledge of our surface position came near the conclusion of the search, when it was necessary to establish precise geodetic coordinates for the SCORPION hulk. It is well known that the Transit suffers from a small number of operational satellites and from the substantial fraction of unusable passes received. However, we recieved a total of 86 adequate passes during the final three week operating period. The final geodetic location for the SCORPION hulk has an uncertainty of about 1500 feet, in both latitude and longitude.

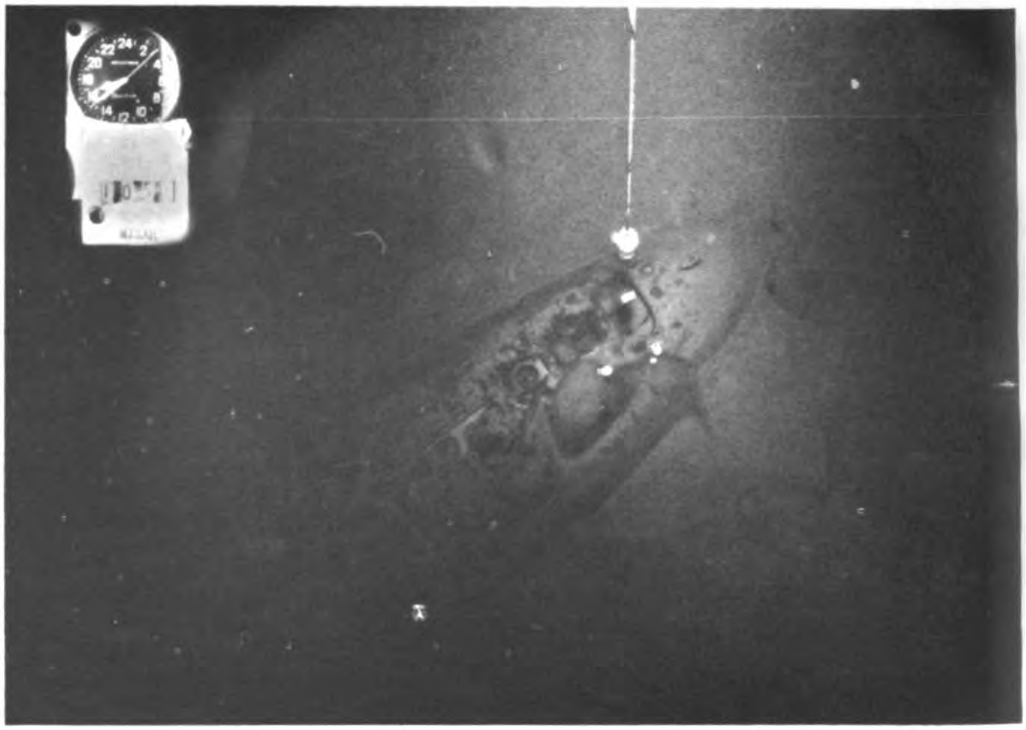

Figure 9 — A photograph of the bow of the SCORPION

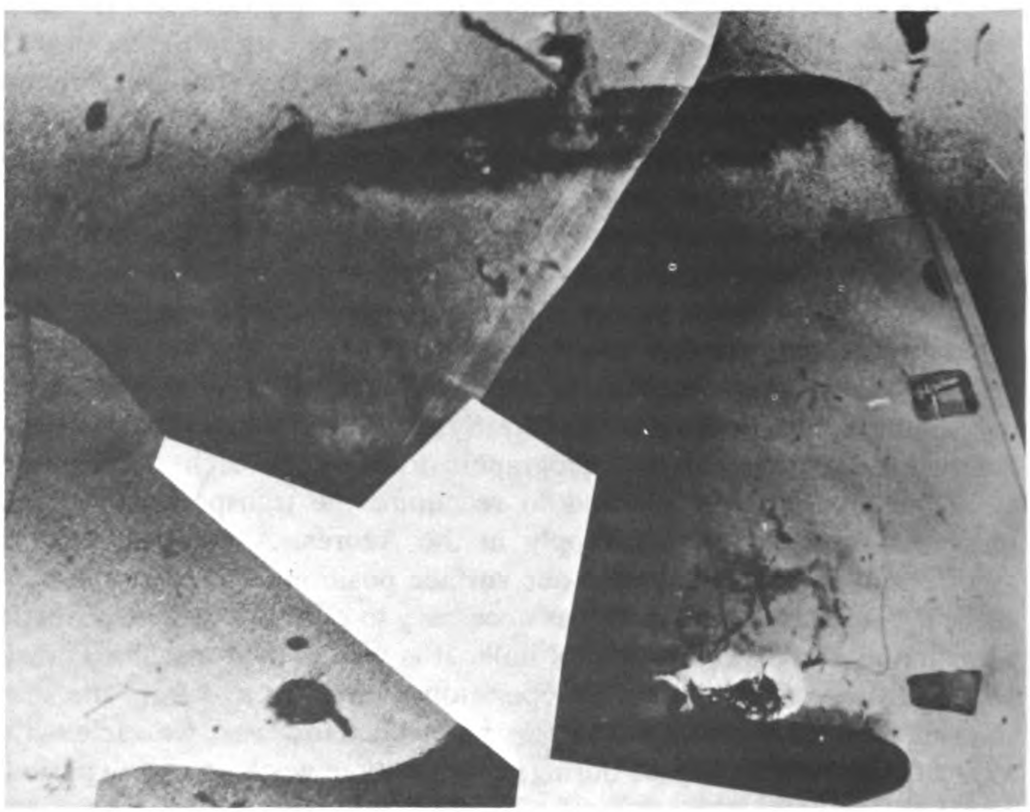

Figure 10 — A mosaic of the SCORPION's sail

Figure 11 — On the left is a mosaic of THRESHER's sail made up of parts of 25 pictures taken in 1964. On the right is a single photograph of SCORPION's sail made with the wide angle lens.

Problems exist in deep ocean search. There is at present no satisfactory doctrine for evaluation of the effectiveness of a search as it progresses. The sensors provide a large amount of raw data but the quantitative interpretation of these data is time consuming, often difficult, and at times impossible. This situation is akin to the problem of extracting a signal from the background noise. "Noise" has several origins, such as false sonar and magnetic contacts, navigation errors, and the loss of optical contrast caused by the backscattering of light. The overall question of sensor performance and interpretation calls for a substantial research effort.

Photographs of the SCORPION wreckage illustrate that even with difficulties success can be achieved in a search. Figure 9 shows the bow of SCORPION. Figure 10 is a mosaic of the sail. Figure 11 illustrates the advances made in the past few years in large area photographic coverage. On the left of Figure 11 is a mosaic of THRESHER's sail, made up of parts of 25 pictures taken with cameras available in 1964. The total area shown is about the same as that on the right, which is a single photograph of SCORPION's sail made with the wide angle lens. However, the old cameras are by no means useless. Once the object of the search has been located, these cameras are good for high resolution photography. For example, Figure 12 shows the after section of SCORPION, centered on the messenger buoy cavity.

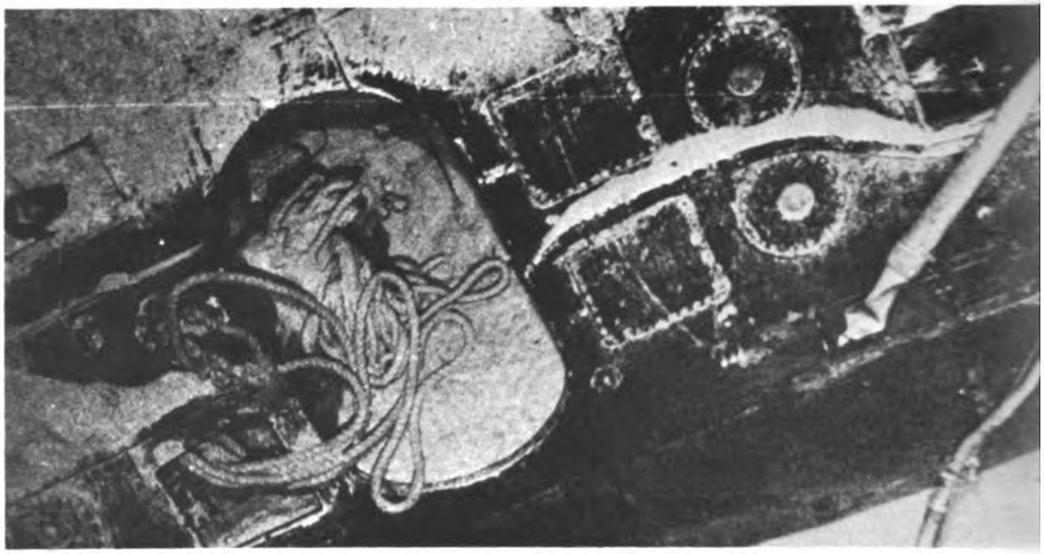

Figure 12 — The after section of SCORPION centered on the messenger buoy cavity

We all hope that a search requirement like this one never occurs again. However, a hope is not an adequate preparation for the future. The search abilities of NRL and the MIZAR represent the Navy's present search capability; specialized search equipment has been placed in the Emergency Special Salvage Material pool of the Supervisor of Salvage.

Hudson Laboratories Closed

The Hudson Laboratories of Columbia University in Dobbs Ferry, N.Y., closed in June. No further activity there is contemplated by Columbia University or by the United States Office of Naval Research which has sponsored the laboratories.

Since 1951 Columbia has been conducting a program of basic underwater acoustic and oceanographic research at the laboratories, supported primarily by the Navy. The program has contributed extensively to basic knowledge and understanding in these fields.

The University and the Office of Naval Research announced simultaneously on April 1, 1968, that the laboratories would close June 30, 1969. The need for the Navy to develop further its own facilities and capabilities in these fields, as well as overall funding implications for both the Navy and the University, were among the considerations leading to the decision to close the laboratories.

At their peak, the laboratories employed 350 persons. About ten percent of the technical staff have relocated to Washington, D.C., to work on related research programs at the Naval Research Laboratory. An additional ten percent of the employees, representing a wide range of occupations, have transferred to other departments of the University. A third group, primarily engineers, have formed a new corporation, Ocean and Atmospheric Sciences, Inc.

Other scientists have taken positions at universities throughout the country. The remaining employees have found employment in the metropolitan area.

Project THEMIS at the University of Notre Dame and the University of Massachusetts

CDR P. M. Palmer
Office of Naval Research

In Greek mythology THEMIS was the mother of PROMETHEUS and embodiment of the law and harmony of physical phenomena. Today THEMIS is the name selected by the Secretary of Defense for a research program first established in 1967. Project THEMIS is the off-spring of a request by President Johnson that Departments broaden the base of the Nation's academic competence in science and engineering. In a statement on September 14, 1965 President Johnson said:

> Our policies and attitudes in regard to science cannot satisfactorily be related solely to achievement of goals and ends we set for our research. Our vision in this regard is limited at best. We must, I believe, devote ourselves purposefully to developing and diffusing-throughout the nation- a strong and solid scientific capability, especially in our many centers of advanced education. Our future must rest upon diversity of inquiry.

It was decided to develop a new program to support unclassified research in defense relevant areas at colleges and universities where a large defense research potential existed which had not yet been tapped. Thus arose the concept of developing new centers-of-excellence across the nation which could become sites for future contract research programs. The strength of the program lies in the fact that it simultaneously fulfills the needs of all participants. It answers the President's request, helps to fulfill the long-term needs of the Department of Defense for expertise in science and engineering, and, through a step-funding arrangement, provides colleges and universities with a source of funds upon which to build substantial research programs for periods of at least three years in advance.

In 1967, responding to hundreds of invitations from the Department of Defense, 479 preliminary THEMIS proposals were submitted by 171 institutions. Careful screening and competitive evaluation resulted in the awarding of 49 contracts averaging $200,000 per annum to 41 universities. The program was enlarged in 1968 when contracts were awarded to 35 more institutions, and again in 1969 when 10 more institutions were added to the program.

Two of the first group of approved THEMIS research proposals for which contracts were awarded in 1967 were from the University of Notre Dame and the University of Massachusetts. Proposals were invited in eight relevant research problem areas:

- Detection, Surveillance, Navigation and Control
- Energy and Power
- Information-Processing Systems
- Vehicle Engineering
- Materials Sciences
- Environmental Sciences
- Medical Sciences
- Behavioral and Social Sciences

Contracts were awarded to Notre Dame and Massachusetts in the Deep-Sea Engineering sub-area of Vehicle Engineering. Both Programs are under the technical direction of the Office of Naval Research, Director of Undersea Programs (Code 466). The scientific officer insures that the schools avoid duplication of effort and support each other's efforts in areas where there is overlap. Furthermore, in an unclassified research program in deep-sea engineering being undertaken by schools having no access to the oceans or tradition of working in the deep-sea environment, it is obviously important for the scientific officer to provide meaningful direction to the research in terms of military application. However, direct military application is not the primary goal of THEMIS research. The chief aim is to achieve a center-of-excellence in defense relevant research—deep-sea engineering in this case. The emphasis is on the inter-disciplinary approach to research.

To get a feeling for the type of inter-disciplinary capability being developed, it is instructive to look at a list of research problems being studied at Massachusetts and Notre Dame:

At the University of Massachusetts

- Streaming of water by interaction with magnetically accelerated colloids
- Static and dynamic fatigue of pristine glass
- Preparation and evaluation of new polymers and new composite materials
- Chemical stress relaxation
- Inertial navigation of deep-sea vehicles
- The non-linear behavior of hull structures
- Impact loading of submarine hulls
- The effect of pneumatic and hydraulic breakwater devices on the motion of submersible vehicle models
- An investigation for the establishment of design criteria for underwater anchorages

- Kinetics of ebullient bed catalytic reactions
- Aerodynamic simulation tests for marine vehicle components
- Propeller and wake noises in deep-sea submersibles

At the University of Notre Dame

- Heat and mass transfer in temperature or density stratified environment
- Turbulent free convection along a vertical plate
- Study on non-Newtonian boundary layer on a flat plate
- Propagation of acoustical radiation in synthetic atmospheres and their transport properties
- Effects of initial imperfections and deformation on the inelastic stability of cylindrical and spherical shells under external pressure
- Finite element analysis of shells
- Maneuverability and control of submerged vehicles
- Sensitivity of systems
- Magnetostrictive transducers for underwater sound

As can be seen, many disciplines are challenged by these projects. Investigators are represented from the fields of chemical, electrical, mechanical, metallurgical, civil and materials engineering as well as mechanics and engineering science. This research activity has stimulated the development of special laboratory equipment and the training of young graduate students oriented toward research in the deep ocean. Even in the short lifetime of the programs to date, several papers have been produced at both schools.

However, the funding of a number of independent research projects in various disciplinary areas would not alone achieve the goals of the THEMIS program. What is really needed is the integration of interdisciplinary talents applied to research projects into an overall research program. This is being accomplished in several ways at Notre Dame and Massachusetts. First, approval of any THEMIS proposal requires endorsement on the part of the university administration insuring support for the program. Secondly, appointment of a THEMIS program manager for overall management of funds and research activity is required as well as an outline of the management organization for the program. Administrative organizations at Notre Dame and at Massachusetts have developed along separate formal lines. Nevertheless, they are similar in that the organizations at both schools have become uniquely identifiable within the normal administrative structure. Further, both institutions have established programs of seminars to bring in outside speakers in an attempt to relate research to efforts going on at other schools, in industry and in Government laboratories. A course has been set up at Massachusetts in Ocean Engineering, and eventually there will be an Ocean Engineering curriculum.

Aside from the research which has been accomplished the single most significant step to date in achieving the aims of the THEMIS program was the First Annual Joint Symposium, Project THEMIS, "Engineering for the Deep Ocean" held at the Center for Continuing Education at the University of Notre Dame. The symposium is to be an annual event which will alternate between the two schools. It would have accomplished much to merely bring the investigators from the two universities together. However, much more was accomplished. The symposium was attended by about 120 persons including representatives from other schools, industry and government. In a two-day session attendees were afforded an opportunity to hear THEMIS papers, lectures by operational managers from Lockheed, Grumman and Westinghouse, Allyn C. Vine of Woods Hole, and Captain John Lindsay, Deputy Project Manager, Deep Submergence Systems. Dr. Arwin A. Dougal, Assistant Director (Research) and Chairman, Project THEMIS Task Group, Office of the Director of Defense Research and Engineering addressed the Group on "The Aims and Objectives of Project THEMIS." The symposium brought about a better understanding between the academic community, industry and government. The second symposium is tentatively scheduled at the University of Massachusetts for 13-15 April 1970.

Although it is impossible to measure the outputs of these two programs in terms of research accomplishments after two years, several tangible benefits have already been realized. Two schools not previously oriented to ocean research and geographically widely separated have now undertaken such programs with considerable enthusiasm. New faculty members with expertise in ocean engineering have been attracted to the schools, graduate students have been trained and new curricula developed, and research equipment has been designed and constructed. With such a start Project THEMIS seems to hold great promise for achieving its goals at the University of Massachusetts and the University of Notre Dame.

RESA Awards

Frank H. Attix and Dr. Albert W. Sáenz received the 1969 Scientific Research Society of America (RESA) awards from the Naval Research Laboratory's branch of that organization. Two RESA awards—one in Pure Science and the other in Applied Science—are presented annually to Naval Research Laboratory scientists judged to have made the most significant contributions in these areas during the year. The program was initiated in 1955 to recognize outstanding work done at NRL.

Attix, a consultant in the Nuclear Physics Division, won the Applied Science Award for his contribution to the understanding and advancement of radiation dosimetry and particularly for his research and development of thermoluminescent dosimeters. Dr. Sáenz, head of the Theory Branch in the Nuclear Physics Division, received the Pure Science Award for his pioneering theoretical analysis of spin waves in crystals and for his prediction and analysis of experimental results on the scattering of polarized neutrons by much spin wave excitation in magnetic crystals.

Research Note

BOMEX Completed

Probably the most extensive investigations ever made of a large-scale ocean area ended last week in the Caribbean east of Barbados. The Barbados Oceanographic and Meteorological Experiment (BOMEX) was a three-month study of air-sea interaction in a 90,000-square-mile area east of Barbados, British West Indies. During the experiment the Floating Instrument Platform (FLIP) joined some 24 aircraft, ten ships, several satellites, and a dozen buoys to gather information in the first of a series of large scale research projects by world nations under the Global Atmospheric Research Program. Taking part were seven federal departments and agencies, and Government of Barbados, 19 Universities, and seven industrial laboratories. Among the participants was Scripps Institution of Oceanography which was sponsored by the Office of Naval Research and the Air Forces Project THEMIS.

FLIP's round trip to the Barbados area totaled some 9,800 miles. She left San Diego in April, worked in the vast BOMEX project during May and north of Puerto Rico for Scripps Marine Physical Laboratory (MPL) in June, and left San Juan for San Diego in early July. Before FLIP returned to San Diego, the scientists had begun poring over masses of data that measured air temperatures and velocities recorded to within three feet of the sea surface.

FLIP carried out several acoustic propagation experiments, some alone, and some, for the first time, with a similar, 355-foot, tug-towed platform, the SPAR (Sea-going Platform for Acoustic Research) buoy operated by the Naval Ordance Laboratory, Silver Spring, Maryland. The Scripps' scientist working with FLIP during BOMEX were mainly interested in conducting measurements of air turbulence and temperature fluctuations. They recorded surface wave heights and studied formation of waves, how they grow, where they come from, and with what frequency. Scientists conducted measurements of turbulent velocity and temperature in the atmosphere above the ocean the generation of surface waves. Many of the BOMEX studies, there were 90 investigations in all had to do with detailed examination of the exchange of energy between the ocean and the atmosphere and the vertical and horizontal spreading of these energies within each of the fluids (ocean and air).

The mechanism of air-sea interaction is almost unknown, yet it is the primary process which drives the atmosphere's circulation and its weather systems. Unless this process is explored and understood, it would be impossible to extend weather predictions to more than a few days.

"Most of the energy the earth receives from the sun is transferred to the tropical ocean on into the atmosphere, and up into the higher latitudes," Dr. Gibson explained.

"So, we were studying the turbulent processes which transfer the energy from the sea surface to higher levels in the atmospheric boundary layer, as well as the transfer of the energy back to the sea surface in the generation of waves by the wind.

"We had studied air turbulence in the laboratory on a minor scale, but never in such a laboratory as the ocean provided us in this project."

Actually, the scientists were doing a fundamental study of turbulence as turbulence, measuring spectra of turbulent velocity and temperatures to compare with universal functions that had been proposed by their colleagues from universal similarity hypotheses.

"If these universal similarity hypotheses as proposed by American, Russian, and English mathematicians are correct, turbulence is turbulence, whether it's over the ocean, within the ocean, in interstellar gas, or even within the laboratory," he said.

"But what we thought was unique about our investigations was that the Reynolds number, a number of great importance in the theory of hydrodynamic stability and the origin of turbulence, was found to be 100 or 1,000 times as large as that which can be generated in a laboratory.

"Never before had it been possible to confirm on such a great scale the laboratory studies."

In one of the investigations utilizing FLIP, the scientists used delicate wire sensors 1/100th the size of the diameter of a human hair to record air temperature and 1/10th the size of the diameter of a human hair to measure wind velocity. These sensors were placed on a vertical-moving probe attached to one of FLIP's outward extending booms, and they "traveled" to within about three feet of the sea surface and upward to 36 feet.

This work and FLIP's operations for MPL, which ONR also supported, were the first involving FLIP in Atlantic waters since she was put in service by Scripps for ONR in 1962. All previous operations had been in the Pacific. FLIP's operations out of San Juan were unique as she worked for the first time with the SPAR buoy. These are the only operating platforms of their kind and this marked the first time FLIP and SPAR had conducted joint operations. They worked in distances from 800 yards to 3,200 yards apart. SPAR was towed by the USNS Lynch, FLIP by the USS Salish (ATA-187). Both FLIP and SPAR are towed horizontally to their ocean stations and "flipped" to the vertical for carrying out scientific investigations, with 300 feet of the platform beneath the sea surface and the working deck and living quarters extending 55 feet above the water.

During the last two weeks in May, the infrared radiometry system aboard Scripps' DC-3 aircraft was tested at sea off Barbados. These tests involved the first use of an airborne, digital data reduction system for the output of the radiometer.

Data was recorded on tape during repeated 30-second flights across a one-mile strip of ocean near FLIP. In spite of severe weather condition, tests made on several days showed values of heat flow from 0.40 calorie per square centimeter per minute at 18 knots wind speed, to 0.05 calorie per square centimeter per minute during intermittent rain squalls. Dr. McAlister said these values resulted from simultaneous readings of radiation from the sea, the sky, and two reference black bodies and the temperatures of the latter.

Thirty thousand such readings were recorded in the 30-second fly-bys. All of these were used to obtain the heat-flow value. This is the first time that airborne total heat-flow measurements have been made. The accuracy of sea-surface temperature measurements using this system is worthy of note as it approaches 0.01 degree centigrade. BOMEX ended July 28, 1969.

On the Naval Research Reserve

CDR Henry E. Bates USNR reported to the Office of Naval Research on 20 June 1969 for duty as Special Assistant to the Chief of Naval Research for Research Reserve. He relieved CDR Robert W. Keniston USNR who retired on 30 June 1969. Before coming to ONR, CDR Bates commanded the Folsom, Pennsylvania Training Center.

Officially Activated Research Reserve Companies

There are 92 Research Reserve companies located throughout the United States. These companies are listed below by Naval Districts. The time and place of meeting, address, and name of the commanding officer are included.

FIRST NAVAL DISTRICT

NRRC 1-1
1930, 1st & 3rd Mondays, Room 4-270, M.I.T., 77 Massachusetts Avenue, Cambridge, Massachusetts 02138. (LCDR Glen M. Reem, II, USNR, 351 Lincoln Street, Lexington, Massachusetts 02173.)

NRRC 1-2
1930, 1st & 3rd Wednesdays, Room 114, Naval & Marine Corps Reserve Training Center, Fields Point, Providence, Rhode Island 02905. (CAPT Robert E. Hill, USNR, 26 Benevolent Street, Providence, Rhode Island 02906.)

NRRC 1-3
1930, 1st & 3rd Tuesdays. (No meetings during July & August.) Holdsworth Hall, Room 339, University of Massachusetts Campus, Amherst, Massachusetts 02103. (CDR Charles F. Cole, USNR, 21 Columbia Circle, Amherst, Massachusetts 01002.)

NRRC 1-5
1930, 1st & 3rd Mondays. (No meetings during July & August.) Higgins Laboratories, Seminar Room 107, Worcester Polytechnic Institute, Worcester, Massachusetts 01609. (LCDR Clarence D. Peterson, USNR, 1 Germain Street, Worcester, Massachusetts 01602.)

NRRC 1-7
1930, 1st and 3rd Tuesdays. (No meetings during July, Aug. & Sept.) College Hall, Room 312, Dartmouth College, Hanover, New Hampshire 03755. (LCDR Wesley Pietkiewicz, USNR, Rayton Road, Hanover, New Hampshire 03755.)

THIRD NAVAL DISTRICT

NRRC 3-1
1830, 1st & 3rd Thursdays, 821 United Nations Plaza, 46th & 1st Avenues, New York, New York 10017. (LCDR Peter B. Lederman, USNR, Polytechnic Institute of Brooklyn, 333 Jay Street, Brooklyn, New York 11202.)

NRRC 3-2
1930, 2nd & 4th Mondays, U.S. Merchant Marine Academy, Kings Point, New York 11024. (CDR Federick E. Roediger, USNR, Glenby Lane, Glen Head, New York 11545.)

NRRC 3-3
2000, 2nd & 4th Mondays, Room G14A, School of Medicine, University of Buffalo, Buffalo, New York 14214. (LCDR Sheldon M. Markel, USNR, 1222 Liberty Bank Building, Buffalo, New York 14202.)

NRRC 3-4
2000, 2nd & 4th Mondays, Bausch & Lomb

Hall, Room 109, University of Rochester, Rochester, New York 14627. (CDR Edward R. Schickler, USNR, 990 Pear Tree Lane, Webster, New York 14580.)

NRRC 3-5
2000, 2nd & 4th Thursdays, Hartford Electric Light Company, 176 Cumberland Avenue, Wethersfield, Connecticut 06169. (LCDR Edward C. Toops, USNR, 179 Westledge Road, West Simsbury, Connecticut 06092.)

NRRC 3-7
2000, 2nd & 4th Thursdays, Naval Reserve Training Center, Scotia, New York 12302. (CDR Benjamin B. Lockett, USNR, 1804 Nott Street, Schenectady, New York 12309.)

NRRC 3-8
1900, 2nd & 4th Tuesdays, Young & Rubican, Inc., 6th Floor, 285 Madison Avenue, New York, New York 10017. (LCDR Harold M. Brewster, USNR, 852 Union Avenue, Hillside, New Jersey 07205.)

NRRC 3-9
1930, 2nd & 3rd Wednesdays, Brookhaven National Laboratory, Upton, Long Island, New York 11973. (CAPT James S. Robertson, USNR, 28 Gnarled Hollow Road, East Setauket, New York 11733.)

NRRC 3-14
1800, 1st & 3rd Tuesdays, Naval Reserve Training Center, 75 Oakley Street, Poughkeepsie, New York 12602. (CDR Richard J. Messina, USNR, Simmons Street, Saugerties, New York 12477.)

NRRC 3-16
2000, 1st & 3rd Thursdays, Sheffield Lab. of Engineering Mechanics, 51 Prospect Street, New Haven, Connecticut. (LCDR Edward P. Yaglou, USNR (Acting), North Pease Road, Woodbridge, Connecticut 06525.)

NRRC 3-18
1945, 1st & 3rd Mondays, Illick Hall, College of Forestry, Syracuse University, Syracuse, New York 13210. (LCDR Arnold A. Bitterman, USNR, 7237 Coventry Road, East Syracuse, New York 13057.)

FOURTH NAVAL DISTRICT

NRRC 4-1
2000, 1st & 3rd Wednesdays, 10 Guyot Hall, Princeton University, Princeton, New Jersey 08540. (CAPT David M. Jewett, USNR, 23 Sunset Boulevard, East Brunswick, New Jersey 08816.)

NRRC 4-3
2000, 1st & 3rd Thursdays, Naval & Marine Corps Reserve Training Center, 4902 Forbes Avenue, Pittsburgh, Pennsylvania 15213. (LCDR Helmuth H. Hansen, USNR, 3043 Swansea Crescent West, Allison Park, Pennsylvania 15101.)

NRRC 4-4
1900, Mondays, 316 Wagner Building, Pennsylvania State University, University Park, Pennsylvania 16801. (LCDR Robert C. Baldwin, USNR, 132 South Sparks Street, State College, Pennsylvania 16801.)

NRRC 4-5
2000, Alternate Mondays, Naval & Marine Corps Reserve Training Center, 3920 Kirkwood Highway, Wilmington, Delaware 19808. (CDR John M. Moore, Jr., USNR, 5 DeVille Circle, Apt. 5, Wilmington, Delaware 19808.)

NRRC 4-7
1930, Alternate Thursdays. (No meetings during July & Aug.) Battelle Memorial Institute, South Conference Room, 505 King Avenue, Columbus, Ohio 43201. (LCDR Charles R. McLean, USNR, 47 Electric Avenue, Westerville, Ohio 43081.)

NRRC 4-8
1800, 1st & 3rd Mondays, Naval & Marine Corps Reserve Training Center, 1089 East Ninth Street, Cleveland, Ohio 44114. (LCDR Gordon D. Pred, USNR, 23401 Effingham Road, Euclid, Ohio 44117.)

NRRC 4-11
1900, Alternate Tuesdays, Naval & Marine Corps Reserve Training Center, Gilbert

Avenue & Victory Parkway, Room 37, Cincinnati, Ohio 45207. (CDR John E. White, USNR 9757 Overview Lane, Cincinnati, Ohio 45231.)

NRRC 4-12
1930, Alternate Tuesdays. (No meetings during July & Aug.) Naval Air Development Center, Johnsville, Warminster Pennsylvania 18974. (CDR William H. Hazlett, Jr., USNR, Naval Air Development Center, Johnsville, Warminster Pa. 18974.)

NRRC 4-13
2000, 1st & 3rd Mondays, Franklin Institute Laboratory, 20th and Race Streets, Philadelphia, Pennsylvania 19112. (CDR Alfred A. Little, USNR, 461 Paxon Hollow Road, Media, Pennsylvania 19063.)

FIFTH NAVAL DISTRICT

NRRC 5-2
2000, Mondays. (No meetings during July & Aug.) Room 310, Hutcheson Hall, Virginia Polytechnic Institute, Blacksburg, Virginia 24061, (LT William J. Kennedy, Jr., USNR, 210 Orchard View Lane, Blacksburg, Virginia 24060.)

NRRC 5-3
1930, 1st & 3rd Tuesdays, Building 560, Fort Detrick, Frederick, Maryland 21701. (LCDR Victor L. Wolfe, USNR, 513 Westhill Drive, Route 7, Box 29, Frederick, Maryland 21701.)

NRRC 5-4
1945, 1st & 3rd Thursdays, Board of Education Building, 3 East 25th Street, Baltimore, Maryland. (LCDR Herman D. Raynes, USNR, 1015 Smoke Tree Road, Baltimore, Maryland 21208.)

NRRC 5-8
2000, 1st & 3rd Thursdays, National Academy of Sciences, 2102 Constitution Avenue, N.W., Washington, D.C. (CDR Theron W. Davidson, USNR, P.O. Box 7, Lexington Park, Maryland 20653.)

NRRC 5-9
1630, 1st & 3rd Fridays. (Except during First Quarter meetings are alternate Wednesdays) U.S. Naval Research Laboratory, 4555 Overlook Avenue, Washington, D.C. 20390. (CDR Russell H. Kyser, USNR, 5985 Ridge Crest Drive, Suitland, Maryland 20023.)

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NRRC 5-10
2000, 2nd & 4th Tuesdays, Naval Medical Research Institute, National Naval Medical Center, Bethesda, Maryland 20014. (LCDR Charles W. Hargrave, MSC, USNR, 800 4th Street, S.W., Apartment N-419, Washington, D.C. 20024.)

NRRC 5-11
2000, 2nd & 4th Tuesdays, Annapolis Division, Ships Research & Development Center, Annapolis, Maryland 21402. (CDR Roy F. Dodd, USNR, 2 Oak Lane, S.W., Glen Burnie, Maryland 21061.)

NRRC 5-12
1900, 2nd & 4th Mondays, Building 1200, Room A135, U.S. Naval Weapons Laboratory, Dahlgren, Virginia 22448. (CDR Thomas W. Truslow, USNR, 702 Sampson Road, Dahlgren, Virginia 22448.)

SIXTH NAVAL DISTRICT

NRRC 6-1
1930, 1st, 2nd, & 3rd Thursdays (No meetings during First Quarter) Naval & Marine Corps Reserve Training Center, 274) Fifth Street, N.W., Atlanta, Georgia 30318. (LCDR Donald A. Reddicks, USNR, 1219 Kinnard Drive, Doraville, Georgia 30340.)

NRRC 6-3
1930, 2nd & 4th Wednesdays, U.S. Army Reserve Armory, Elza Gate, Oak Ridge, Tennessee 37830. (LCDR Harry A. Nelms, USNR, Route 6, Box 453, Vista Trail, Concord, Tennessee 37720.)

NRRC 6-5
1930, 1st, 3rd & 5th Mondays, Naval & Marine Corps Reserve Training Center, P.O. Box 1180, Broad Avenue, Gulfport, Mississippi 39502. (LCDR Walter R. Congdon, USNR, 715 St. Louis Avenue, Pass Christian, Mississippi 39571.)

NRRC 6-6
1800, Mondays. (No meetings during First Quarter) NROTC Building, University of North Carolina, Chapel Hill, North Carolina. (LCDR William E. Hammond, USNR, 10 Forrest Dale Drive, Durham, North Carolina 27705.)

NRRC 6-8
1930, 1st & 3rd Mondays, Naval Reserve Training Center, Livingston & Parramore Streets, Orlando, Florida. (CDR Clarence R. Bachmann, USNR, 1121 Willowbrook Trail, Maitland, Florida 32751.)

NRRC 6-9
1900, 1st, 3rd & 4th Mondays, Smith Hall, U.S. Navy Supply Corps School, Athens, Georgia. (LCDR Louis De Vorsey, Jr., USNR, 335 Kings Road, Athens, Georgia 30601.)

NRRC 6-17
1900, Tuesdays, Naval Reserve Training Center, 203 Leeman Ferry Road, S.W., Huntsville, Alabama. (LCDR Alfred R. Morse, USNR, 2613 Vista Drive, S.E., Huntsville, Alabama 35803.)

NRRC 6-18
2000, 1st & 3rd Mondays, School of Engineering, Vanderbilt University, Nashville, Tennessee. (LCDR Hugh G. Eldredge, Jr., USNR, Trust Department, Third National Bank, P.O. Box 76, Nashville, Tennessee 37202.)

NRRC 6-19
1930, 1st, 2nd & 3rd Thursdays, Naval Reserve Training Center, 12 Meadow Street, Chattanooga, Tennessee 37405. (LCDR Walter J. Rogers, Jr., USNR, 203 West Daytona Drive, Chattanooga, Tennessee 37415.)

EIGHTH NAVAL DISTRICT

NRRC 8-1
1930, Alternate Tuesdays, Richardson Memorial Building, Room 203, Tulane University, 6823 St. Charles Avenue, New Orleans, Louisiana 70188. (CAPT Marlin C. Ludwig, USNR, 34 Versailles Boulevard, New Orleans, Louisiana 70125.)

NRRC 8-3
1930, Mondays, Petroleum Engineering Building, Texas A&M College, College Station, Texas 77843. (CDR Ronald Darby, USNR, 3503 Carter Creek Parkway, Bryan, Texas 77801.)

NRRC 8-4
1930, 1st & 3rd Wednesdays, Naval Reserve Training Center, Houston, Texas 77025. (LCDR Charles N. Coleman, USNR, 7914 Skyline Drive, Houston, Texas 77042.)

NRRC 8-5
1900, Mondays, Experimental Science Building 115, University of Texas, Austin, Texas 78712. (CDR Thomas E. Burris, USNR, 8071 N. Lamar Boulevard, Austin, Texas 78753.)

NRRC 8-7
1930, Wednesdays, NROTC Building, University of New Mexico, Albuquerque, New Mexico 87106. (CDR Calvin B. Rogers, USNR, 1312 Alcazar N.E., Albuquerque, New Mexico 87110.)

NRRC 8-8
1930, 1st & 3rd Tuesdays, Post Office Building, Bartlesville, Oklahoma 74003. (LT Carlos G. Cardenas, USNR, 4017 S.E. Kentucky, Bartlesville, Oklahoma 74003.)

NRRC 8-9
1700, 1st & 3rd Tuesdays, Lecture Room Administration Building, Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87544. (LCDR Larry W. Mann, USNR, 3208-A Villa, Los Alamos, New Mexico 87544.)

NRRC 8-12
2000, 1st & 3rd Tuesdays, Santa Fe Building, 114 Commerce Street, Dallas, Texas 75202. (LCDR Charles P. Grier, USNR, 7538 Spring Valley Road, Dallas, Texas 75240.)

NRRC 8-13
2000, 2nd, 3rd & 4th Mondays, Room 147, Physical Sciences Building, Oklahoma State University, Stillwater, Oklahoma 74075. (LT Eldon C. Nelson, USNR,

401 N. Donaldson Drive, Stillwater, Oklahoma 74074.)

NINTH NAVAL DISTRICT

NRRC 9-1
1900, 2nd & 4th Tuesdays, Naval Armory, Randolph at the Lake, Chicago, Illinois 60601. (CDR John Dvorscek, USNR, 10329 S. Washington St., Oak Lawn, Illinois 60453.)

NRRC 9-2
1930, Mondays, Law Building, University of Illinois, Urbana, Illinois 61803. (LCDR Frederick L. Neumann, USNR, 2211 South Cottage Grove, Urbana, Illinois 61801.)

NRRC 9-3
1930, Mondays. (Varied dates July, Aug. & Sept.), 62 North Hall, University of Michigan, Ann Arbor, Michigan 48104. (LCDR Craig Comstock, USNR, 1608 Ferndale Place, Ann Arbor, Michigan 48164.)

NRRC 9-4
2000, 2nd & 4th Tuesdays, Naval & Marine Corps Reserve Training Center, Milwaukee, Wisconsin 53207. (CDR John E. Housiaux, USNR, 7490 North Navajo Road, Milwaukee, Wisconsin 53217.)

NRRC 9-5
1900, 1st, 2nd & 3rd Wednesdays, NROTC Building, Iowa State College, Ames, Iowa 50010. (LCDR Martin D. Secker, USNR, Timberland Heights, RR 4, Ames, Iowa 50010.)

NRRC 9-6
1930, 2nd & 4th Mondays, Room 208, Mechanical Eng. Building, University of Minnesota, Minneapolis, Minnesota 55414. (CDR Carl E. Lewis, USNR, 7908 28th Avenue, North, Minneapolis, Minnesota 55427.)

NRRC 9-7
1900, Tuesdays, C/O NROTC Unit, AES Annex, Purdue University, Lafayette, Indiana 47907. (LT Curtis M. Paulsen, USNR, Box 922, St. Joseph's College, Rensselaer, Indiana 47928.)

NRRC 9-8
1900, 2nd & 4th Wednesdays, Meramec Community College, St. Louis, Missouri 63130. (LT William A. Wundrack, USNR, 24 Black Oak Drive, St. Louis, Missouri 63127.)

NRRC 9-10
1800, Alternate Tuesdays, Sargent Hall, Northwestern University, Evanston, Illinois 60201. (LT Jacob D. Dumelle, USNR, 1655 W. 17th Street, Chicago, Illinois 60608.)

NRRC 9-12
1930, Thursdays, Wood Utilization Laboratory, Colorado State University, Fort Collins, Colorado 80521. (LCDR Ronald A. Ryder, USNR, 748 Eastdale Drive, Fort Collins, Colorado 80521.)

NRRC 9-14
1930, Alternate Mondays, State Lab of Hygiene, University of Wisconsin, Madison, Wisconsin 53706. (LDCR Charles W. Threinen, USNR, 2121 Gateway Street, Middleton, Wisconsin 53562.)

NRRC 9-15
1900, 2nd & 4th Wednesdays, Midland Community Center, Midland, Michigan 48640. (CDR Donal D. Hammond, USNR, 3318 Garland, Midland, Michigan 48640.)

NRRC 9-16
1930, Tuesdays, 221 Computing Center, Michigan State University, East Lansing, Michigan. (LCDR Emanuel Hackel, USNR, 244 Oakland Drive, East Lansing, Michigan 48823.)

NRRC 9-19
1930, Mondays, Naval Reserve Training Facility, Iowa City, Iowa 52240. (LTJG Thomas R. Breese, USNR, 227 Mahaska Drive, Iowa City, Iowa 52240.)

NRRC 9-21
2000, 1st & 3rd Thursdays, Student Union, University of Denver, Denver, Colorado 80210. (LCDR Jack A. Horst, USNR, 5260 West Rowland Avenue, Littleton, Colorado 80120.)

NRRC 9-23
1930, 2nd & 4th Wednesdays, Argonne National Laboratory, Argonne, Illinois 60439. (LT Thomas A. Richter, USNR, 533 Wilshire Avenue, Glen Ellyn, Illinois 60137.)

NRRC 9-25
1930, 1st & 3rd Wednesdays, Naval Reserve Training Center, Indianapolis, Indiana 46208. (CDR Theodore Pacala, USNR, 109 Betsy Lane, Apt. 104, Indianapolis, Indiana 46227.)

NRRC 9-26
1930, Tuesdays, Naval Reserve Training Center, Colorado Springs, Colorado 80906. (LCDR James H. Ryan, USNR, 2205 Drakestone, Colorado Springs, Colorado 80909.)

NRRC 9-27
1930, Thursdays, Naval Reserve Training Center, Building 512, Great Lakes, Illinois 60088. (CDR Carl E. Sall, USNR, 800 Maple Court, Elk Grove Village, Illinois 60007.)

NRRC 9-28
1900, Wednesdays, NROTC Armory, 6th Street & Stewart Road, Columbia, Missouri 65201. (LCDR William D. Noteboom, USNR, 2401 West Broadway, Columbia, Missouri 65201).

ELEVENTH NAVAL DISTRICT

NRRC 11-2
2000, 1st & 3rd Thursdays, Naval & Marine Corps Reserve Training Center, 2727 Paloma Street, Pasadena, California 91107. (CDR Edward H. Rayermann, USNR, 574 Los Arboles Lane, San Marino, California 91108.)

NRRC 11-5
1930, 2nd, 3rd & 4th Tuesdays, Naval Reserve Training Center, Camp Decatur, San Diego, California 92133. (LCDR Craig R. Allen, USNR, 1985 Alameda Terrace, San Diego, California 92103.)

NRRC 11-7
2000, 1st & 3rd Thursdays, Naval & Marine Corps Reserve Training Center, 1100 South Alvernon Way, Tucson, Arizona 85711. (LCDR Robert L. Voigt, USNR, 2131 East La Madera Drive, Tucson, Arizona 85719.)

NRRC 11-8
1645, 2nd & 4th Wednesdays, Pacific Missile Range, Conference Room, Building 1, Point Mugu, California 93041. (CDR Kent A. Yoke, USNR, Headquarters, Pacific Missile Range (Code 01-3), Point Mugu, California 93041.)

NRRC 11-9
2000, 2nd & 4th Wednesdays, Aerojet-General Corporation, Dept. 3521, Building 170, Azusa, California 91740. (LCDR Harry E. Waldorf, USNR, 7238 North Barranca Avenue, Glendora, California 91740.)

NRRC 11-11
2000, 1st & 3rd Mondays, Naval & Marine Corps Reserve Training Center, 3400 Airport Avenue, Santa Monica, California 90405. (LCDR Freeland F. Stecker, USNR, 5549 Scotwood Drive, Palos Verdes Peninsula, California 90274.)

TWELFTH NAVAL DISTRICT

NRRC 12-2
1700, 1st, 2nd & 3rd Mondays, Room 118, Building 311 Lawrence Radiation Laboratory, Livermore, California. (LCDR Robert L. Chapman, USNR, 174 Midland Way, Danville, California 94526.)

NRRC 12-3
1930, 1st & 3rd Wednesdays, Ames Research Center Naval Air Station, Moffett Field, California. (LCDR Bruce D. Marshall, USNR, 936 El Cajon Way, Palo Alto, California 94303.)

NRRC 12-4
2000, Wednesdays (As scheduled), Room 119, Agricultural Building, Fresno State College, Fresno, California. (LCDR Wayne E. Biehler, USNR, 3314 Griffith Way, Fresno, California 93726.)

NRRC 12-5
1930, 2nd & 4th Wednesdays, Room 247,

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Cory Hall, University of California, Berkeley, California. (CDR Walter D. Thomas, Jr. USNR 2173 Roskelley Drive, Concord, California 94520.)

NRRC 12-6
1930, 1st, 2nd, & 4th Thursdays, Room 184, Young Hall, University of California, Davis, California. (CDR Robert H. Brownson, USNR, 2927 Country Club Circle, El Macero, California 95618.)

NRRC 12-8
2000, 2nd & 4th Wednesdays, Room S-136, USN Postgraduate School, Monterey, California. (CDR Oscar B. Wilson, Jr., USNR, 14 Cuesta Vista Drive, Monterey, California 93940.)

NRRC 12-9
1715, Tuesdays (As scheduled), Main Conference Room 2001, Aerojet-General Corporation Sacramento, California. (LT Earl A. Sheridan, USNR, 4915 Timothy Way, Fair Oaks, California 95628.)

THIRTEENTH NAVAL DISTRICT

NRRC 13-1
1930, 1st, 2nd & 3rd Mondays, Naval Reserve Training Center, 860 Terry Avenue North, Seattle, Washington 98109. (CDR Albert S. Hanson, USNR, 3215 - 98th N.E., Bellevue, Washington 98004.)

NRRC 13-4
200, 2nd & 4th Tuesdays, Naval & Marine Corps Reserve Training Center, Swan Island, Portland, Oregon 97217. (CDR Delmer L. Kuns, USNR, 14465 S.W. 114th Avenue, Tigard, Oregon 97223.)

NRRC 13-5
1930, 2nd & 4th Mondays, NROTC Armory, Oregon State University, Corvallis, Oregon 97330. (LCDR James D. Hall, USNR, 3106 Harrison Street, Corvallis, Oregon 97330.)

40th Symposium on Shock and Vibration to be held in Fort Monroe, Virginia, October 21, 22, and 23, 1969. Additional information may be obtained from Dr. W. W. Mutch (Code 6020), Naval Research Laboratory, Washington, D.C. 20390. Phone: Area Code 202, 767-2220, IDS 197-2220. Sponsored by the Office of the Director of Defense Research and Engineering.

27th U.S. Navy Symposium on Underwater Acoustics to be held at the U.S. Naval Undersea Research and Development Center, San Diego, California, October 28-30, 1969. Additional information may be obtained from Mr. John B. Hough, Office of Naval Research (Code 466), Washington, D.C. 20360. Phone: Area Code 202, 696-2693. Sponsored by the Office of Naval Research.

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

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IN THIS ISSUE

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The Sea Robin Buoy went through a thirty-day moored test in approximately 4200 feet of water, 7 miles south of Bermuda. *See page 1.*

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