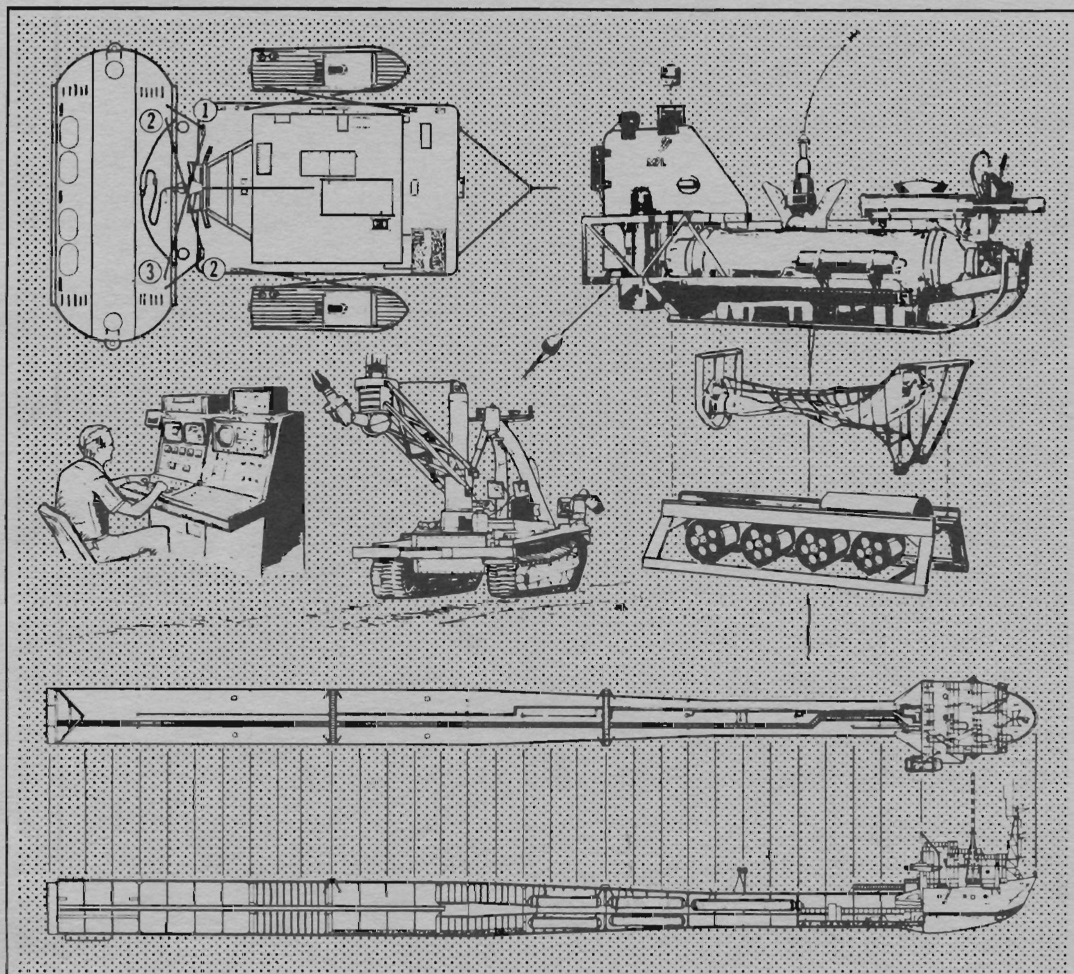
# MARINE PHYSICAL LABORATORY
## Research Facilities



University of California, San Diego
Scripps Institution of Oceanography
San Diego, California 92152

The purpose of this brochure is to provide personnel of key research and development activities with an introduction to the various unique facilities of the Marine Physical Laboratory which might be useful in programs under their cognizance.

These facilities were developed to support Navy research programs at the Marine Physical Laboratory, and most are still so employed. They represent assets of potential value to authorized users in the research and development community as hardware facilities, and as examples of effective solutions to problems in marine technology. Our continued use of these platforms and devices keeps us thinking about how to match their capabilities to the needs of new seagoing research programs. We would be pleased to share this knowledge and, where feasible, these facilities with other government research and development activities.

The availability of these Navy-provided facilities and, to some extent, Navy support of maintenance and operation, makes it possible to use them at costs much lower than their replacement or full support would require.

Persons interested in learning more about the capabilities of these facilities, or about their availability to support specific research, development, or test programs should contact:

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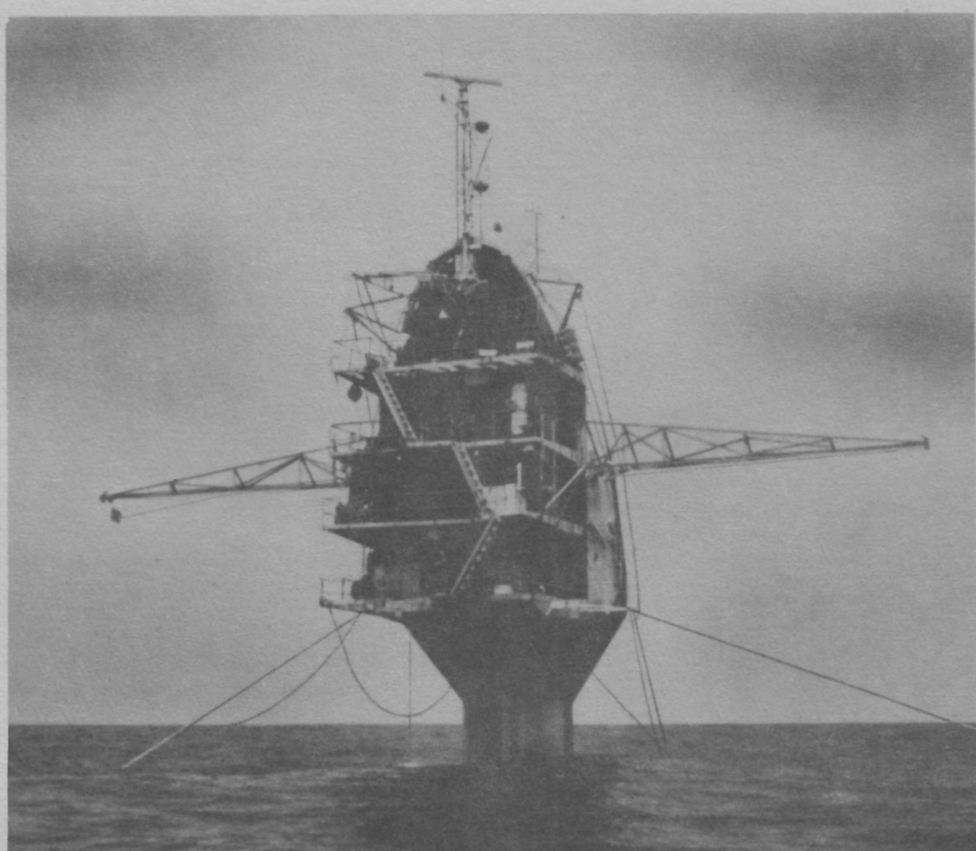


## FLIP -
## Floating Instrument Platform

FLIP is an unusual vessel developed in 1962 under the sponsorship of the U.S. Navy's Office of Naval Research 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 108 meters, was constructed with about 700 tons of steel and concrete ballast; it displaces about 1500 tons of water in the horizontal and 2200 tons in the vertical position. At the forward (or upper) end of this structure is the 17 m prow. Five compartments in the prow and four more in the adjacent cylindrical hull provide space for machinery, electronics equipment and living quarters for five crew members and as many as 11 scientists.

It has no propulsion power of its own other than two small hydraulically operated 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 a heading. Three diesel generators supply 360 KW electrical power for all the ship and scientific needs. Engines are gimbaled for operation in either horizontal or vertical positions. Practical tow speeds for FLIP vary up to about 10 knots in the horizontal position. It can be towed slowly in the vertical position for station-keeping or small changes in position.

FLIP 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 84 m of the vessel are flooded. In about 20 minutes the vessel is completely vertical with approximately 17 m of prow pointed skyward and the remaining 91 m of vessel under water.

The diameter of the hull, which is 6.5 m from the 91 to 49 m depth, tapers down to 4 m at the 20 m depth. This change in diameter gives FLIP a natural period of 27 seconds for vertical motion compared to an 18-second period for a cylinder of the same depth. The longer period reduces FLIP's response to wave motion since wave energy in the ocean usually occurs at periods below 18 seconds; for a 10 m wave, FLIP's vertical motion is less than 1 meter.

FLIP's stability, 91 m draft, and low acoustic noise levels have made it uniquely suitable for a wide variety of research experiments: hydrophones can be positioned at a variety of depths for listening to acoustic signals; the same applies for other instrumentation such as pressure sensors for measuring wave heights, tilt and depth of FLIP, or temperature sensors for measuring thermal structure in the ocean. In order to study the horizontal extent of thermal variations in the ocean, three booms can be extended so that temperature sensors can be lowered simultaneously at known distances from one another. Density variations in the upper levels can be studied with high resolution Doppler sonars. Meteorological instruments mounted on a vertical mast that can move up and down at the end of a boom make it possible to make measurements immediately above the sea surface. Its deep sea winch can lower instrumentation packages to a depth of 4000 meters. Booms below the waterline can also be mounted on the hull for obtaining horizontal separation of sensors. In the vertical position FLIP either drifts freely or is held in position by using up to a three-point moor in any ocean depth.

The early demonstration of FLIP's unique capabilities as an ocean-going measurement platform with very low motions has led to its use for many other programs. Research conducted on FLIP has included studies of: (1) the relation of temperature variations in the ocean to fluctuations in intensity and direction of sound waves; (2) waves generated from storms in the South Pacific, for which FLIP was stationed between Hawaii and Alaska; (3) turbulence and thermal structure of the ocean; (4) amplitude and directionality of internal waves; (5) energy transfer between the ocean and atmosphere in which wind velocity, humidity and temperature profiles immediately above the ocean surface were measured; (6) ambient noise intensity and direction using vertical hydrophone arrays suspended from FLIP and horizontal arrays (DIMUS) at the bottom of FLIP; (7) long-range sound propagation; (8) variation in properties of the earth's crust, for which FLIP was used as a listening platform for explosive sound signals launched from four ships going away from FLIP in four different directions; (9) depths to which whales dive; (10) effects of pressure on sound attenuation; (11) scattering of sound from the sea surface and reverberation.

Scientists from many other universities and government laboratories have participated in the research conducted with FLIP. It has remained at sea for as long as 45 days with 35 consecutive days in the vertical position: the longest when it was in the Gulf of Alaska, 1800 nautical miles from home. Other operations, in addition to the many conducted along the California coast, have included four in Hawaiian waters and one in the Caribbean, where FLIP remained vertical, on station, making meteorological measurements for 30 consecutive days as a part of the Barbados Oceanographic Meteorological Experiment (BOMEX).

In over 19 years of service FLIP has spent over 1000 days at sea and has completed the transition from horizontal to vertical and return over 200 times.

*FLIP transition from horizontal to vertical.*

## ORB - Oceanographic Research Buoy

ORB a 21 x 14 meter rectangular shaped vessel displacing approximately 330 tons, was developed by the Marine Physical Laboratory in 1968 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, unmanned, bottom crawling vehicle with a manipulator arm for performing tasks.
2. "Benthic Laboratory"; an electronic control and data transmission center, remotely operated and maintained on the sea floor.
3. Acoustic transmitters, receivers, transducers and hydrophone arrays, particularly for studying ambient noise and reverberation.

In contrast to FLIP, ORB is designed to follow 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 9- by 6-meter area which can be opened to permit the lowering of equipment. The well doors when closed provide a dry work space and will safely support a weight of 12,000 kg. Loads up to 12 tons can be lowered to a maximum depth of 2,000 meters. They are safely handled with a system that includes a number of automatic control features. The supporting cable also serves simultaneously to transmit as much as 30 kilowatts of power and all necessary control signals to the remote equipment, and to return from it a variety of data, including television video signals.

ORB is 8 meters high from keel to upper 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 which provide up to 240 kilowatts of electrical power. ORB's equipment also includes a normal amount of navigation aids, communication and safety equipment. It can carry sufficient fuel and water for a stay of up to 45 days while moored on station. Personnel rotation and provisioning at sea where necessary have been accomplished by small boat.

In addition to laboratory work spaces and machinery space, ORB is equipped with complete living facilities for 16 people including four crew members.

ORB, during her first ten years of operations in support of over a dozen different projects, has been moored at over 20 sites ranging up to 400 km off the southern California coast and at depths from 30 to over 4,000 meters.

## Doppler Sonar

The accurate measurement of the oceanic water velocity field is a difficult task. Traditionally, currents are measured directly by discrete current meters which are suspended in the sea from moorings, or are inferred from the measurements of the oceanic density field. FLIP's ability to drift while vertical made possible the development of an alternative method using Doppler Sonar. In this approach, high frequency sound is transmitted in a narrow beam. The sound scatters off the plankton drifting in the upper ocean. From the Doppler shift of the returning sound, the component of scatterer velocity parallel to the sonar beam can be deduced at many ranges.

After preliminary experimentation with existing sonars, a special purpose Doppler scattering sonar was developed. The sonar consists of a 1.5 m diameter array of 1680 individual transducers, each driven in uniform phase and power. The total array is driven at 32 KW peak power, between 65 and 90 kHz.

In preliminary tests during January 1979 the sonar was mounted near the bottom of FLIP and directed downward at a 45$^{o}$ angle from horizontal. Profiles of velocity were obtained down to a depth of 1.2 km, a range of 1.6 km. The information from the single sonar duplicates that from a linear array of 64 (one-component) conventional current meters. Following successful tests of the prototype a duplicate was constructed, as well as two smaller sonars. The complete four-sonar system has been mounted on FLIP and will be used to measure the horizontal and vertical variability in water velocity in the top kilometer of the sea. The initial use of the system will be to study the upper ocean internal wavefield. With time, emphasis will gradually shift to observations in the mixed layer and to air-sea interaction processes.

## RUM - Remote Underwater Manipulator

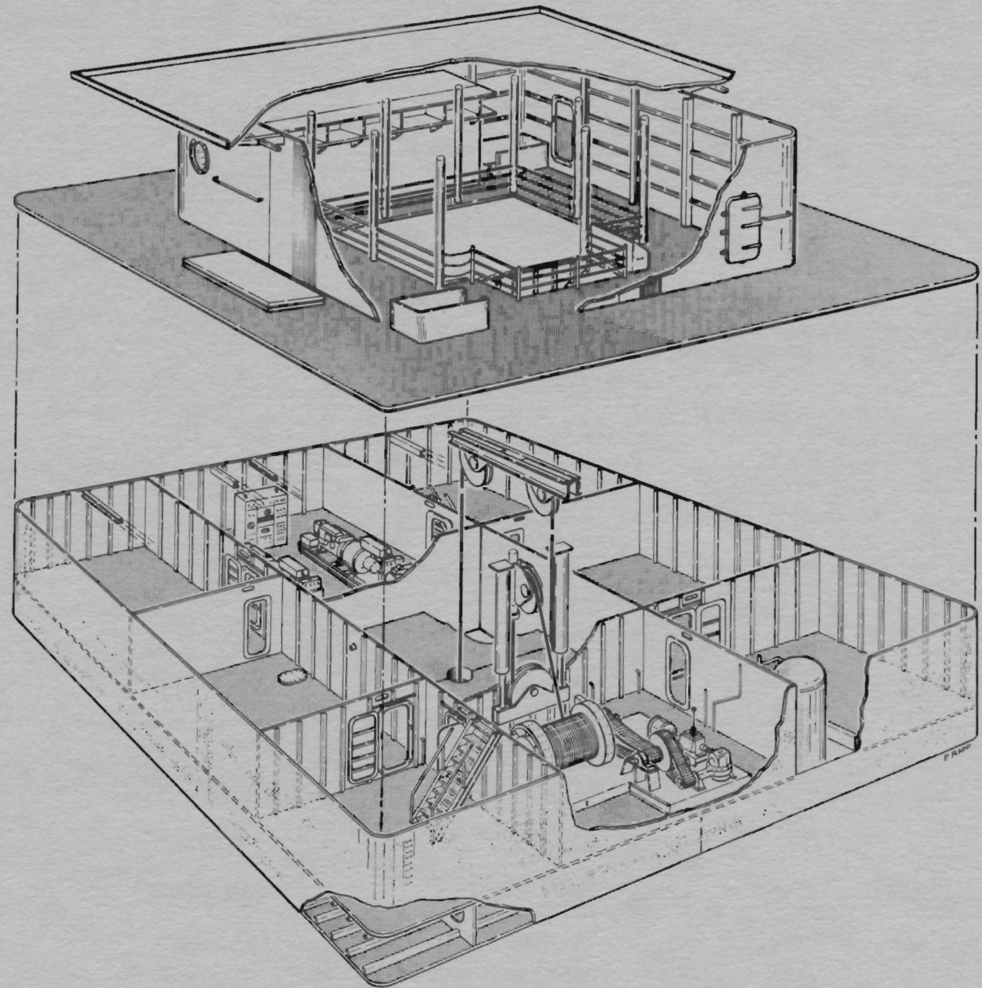
Development of a series of RUM (Remote Underwater Manipulator) vehicles began at the Marine Physical Laboratory in 1959 to provide tools for seafloor technology experiments and to establish design criteria for future seafloor technology systems. RUM I was a shore-based vehicle which carried 5 miles of cable for power and telemetry. It was modified in 1969 to operate through the enclosed well of the surface platform ORB by cable control. This version, RUM II, was designed for 2400 meter depth, and has operated in Southern California waters in depths from 30 to 1800 meters. It has provided useful data on seafloor vehicle trafficability, remote manipulation, navigation and control, cable telemetry systems, ambient pressure effects on electronics, and mechanical and environmental design considerations. RUM II is now out of service. Design of RUM III is in progress, combining and improving features of RUM II and of Deep Tow to provide a remotely-controlled vehicle capable of both search and recovery operations at the deep seafloor.

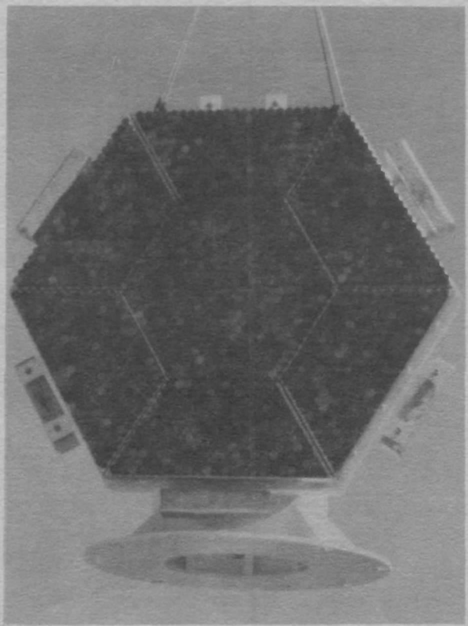
## LAKE SAN VICENTE - Transducer Calibration Facility

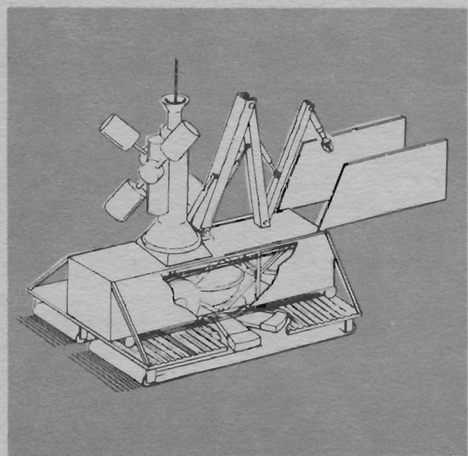
The Marine Physical Laboratory maintains a 7 by 15 meter covered test and calibration barge at San Vicente Lake, one of the reservoirs of the San Diego water system, located approximately 48 km northeast of the laboratory. This research platform is equipped with electrical power and complete electronic instrumentation for calibration of acoustic transducers and hydrophones and for conducting a variety of other tests and calibrations in the quiet calm of a 30 meter deep fresh water lake.

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

*Top to Bottom Counterclockwise: ORB at sea; Doppler Sonar; Original RUM I vehicle series; RUM II modified to operate at a 2400 meter water depth; Artists sketch of RUM III design is in progress; Three-dimensional view of ORB.*







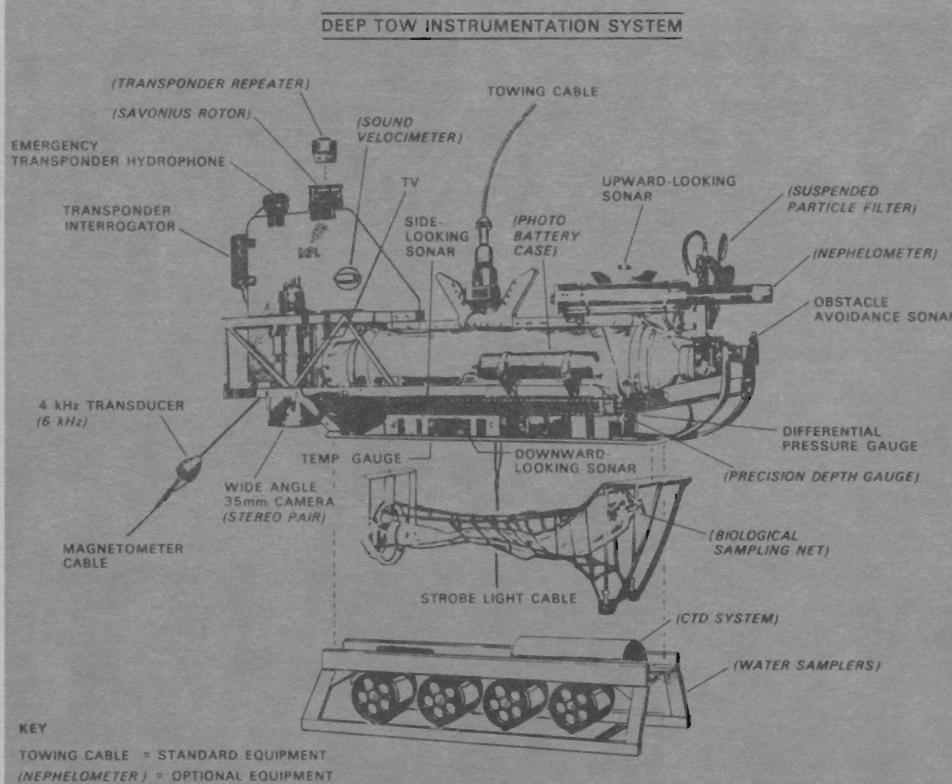
## Deep Tow Instrumentation System

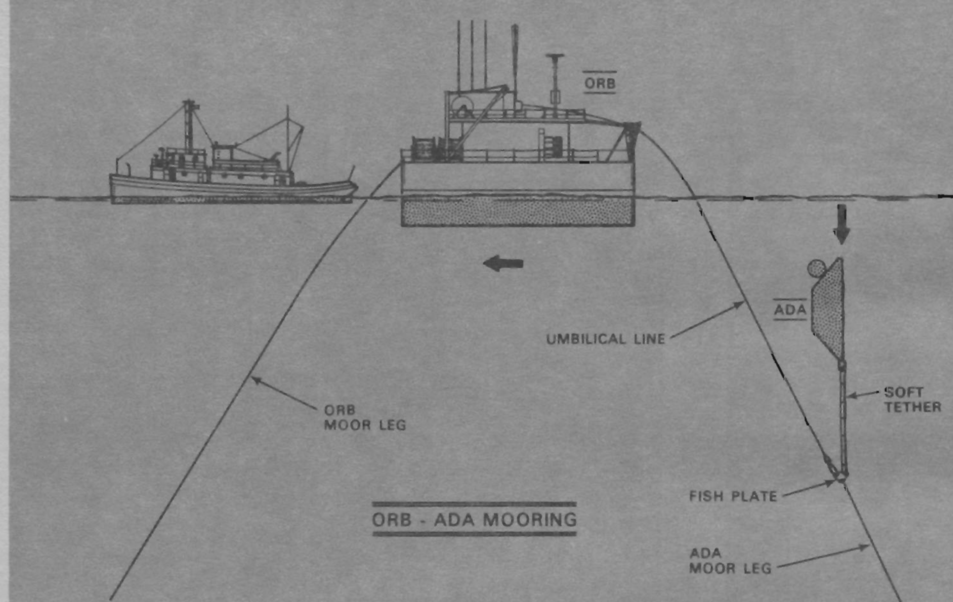
Development of MPL's Deep Tow Instrumentation System began in 1961 to study the details of sea floor topography and related characteristics. It consists of an instrumented vehicle, commonly called a FISH, towed at 1.5 knots by a research ship with a five-mile length of electro-mechanical cable. A network of acoustic transponders at the seafloor is used to provide precise navigational information. The system requires a capable winch and crane or A-frame mounted on a maneuverable ship for effective operation.

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 7000 m. 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 or precision pressure gauge 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 500 meters; a bottom penetration sonar for detecting subbottom 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 conductivity element to provide information on water salinity; a camera and strobe light system for sea floor photography; a slow scan television system to permit the operator on the ship to view the area below the FISH on a monitor screen within 2 or 3 seconds after pushing a button; and an obstacle avoidance sonar system to alert the operator to the presence of objects forward of the FISH.

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. The transponders are used to locate both the towed vehicle and the ship in relation to the network to an accuracy of 5-10 meters. Their usable range is from 5 to 10 nautical 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 of its height off the bottom can be maintained.

On a typical operation, upon arriving at a survey site, the research ship will 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 long-lived transponder is left to help start the next survey.

The Deep Tow Instrumentation 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 instruments and the precision of its acoustic transponder navigation system, magnetic, topographic, subsurface 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 seafloor structure than has been possible with the isolated random observations of the past. Additional instrumentation has been developed to acquire chemical and biological samples at great depths using the Deep Tow Instrumentation System.

## ADA - Unmanned Tethered Submersible

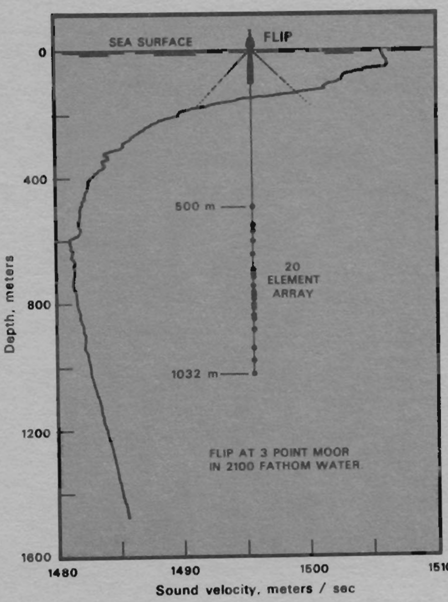
The experimental ADA (Acoustic Distribution Array) platform was designed and constructed to investigate the detection capabilities of a high gain, large aperture, acoustic receiving array and to measure the properties of the ambient noise field in the ocean which affect array performance. The 7 m high x 20 m long aperture of the ADA vehicle contains a set of 720, two-element, directional hydrophones. ADA is designed to be towed to sea in conjunction with its support platform ORB (Oceanographic Research Buoy) and submerged to water depths as great as 1200 m. Signal processing electronics hardware, within the ADA vehicle, combines the signal outputs from the 720 hydrophones into a set of 1500 simultaneous preformed beams. The power in these beams is transmitted over a cable telemetry link to the surface support platform ORB for further processing, recording and analysis.

In its mechanical aspects, the array vehicle is a blend of instrument package and submersible, and neither part is conventional. A dominant feature of the platform is the pressure hull, a ring stiffened cylinder that is 1.825 meters in diameter, 18.9 meters in length and is designed to resist the submergence pressure at 1200 meters depth.

The pressure hull is carried inside a steel barge-like structure, which also serves as the mounting surface for the acoustic array. ADA is towed to station, array side down. When on station the barge interior is flooded for submergence. The array vehicle rolls 90 degrees as it is pulled down in the moor, making the array vertical.

The pressure hull contains the array beamformer, signal conditioning electronics, power converters and controls, telemetry systems and a host of ancillary sensors. Electrical penetrators are provided for over 3,000 electrical conductors through the shell plating of the pressure hull.

Two 20 HP thrusters are used to orient the array when submerged. The vehicle is operated unmanned. All power, controls, acoustic data and sensor outputs are transmitted over a 1770 meter long cable which connects ADA with the surface support platform ORB.




## Acoustic Vertical Array

Investigations of the time-varying characteristics of ambient noise and acoustic propagation in the deep ocean basins can be conducted using a vertical array of hydrophones suspended at various depths from a stable platform at a fixed location. The ability to moor FLIP in the deep ocean makes these measurements possible.

The hydrophone system is deployed after FLIP becomes vertical and after it is anchored by a multipoint moor to the seafloor, usually at depths of 4000 meters or more. Each of the twenty hydrophones is mounted in a protective cage which contains the FM telemetry package. The cage supports the hydrophone by the Whitney eight-point compliant suspended system which decouples cable motions from the acoustic sensor. Variable array geometry is achieved since the hydrophone modules are assembled at sea by using predetermined lengths of 1 cm diameter double-armored coaxial cable. With the deep sea winch, hydrophones can be lowered to any depth directly beneath FLIP on the primary coaxial cable. Signals from the individual hydrophones in the frequency range from 5-2000 Hz are FM multiplexed and telemetered by coaxial cable to FLIP where data can be processed in real time using computers or stored on analog or digital tapes.

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*Aerial photograph of the Marine Facilities pier in Pt. Loma with FLIP, ORB, and Scripps research ships in view.*

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