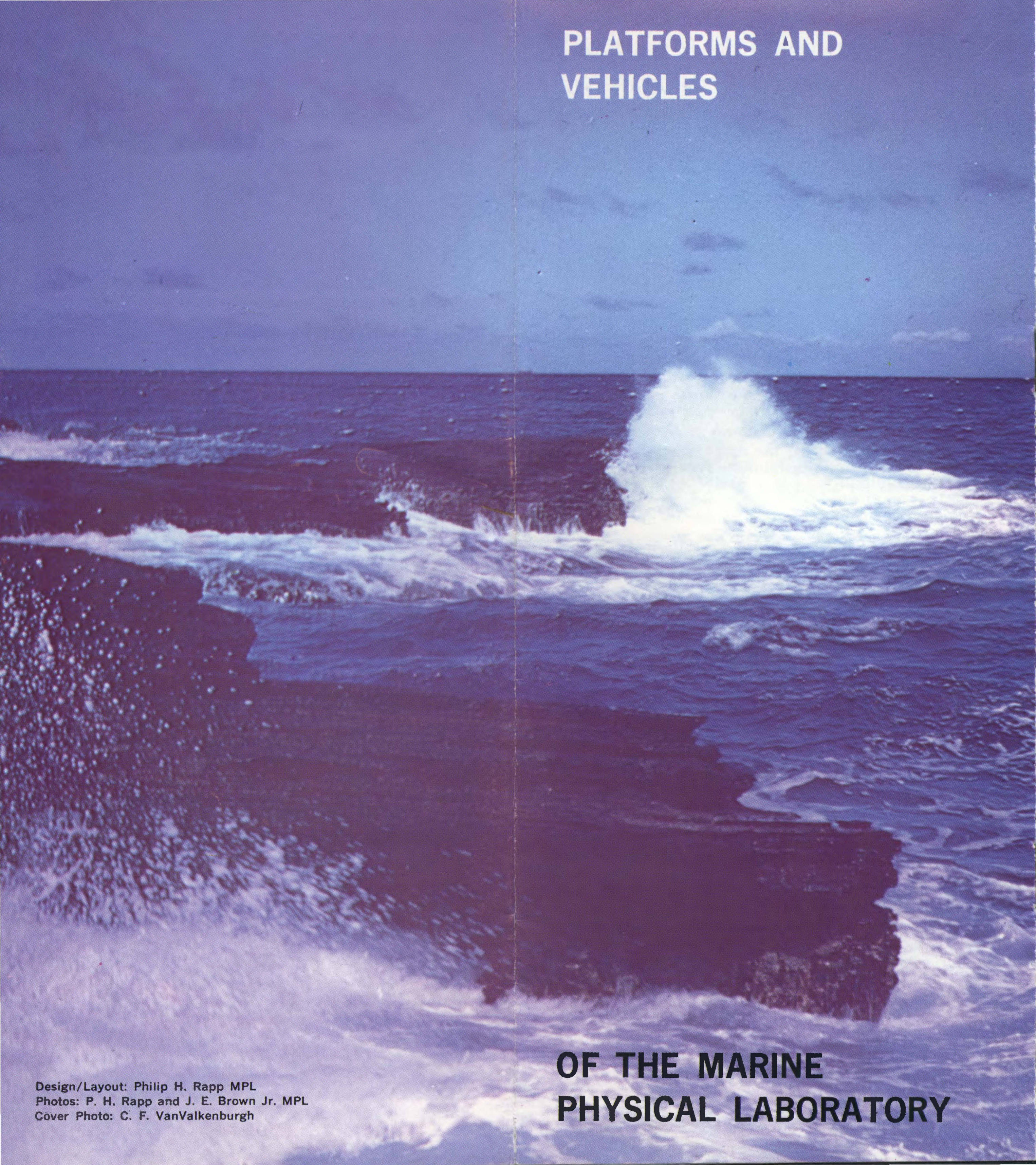

PLATFORMS AND VEHICLES

OF THE MARINE PHYSICAL LABORATORY

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PLATFORMS AND VEHICLES OF THE MARINE PHYSICAL LABORATORY OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO

The Marine Physical Laboratory is one of the research laboratories of the Scripps Institution of Oceanography, an institution of the larger University of California, San Diego campus. Headquarters for the laboratory are located within the Naval Undersea Research and Development Center compound on Point Loma. Some of the staff carry out their research program on the La Jolla campus of the University.

The work of the Marine Physical Laboratory, since its origin in 1946, has been continuously directed toward furthering understanding of the generation, propagation and detection of energy in the ocean and surrounding media. A simplified overview of the laboratory program would divide the work into five general categories: The Ocean Acoustic Environment. Sea Floor Properties, Signal Processing, Ocean Technology, and Advisory and Exploratory functions of the staff. Acoustic studies in the program range from the conduct of ocean experiments using complicated electronics data processing systems to small boat recording of sounds emitted by whales in the ocean. Studies of sea floor properties span from the measurement of residual magnetism of cores taken from the sea floor to the investigation of fine scale topography using advanced sonar equipment. Signal processing theoretical studies are augmented by hardware development and practical ocean experiments. Ocean Technology efforts at the laboratory have developed a variety of research platforms, tools and techniques for use in the program. Over and above the research program, members of the laboratory participate in many ways in the planning of Navy and University long range programs.

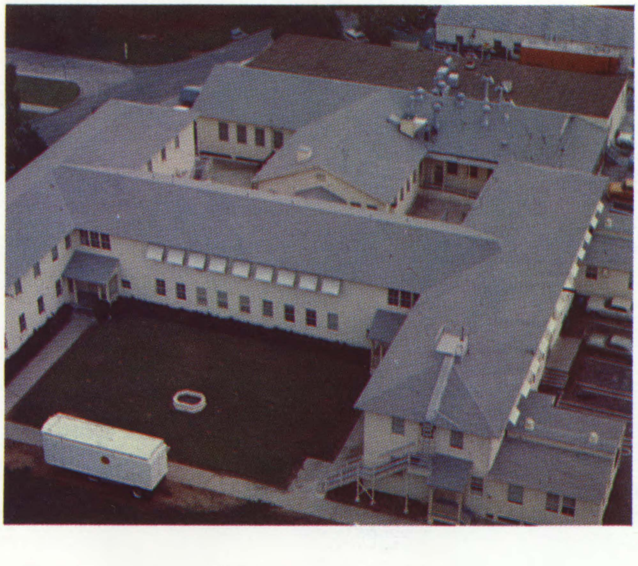
Primary support for the laboratory comes from the U.S. Navy. The basic support from 1946 to 1958 was provided through the Bureau of Ships (now Naval Ship Systems Command). Since 1958 basic support funds have been received through the Office of Naval Research; this basic support has been augmented by other branches of the Navy for special projects. The National Science Foundation also contributes support for specific problems.

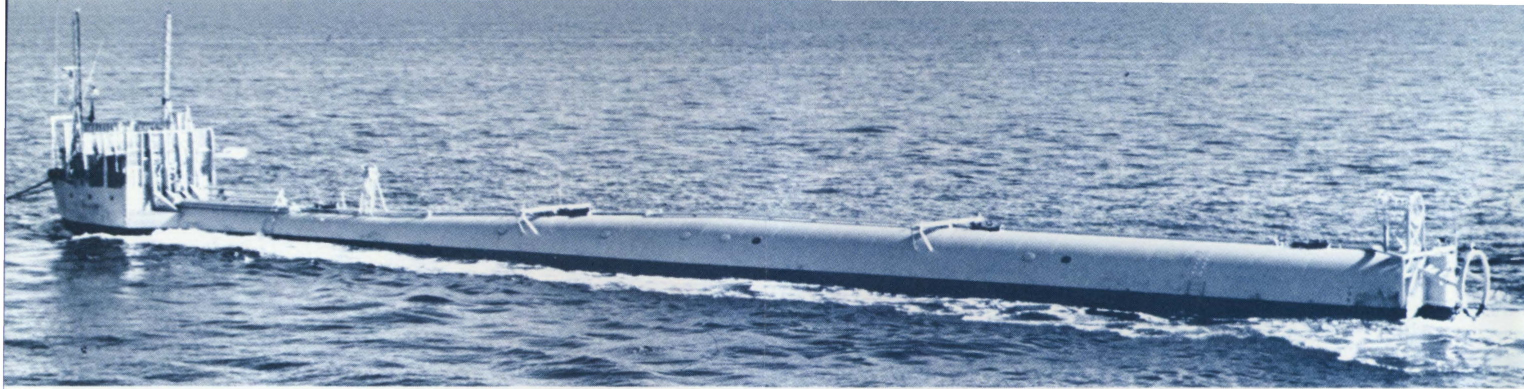
The first director of the Marine Physical Laboratory was Dr. Carl Eckart, a leading scientist from the World War II University of California Division of War Research at Point Loma. Dr. Eckart served as director from 1946 to 1952. He was succeeded in 1952 by Sir Charles S. Wright, followed in 1955 by Dr. A. B. Focke and in 1958 by the present director, Dr. F. N. Spiess.

The present staff of the laboratory numbers about 135, of which 14 are senior academic staff members, 11 junior academic staff members, 26 engineering, 29 technical, 22 administrative and clerical and 33 support people.

In pursuit of the understanding of the ocean under the broad charter of the laboratory, the staff members have developed a number of specialized platforms and vehicles to carry their research instruments on and in the ocean. Some of these are described on the following pages to illustrate the length to which one must go to unlock the secrets of the sea.

POINT LOMA HEADQUARTERS "MPL"

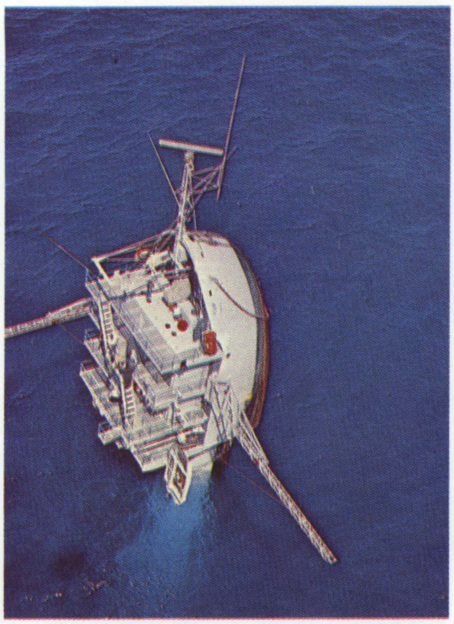




"FLIP"
(Floating Instrument Platform)

FLIP is an unusual vessel, the first of its kind, destined to be the fore-runner of a new family of research platforms. FLIP was developed by the Marine Physical Laboratory under the sponsorship of the U. S. Navy to fulfill a need for an extremely stable and yet mobile platform from which accurate acoustical measurements could be made at sea.

FLIP, which has an overall length of 355 feet, is towed in the horizontal position to the area where scientific operations are to be carried out. Upon arrival on station the tow line is cast off and ballast tanks distributed throughout the after 255 feet of the vessel are flooded. As these tanks are flooded the stern gradually sinks causing the prow to rise. Ultimately the vessel is completely vertical with approximately 55 feet of prow pointed skyward and the remaining 300 feet of vessel under water.



AERIAL VIEW OF "FLIP" VERTICAL

The hull is necked down to only 12½ feet in diameter for some distance above and below the vertical water line so that the rise and fall of waves about the neck cause a very small percentage change in displacement. Consequently the vertical motions which occur are extremely small compared to those of a conventional ship.

This stability, coupled with the unusually deep draft of FLIP in the vertical position, makes an ideal platform for many sea experiments. Measuring instruments may be mounted anywhere along the full 300 feet of submerged hull and, by use of precision navigation and orientation equipment, the location, depth and orientation of those instruments may be determined and controlled to a higher precision than can be achieved with any other platform. Many experiments which, before the advent of FLIP, were carried out on board submarines of the U. S. Navy can now be performed with far greater precision and scheduling flexibility by using this special platform.

Although FLIP was first developed for acoustical experiments it has found many other uses since it commenced operations on August 15, 1962. Sixty-five scientific operations have been conducted with more than 600 days at sea. The transition from horizontal to vertical and return has been made more than 150 times. Operations have included experiments or studies of wave attenuation, sound propagation, bearing accuracy phase fluctuation, signal processing, ambient noise, sound scattering or reverberation measurements, seismic wave recording, wave pressure and acceleration measurements, meteorological work and measurement of internal waves by means of thermistor chains. Scientists from many other universities and government laboratories have participated in the research. FLIP has remained at sea for as long as 45 days with 27 consecutive days in the vertical position. This longest of operations was in the Gulf of Alaska 1800 miles from home. Other operations, in addition to the many conducted along the California coast, have included three deployments to Hawaiian waters, one of 7 months duration, and most recently, participation in the BOMEX expedition in the Caribbean, where FLIP remained vertical, on station, making meteorological measurements for 30 consecutive days.

Although a number of oceanographers had recognized the need for such a platform for some time, it was under the direction of Dr. Fred N. Spiess that the Marine Physical Laboratory with the sponsorship of the Office of Naval Research took the lead and originated a practical design. Dr. Frederick H. Fisher, Research Physicist at the Marine Physical Laboratory, was the project officer. With Dr. Spiess and Dr. Philip Rudnick he is largely responsible for developing the shape, size and capabilities of this research platform including model tests up to a tenth scale operating model. Final design and engineering was by L. R. Glosten and Associates of Seattle, Washington. FLIP was constructed in just six months in the Gunderson Brothers Engineering Corporation shipyard in Portland, Oregon at a total cost of under $600,000.00. Commander Earl Bronson (USN Ret.) followed FLIP's construction as contract representative and then served as her first Officer in Charge during sea trials and her first four years of operation. In his present position as Marine Coordinator he continues to carry the responsibilities for FLIP's operation.

FLIP, with its 355-foot overall length, displaces about 700 tons of water in the horizontal position and about 2200 tons in the vertical position. The hull consists of a number of sections; the stern-most (or lowest) is cylindrical with 20-foot diameter and 150-foot length, followed by a 90-foot tapered section and another 60-foot cylindrical section of 12.5-foot diameter. At the forward (or upper) end of this structure is the 50-foot "cobra head" shaped prow (or cabin). Four compartments in the prow/cabin and four more in the adjacent cylindrical hull provide machinery space and working and living quarters for six crew members and as many as 15 scientists.

FLIP has no propulsion power of its own other than two small orientation propellers located below the vertical water line which rotate the vessel about its vertical axis. These propellers can be servo controlled from the gyro compass to maintain an accurate heading. Three diesel generators supply electrical power

"FLIP" MIDWAY IN TRANSITION

for all ship's and scientific needs. Practical tow speeds for FLIP vary up to about 10 knots in the horizontal position. It is sometimes towed slowly in the vertical position for stationkeeping or small changes in position.

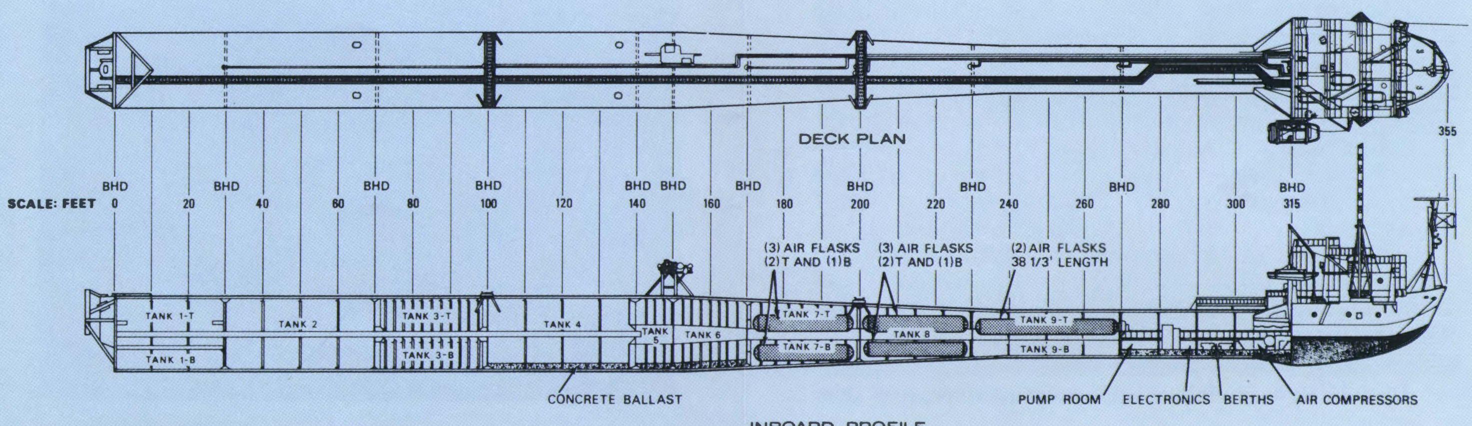
As a special platform FLIP has extended the research capabilities of the Marine Physical Laboratory in a unique way. The experience gained from operation of FLIP has proven the value and economy of this concept of a highly stable, versatile platform for making scientific measurements at sea.

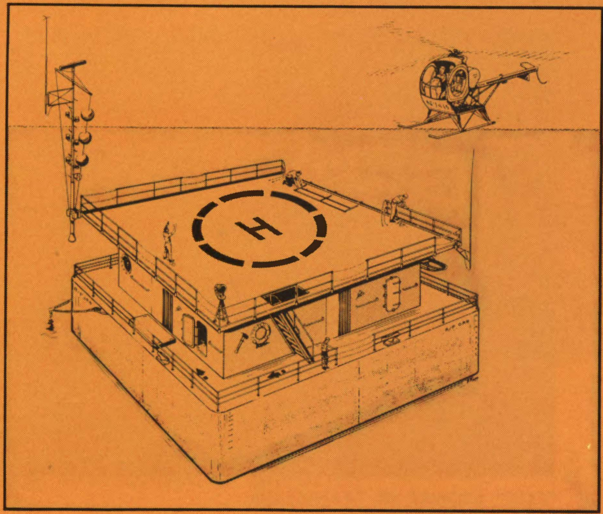
Technical papers describing the structure and performance of FLIP have been published in a number of journals:

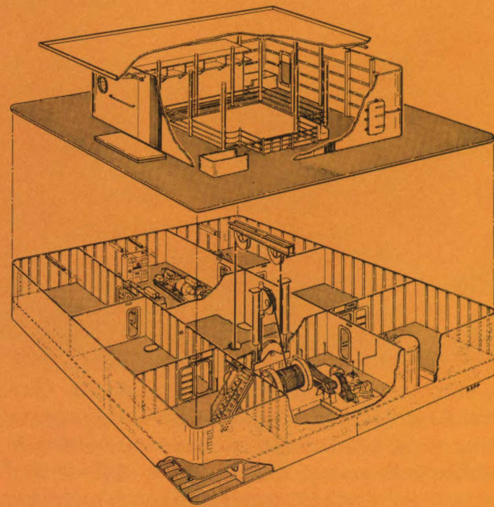
Rudnick, Philip, "Motion of a Large Spar Buoy in Sea Waves," J. Ship Research, 11, No. 4, pp 257-267, December 1967.

Fisher, F. H. and F. N. Spiess, "FLIP — Floating Instrument Platform," J. Acoust. Soc. Am., 35, No. 10, pp 1633-1644, October 1963.

Rudnick, Philip, "FLIP — An Oceanographic Buoy," Science, 146, 1268, 4 December 1964.







ORB INTERIOR

"ORB" Oceanographic Research Buoy

ORB, a 45-foot square vessel displacing approximately 180 tons, was developed by the Marine Physical Laboratory to serve projects at the laboratory which require the launch, retrieval, implantation or handling of large equipments or systems in the open ocean. Among these are:

1. "RUM" (remote underwater manipulator); remotely controlled, bottom crawling vehicle.
2. "Benthic Laboratory"; an electronic control and data transmission center, remotely operated and maintained on the sea floor.
3. Acoustic transducers and hydrophone arrays.

In contrast to FLIP, ORB is designed to follow the motion of the sea surface as closely as possible, in order to simplify the task of placing and retrieving large objects in the ocean. The vessel has a center well of 15- by 20-foot area which can be opened to permit equipment to be lowered through it. Loads up to 12 tons are safely handled with a system that includes a number of automatic control features, and can be lowered to a maximum depth of 10,000 feet. The supporting cable also serves simultaneously to transmit as much as 30 kilowatts of power to the remote equipment, and to return from it a variety of data, including television video signals.

ORB is 24 feet high from keel to helicopter deck. It has no means of self-propulsion and must be towed to and from operating areas. The vessel is equipped with diesel generating sets to provide 90 kilowatts of electrical power. ORB's equipment also includes a normal amount of navigation aids, communication and safety equipment. It carries fuel and water for a stay of up to 45 days while moored on station. Personnel rotation at sea where necessary may be accomplished by either small boat or helicopter.

In addition to laboratory work spaces and machinery space, ORB is equipped with complete living facilities for 12 people including 4 crew members.

The "ORB" concept originated with Dr. Victor C. Anderson, Associate Director of the Marine Physical Laboratory. Preliminary design was carried out by Dr. Anderson, Associate Engineer F. N. Biewer and Marine Coordinator E. D. Bronson. The firm of L. R. Glosten and Associates of Seattle provided the Naval Architect services for final design. Construction was accomplished by California Steel Fabricating and Welding Engineering Corporation of San Diego under the sponsorship of the Office of Naval Research. The design of the buoy ORB emphasized simplicity and economy of construction and operation, functional utility, and minimum maintenance. Design, construction and outfitting were carried out at a total cost of $275,000.00.

ORB (OCEANOGRAPHIC RESEARCH BUOY)

"RUM"

The RUM (Remote Underwater Manipulator) is a remotely controlled, tracked sea floor work vehicle which has been developed under the sponsorship of the Office of Naval Research at the Marine Physical Laboratory for use as a research tool in sea floor technology experiments.

Project goals are to determine feasibility, define problem areas and establish design criteria for future sea floor technology systems.

Areas of particular interest are remote manipulation, navigation, cable telemetry systems, ambient pressure exposed electronics and environmental and mechanical design considerations.

Design depth for the RUM vehicle is 10,000 feet. Operations are contemplated to 6000-foot depths. RUM has been driven over several miles of sea floor in shallow water tests at a depth of approximately 100 feet. It has been lowered in deep tests with all systems working to 1500 feet. Driving and navigation skills are being developed.

During operations the vehicle is launched through the well on ORB, lowered to the sea floor and the cable tensioning system set for a reasonable tension from 5000 to 10,000 pounds depending on bottom conditions and depth of water. Once RUM is on the bottom it serves as a more than adequate anchor for ORB. As RUM drives across the sea floor it tows ORB across the surface above it at speeds up to 1 knot. The cable constant tensioning system on ORB automatically pays in or pays out cable as needed.

The hull, tracks and suspension system of the RUM vehicle are those of an "ONTOS," a surplus Marine Corps tracked rifle.

All power, telemetry for control and instrumentation, sonar, navigation aids and television are transmitted over the single coaxial umbilical cable connecting the RUM to ORB.

The vehicle is propelled by two independently controlled reversible $7\frac{1}{2}$ horsepower direct current motors, one driving each track. Other equipment includes two television cameras, eight 500 watt lights, a scanning sonar, depth sounder, magnetic compass, an acoustic transponder navigation system and numerous other kinds of instrumentation to monitor operational conditions.

The manipulator is capable of working off of either side or to the rear of the vehicle and is capable of exerting 50 pounds of force in any direction at full arms length. In addition the manipulator boom is equipped with a hook capable of lifting loads of up to 1000 pounds and moving them about on the ocean floor. The manipulator boom swings in an arc of about 300° about a king post located at the rear center of the vehicle. The boom is raised and lowered by a motor-driven wire rope topping lift.

The manipulator at the end of the boom rotates about its mount at the shoulder, pivots at the shoulder, pivots at the elbow, rotates at the wrist and is equipped with a sizable grip having jaws 6 inches long which open to grasp objects up to 7 inches across.

The portside TV camera is boom-mounted with the pivot point near midway on the port side. The camera stows forward for driving but may be swung in a wide arc away from the side of the vehicle and around to the rear for close-in viewing of the manipulation areas. The starboard camera is mounted on a dolly which travels fore and aft and may be positioned anywhere from an extreme forward stow position for driving to the extreme rear for manipulation viewing.

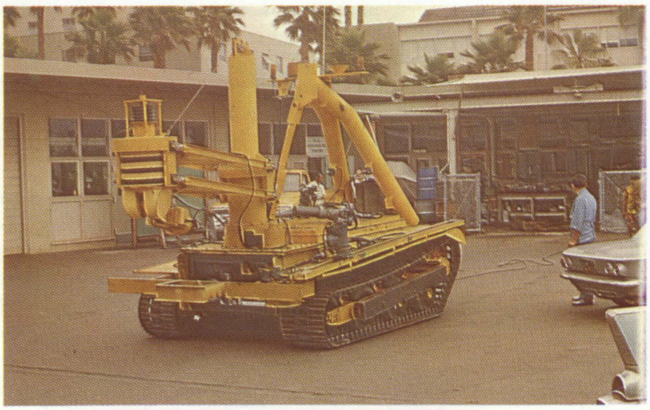
Eight 500 watt lights are provided, two of which pan and tilt with each TV camera and four of which are mounted low in the front for increased visibility while driving.

Two telemetry systems are used for control and instrumentation, one, a time multiplex system providing 64 channels each way, up and down the cable, and an amplitude modulated carrier system with four carriers transmitted down cable and eight carriers returned.

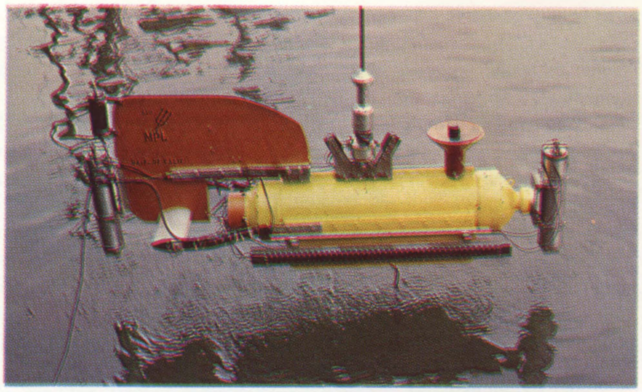
DIVER OVER THE SIDE OF "ORB"

RUM physical specifications:

Length overall	— 15′ 0″
Width overall	— 8′ 7″
Height overall	— 10′ 9″
Weight in air	— 23,000 lbs.
Weight in water	— 13,500 lbs.
Tread pressure on sea floor	— 3 lbs per square inch
Maximum speed	— 1.4 knots
Power supply	— 240 volts, 60 Hertz, 1 phase 30 kilowatts
Transmission line voltage	— 2400 volts, 60 Hertz, 1 phase



RUM (REMOTE UNDERWATER MANIPULATOR)



DEEP TOW VEHICLE BEING LAUNCHED

The DEEP TOW system was designed to study the details of sea floor topography and related characteristics. It consists of an instrumented vehicle, commonly called a FISH, towed by a research ship with a five-mile length of specially constructed cable. A network of bottom-mounted acoustic transponders is used to provide precise navigational information.

The unmanned vehicle consists mainly of a pressure case which houses and protects the electronics unit from the sea pressure down to depths as great as 18,000 feet. The following instrument sensors are mounted in various locations on the outside of this case:

A precision downward looking echo sounder which combined with the upward looking echo sounder gives a detailed profile of the depth of the ocean bottom under the vehicle.

Right and left side looking sonars which record objects on either side of the vehicle out as far as 1200 feet.

A bottom penetration sonar for detecting sub-bottom strata.

An acoustic ranging transducer which interrogates the transponders and also receives their return signals.

A proton magnetometer for detecting fine scale anomalies in the survey area.

A temperature sensor for measuring the horizontal micro-temperature structure of the water the FISH passes through.

A sound velocimeter for making sound velocity profiles. This data is used to improve the accuracy of the transponder ranges.

A camera and strobe light system for sea floor photography.

The communications link between the vehicle and the ship's laboratory is provided by the single electrical conductor in the core of the tow cable. The ship's winch is equipped with a slip ring assembly that permits uninterrupted operation while the winch is running. The cable transmits simultaneously the vehicle power and all command and data signals.

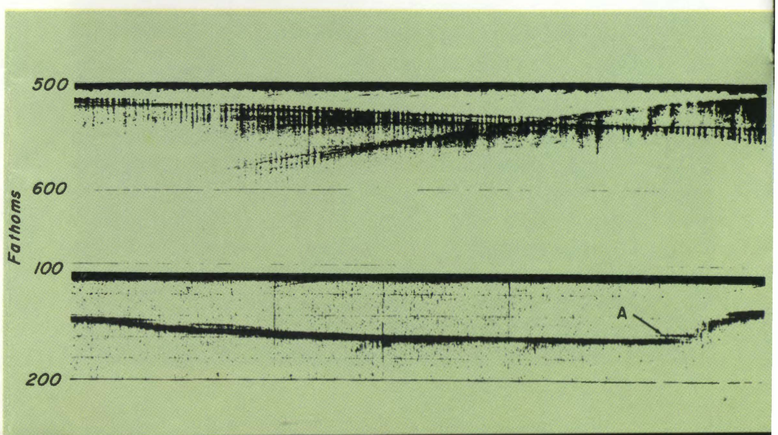
Precise navigation in the survey area is provided by the acoustic transponders which are dropped from the ship at appropriate locations at the beginning of the operation. Some of these are permanently placed in the area while others are recoverable. The transponders are used to locate both the towed vehicle and the ship in relation to the network to an accuracy of 10 meters. Their usable range is from 5 to 10 miles.

The ship's laboratory contains the vehicle sensor control rack, the power supplies, the data recorders, and other instruments related to the survey. A computer is used for rapid navigational computation and data logging. The ranges from the transponders are fed into the computer and the positions are automatically marked on the plotter. A remote winch control is located in the laboratory for use by the scientific staff. During a run the console operator monitors the ship's echo sounder which gives a plot of the sea floor depth a mile or two in advance of the vehicle, and then, observing the precision depth record from the FISH he controls the height above the bottom by paying in or paying out cable. The response of the FISH to cable length is nearly instantaneous so that rapid and precise control can be maintained of its height off the bottom.

On a typical operation the research ship will, upon arriving at a survey site, make a preliminary bathymetric survey. After the transponders are dropped into position on the sea floor and the vehicle is launched the deep tow survey is under way and will continue for several days. Upon completion the recoverable transponders are retrieved. If it is planned to return to an area at a later time, a permanent transponder is left to help start the next survey.

The DEEP TOW system is a powerful research tool for studying the geology of the sea floor and thereby its influence on acoustic and magnetic systems. By virtue of its complex of instruments and the precision of its acoustic transponder navigation system, magnetic, topographic, sub-surface sediment, and photographic data may be closely correlated to identify features of special interest and to obtain a much more complete general understanding of the processes of formation of the sea floor structure that has been possible with the isolated random observations of the past.

TYPICAL DEEP TOW RECORD



"IMP" (Instrumented Mobile Platform)

IMP, a small unmanned radio controlled boat, is being developed by the Marine Physical Laboratory for use in detailed study of sea floor topography.

The basic craft itself is a diesel powered "Firefish" drone manufactured by the Ryan Aeronautical Company. The normal mission of this type of craft is to serve as a naval surface gunnery target, however, as it is being developed at the laboratory it is equipped with an acoustic echo sounder for measurement of depth under the craft. Output information from the echo sounder is transmitted to the mother or control ship via radio telemetry where it is recorded.

Two simultaneous parallel echo-sounding profiles can be recorded, one from the control ship and the other from IMP which runs abeam of the ship at a fixed distance determined by radar. This gives the capability of gathering and recording twice the data with a given survey ship, crew and scientific party in a fixed amount of time. Two IMP craft, one running out to the proper distance at each side of the control ship, would triple the data gathered.

IMP is capable of sustained speeds to 12 knots in moderate seas for a period of 24 hours.

Test Facility — Lake San Vicente

The Marine Physical Laboratory maintains a 24 by 50 foot covered test and calibration barge at San Vicente Lake, one of the reservoirs of the San Diego water system, located approximately 30 miles northeast of the laboratory. This research platform is equipped with electrical power and complete electronic instrumentation for calibration of acoustic transducers and hydrophones and for conducting a variety of other tests and calibrations in the quiet calm of a large fresh water lake.

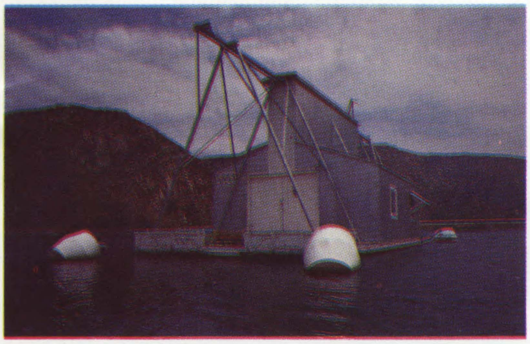
Permission to moor this facility in the lake is by courtesy of the City of San Diego.

Sea Floor Magnetometer

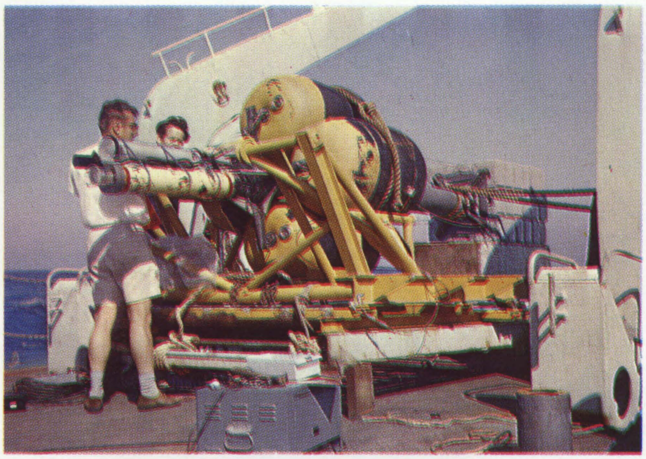
A free-falling, self-contained vehicle system has been developed at MPL which places a fluxgate magnetometer on the deep ocean floor to record magnetic field variations. Gasoline filled flotation bags make it positively buoyant and ballast is used to transport it to the bottom. Ballast is jetisoned by acoustic command or by an internal pre-set timer causing the vehicle to surface.

This vehicle 20′ long with a launch weight of about 3600 pounds requires a special launcher for a vertical drop overside. A recording compass and tilt angle recorder relate the instrument coordinate system to the earth's magnetic field and horizontal plane.

"IMP" INSTRUMENTED MOBILE PLATFORM



SAN VICENTE CALIBRATION BARGE



DEEP SEA MAGNETOMETER