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The Scientific Research Support Potential of the Submersible *MARITALIA* 3GST9

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INTRODUCTION

Deep submergence facilities are now considered to be a vital component of the U. S. Navy fleet and the National Oceanographic Laboratory System facilities inventory. Scientific use of manned submersible systems is now routinely applied to a broad range of scientific disciplines. Advancements in deep submergence technologies continue to require evaluation and assessment for their scientific support potential. This study report assesses the scientific support potential of a specific new diver lockout submersible, the MARITALIA (3GST9), that may be added to the U.S. Navy deep submergence facilities inventory.

OBJECTIVE AND APPROACH

The objective of this study was to assess the scientific support potential of the MARITALIA 3GST9.

A study goal was to answer the following questions:

- What scientific disciplines can be significantly advanced by a closed-cycle, diesel-powered, lockout submersible facility?

- What new knowledge and understanding can be expected from the application of a diesel-powered, lockout submersible?

- What voids exist in present research facility capabilities that can be effectively filled by the availability of a diesel-powered, lockout submersible?

A literature review was conducted that reconfirms that there exists a broad range of scientific projects that could benefit from the availability of a diver lockout submersible. The scientific areas that could benefit from the availability of the MARITALIA 3GST9 appear in this report.

Particularly germane candidate research projects are given in a Report of a Study by a Subcommittee of the Ocean Sciences Board, National Research Council, National Academy of Sciences, entitled Oceanlab Concept Review, Washington, D.C. 1980. (see Appendix A for Review Objectives and Participants)

Studies conducted by the U. S. Department of Commerce determined that an autonomous submarine was the best system to perform the Oceanlab missions. The missions were described by oceanographers throughout the U.S. in response to solicitation from the National Oceanic and Atmospheric Administration. About 400 individual items emerged and they effectively covered the entire spectrum of disciplines defined as oceanography with biology and geology dominating. The biologists and geologists can thus gain more from use of man's capabilities as an intelligent observer and collector.

Professionals were contacted for their comments regarding their personal saturation diving experience using fixed habitats (diver lockout-types), tethered personnel transfer capsules, and diver lockout manned submersibles.

A workshop was convened at the University of California San Diego, wherein Scripps Institution of Oceanography staff and other invited scientists considered the capabilities of the MARITALIA 3GST9 to support their research projects; particularly those that could be carried out in the Southern California region. Findings derived from the above sources were incorporated into this assessment.

BACKGROUND

The U.S. Navy has made deep submersible assets available to the oceanographic community since 1956. The Office of Naval Research (ONR) sponsorship of deep-sea scientific research facilities, such as the bathyscaph TRIESTE and the ALVIN, have served as the primary catalyst for significant United States scientific achievements in exploration of the deep ocean. ONR sponsored academic projects using these unique facilities have contributed to many U.S. "firsts" in accomplishment and revolutionary oceanographic discoveries that have changed the course of research in several oceanographic disciplines. In addition, the U.S. Navy deep submersibles NR-1, TURTLE and SEA CLIFF have been made available for scientific studies with excellent results.

In the United States scientific use of manned submersibles has been supported principally by the Undersea Research Program, National Oceanic and Atmospheric Administration (N0AA), U.S. Department of Commerce and the U.S. Navy (Office of Naval Research (ONR) and Submarine Development Group ONE and Submarine Development Squadron TWELVE). Scientific use requirements for manned submersible dive time continues to exceed funding availability.

Each year several hundred scientists representing the disciplines of geology, biology, chemistry and physics, use both U.S. Navy fleet, Navy ONR, and civilian owned submersibles facilities to further their research. NOAA does not own any submersibles, but leases facilities from civilian firms. Major NOAA applications of submersibles are for baseline environment measurements; monitoring and assessment of areas planned for ocean dumping, undersea mining, oil and gas production activities, development of offshore power plants and offshore deep-water structures, biology, geology, and for fisheries research and management. Additionally, submersibles have been used in salvage operations, sediment transport studies assessing the fate of pollutants and bottom nutrients, and in test and evaluation of new marine instrumentation.

In some diver lockout research, submersibles are the best means available for detailed examination and sampling of deep ocean features. Of the 88 dive-days logged by Harbor Branch Foundation (now Harbor Branch Oceanographic Institution) in FY 1976, 57 were lockout dives performed from the JOHNSON-SEA-LINK I and JOHNSON-SEA-LINK II. Maximum lockout depth was 180 m. (Anonymous, Manned Undersea Science and Technology Fiscal Year 1976 Report, Department of Commerce, Washington, D. C. March 1977)

Other diver lockout facilities include several stationary habitats (LA CHALUPA, EDALHAB and HYDROLAB). Stationary habitat facilities have proven to be valuable for ocean and biological monitoring, e.g., biological and geological. A new habitat has been developed and installed off St. Croix, U. S. Virgin Islands.

The long underwater endurance, diver lockout potential, and other attributes of the MARITALIA 3GST9 represent a significant advance in deep submersible state-of-the-art that merits an assessment of its capabilities to support oceanographic research .

THE MARITALIA 3GST9

The design and fabrication of diesel-powered (closed-cycle), diver lockout submersibles is a specialty of the Italian firm MARITALIA. This study assesses the scientific research support potential of the MARITALIA 3GST9 only.

This advanced design submersible has the capability of cruising for 24 hours at eight knots to a design depth of 2,000 feet. It can carry a diver lockout crew of two plus a pilot, co-pilot, and a scientific party of three. With an operating radius of 80 miles it offers an improved capability, for a manned submersible. It is a submersible that, once launched, can be operated from a shore base, thus avoiding at-sea launch and recovery requirements common to other diver lockout submersibles.

A unique MARITALIA 3GST9 feature is a closed-cycle diesel main propulsion system. An additional, and again unique, feature is the pressure hull that is constructed of toroidal tubes (doughnuts formed of steel tubing). The individual toroids can serve as storage vessels for various gases, gas mixtures, and waste gas products from the diesel engine. There are accommodations for a crew of two and a scientific party of three. Payload capacity is 3000 pounds. A large viewing port located in the bow is available for both the crew and scientific party. The craft has not been outfitted with scientific equipment.

If current plans are implemented, this vehicle will undergo thorough engineering tests in Italy by the U. S. Navy. Following a successful period of operational tests in Italy the vehicle will be transferred to San Diego for further military evaluation and operation by Naval Special Warfare Group One working in close coordination with Submarine Development Group ONE. The latter organization now operates and makes the services of the manned submersibles SEA CLIFF and TURTLE available to the oceanographic community for 60 days of diving per year. When purchased by the U. S. Navy similar scientific use time is anticipated for the MARITALIA 3GST9.

A somewhat standard suite of oceanographic instrumentation available for every dive has been developed for the manned submersibles ALVIN, JOHNSON-SEA-LINKs I and II, NR-1, and SEA CLIFF and TURTLE. Hardware/software is available to readily create a customized oceanographic instrumentation suite for the MARITALIA 3GST9. It is expected that most new scientific requirements can be met using existing instrumentation or off-the-shelf technology.

Many tactics may be employed to increase the usefulness of saturation diving. As the divers are pressurized to their maximum saturation depth, they can make a series of lockout dives at lesser depths. This technique is defined as a sliding saturation dive. If, for example, a saturation dive were planned for 120 m, lockouts might also be made at 60, 80, and 100 m prior to making the deepest

(120 m) dive. At any given saturation depth, divers can make limited downward (or upward) excursions for long periods of time without incurring additional decompression. For example, even a diver locking out at 250 m may make a lengthy (1 or more hours) excursion dive to 305 m and then return to 250 m without decompressing (Boyd, J.H., 1973).

U.S. Navy divers have successfully measured ocean current and temperature, made video recordings which were used to estimate aggregate sites and densities, and collected samples of sediment "fluff," the fragile upper mm of sediment which is often destroyed in regular coring.

Availability of this vehicle and the saturation diver capability will provide marine scientists and ocean engineers with the means to more effectively investigate the depth region between 50 meters and 425 meters. It will also provide an opportunity for a significant number of non-diver scientists from various disciplines to sample and measure study areas difficult to reach for human intervention.

NATIONAL OCEAN RESEARCH THRUSTS

National ocean research planning emphasis is being directed to the following categories which are likely to be given the most serious consideration by government funding agencies. The project areas identified above are compatible with the broad-area topics listed below. A diver lockout submersible could be effectively used for data collection and in situ observations in all of the following:

Ocean Lithosphere and Mineral Resources

- Continental margins, their evolution and structural framework
- Tectonics, structure and lithosphere of ridges and basins
- Chemical and physical evolution of oceanic crust

- Pathways, transport and fate of marine sediments

- Geologic and environmental history of the oceans

- Aid in the precise placement of bottom mounted instrumentation

- Assist in the maintenance, repair and recovery of moored data collection systems

Biological Productivity and Living Resources

- Understanding the mechanisms of the natural history of important marine species, in the context of overall ecological structure and dynamics

- Determining specific habitat requirements of important commercial species

- Determining the general health of habitats and the extent of their degradation

- Determining means to enhance specific habitats

- Understanding behavior patterns that directly relate to management

- Recruitment of eggs, larvae and juveniles into nursery grounds

- Recruitment of adults into a fishery, and the effects of natural predators on adult survival

- Better understanding of physical parameters and how they affect living resources

- Understanding the role that broad meteorological and oceanic parameters have on coastal fisheries over the long-term

- Systematic exploration of potential fishing grounds

- Additional research in culturing techniques aimed at alleviating pressure on heavily fished species

- Exploration and development of new or under utilized resources

- Understanding the dynamics of pollution on survival tolerance levels, reproduction and the recovery of various species at various stages

- Aid in the precise placement of bottom mounted instrumentation

- Assist in the maintenance, repair and recovery of moored data collection systems

Pathways and Fate of Materials in the Ocean

- Determine how geographical setting and physical dynamics quantitatively influence the suspended particulate matter and the biological productivity and evolution in coastal regions

- Determine the flux of dissolved and particulate matter brought into the (coastal) boundary zone by rivers and carried out from shelf areas to the deep ocean

- Determine how these fluxes vary from place to place, with time, and as a result of biological and chemical alteration processes

- Assess the current status and spatial and temporal trends of marine environmental quality of coastal areas

- Aid in the precise placement of bottom mounted instrumentation

• Assist in the maintenance, repair and recovery of moored data collection systems

SIO SCIENTIFIC WORKSHOP

A scientific requirements workshop was convened at the Scripps Institution of Oceanography on April 13, 1989. Scientists representing the disciplines of biology, geology, chemistry and physics, and instrumentation development were present. Attendance list is included as Appendix B.

Mr. Charles Duchock, Honeywell Advanced Marine Systems, provided a technical briefing on the physical characteristics and capabilities of the MARITALIA 3GST9 manned submersible. He identified those features that are unique to the submersible and those that offer new advantages and capabilities for research projects.

Each attendee was provided with an overview paper that identified areas of research that are currently considered to be important science and a Research Projects Requirements Summary form for each attendee to complete, from his own perspective, a suggested research project that would benefit from the availability of the MARITALIA 3GST9 facility.

As operations of the MARITALIA 3GST9 will likely be primarily from the San Diego area it was suggested that candidate scientific projects be described for the Southern California Bight (Point Conception south to the Mexican Border including the Channel Islands). For purposes of this workshop it was assumed that the saturation divers would be U.S. Navy personnel, not the individual scientist, and that the maximum lockout depth would be 122 m. Maximum operating depth was set at 427 m with a submerged endurance estimate of 20 hours at 8 knots. Operations would be accomplished from either a support ship or from shore facilities, e.g., Point Loma or San Clemente Island.

The southern California region was of interest to all but one investigator who was primarily interested in collecting sponges off Palau. The Research Projects Requirements Summary form submitted by Michael C. Clifton proposed to use the facility for the deployment and recovery of 500 kg seafloor instruments to measure surface wave energy in water depths between 30 and 60 meters. Paul Dayton desires to survey water column scattering layers and benthic communities. J. K. Orzech is interested in the collection of living and non-living gelatinous materials from the water column and at the seafloor. In addition, he is interested in low-light level biophotic measurements. Richard Casey plans to deploy, monitor, and recover sediment traps on the San Diego Trough slopes.

Not all attendees at the meeting submitted a completed Research Projects Requirements Summary form. The attendees and others have expressed interest in the availability of the MARITALIA 3GST9, and would likely submit a specific request when the submersible's operating schedule becomes more firm. Appendix C lists individuals that have recently indicated interest in using a submersible facility in the southern California region.

DISCUSSION

Human access to work sites is often essential or most appropriate for the initial exploration, evaluation, and comprehension of scientific study sites. The functions and tasks that the human diver can perform well are:

- Manipulation that must be performed in a manner superior to mechanical manipulators, e.g. speed, two arms in unison functions, tactical sensing, hand and finger dexterity; catching live and extremely delicate specimens.

- Precision placement of data collection and sampling devices.

- Fast task completion.

- Use of tactical senses; particularly under conditions of poor visibility or when viewing areas are blocked by physical barriers.

- Simultaneous handling and manipulation of a spectrum of data collection and sampling devices.

- Visual counting.

- Human hearing.

"Why diver lockout?" is most analogous to "Why Live In the Sea?". Experienced gained from scientific studies conducted from undersea habitats has demonstrated significant value from being in situ and on-site for extended periods (Miller and Koblick, 1984).

Dr. Sylvia Earle (personal communication) stated that extended observation periods have repeatedly given new insights regarding the behavior and habits of marine organisms; both day and night. Marine animals rapidly became accustomed to the intrusion of a habitat and the human divers; thus allowing for observations to begin within minutes after a habitat has reached its position on the seafloor.

Scuba technology has been adopted widely by investigators desiring to access underwater study areas for direct observation and manipulation. By moving into the saturation regime one can achieve an order-of-magnitude increase in depth capability. Mixed gas saturation dives by highly conditioned and trained personnel have gone as deep as 500 m (Buckman, 1977), and 518 m (COMEX, 1989). Accordingly one should expect to be able to carry out human diver scientific missions with the MARITALIA 3GST9 to 122 m (370 feet) with safety and efficiency.

The function capabilities of the diver reflect extraordinary dexterity and rapid mental integration of a myriad of interactive factors for direct observation, collection and complex manipulation in performing underwater tasks--all of immediate value to a broad range of scientific research.

Direct Observation

- Unlike sampling devices such as nets which are blind and random, divers can explore, identify and select their targets

- Divers are able to recognize associations among organisms and/or physical features, such as patch distributions, predator-to-prey relationships, effects of thermoclines on particle size, etc., which might not be apparent or might be destroyed by traditional methods

- Behavior of organisms can be directly studied in their natural environment, and data on their life histories can be obtained

- Divers are able to measure in situ factors such as particulate size, rates of flux, currents and other physical conditions such as temperature in close proximity to the phenomena being investigated

- Observed phenomena such as bioluminescence and patchiness can be monitored and tracked with relative ease

Collection

- Divers can see what is being sampled and how it relates to the natural environment

- The diver can selectively collect specimens of specific species

- Specimens that elude nets or other mechanical capture devices can be seen and successfully collected by divers

- Fragile gelatinous zooplankton and "marine snow" can be collected by divers using specialized collecting devices

• Healthy specimens can be collected for taxonomic or laboratory physiological studies

Complex Manipulations

• Divers can sèlectively collect and photograph organisms or associations of organisms

• The environment can be precisely and selectively affected by chemical or dye markers introduced into a study area and results subsequently determined

• Specimens of microorganisms can be fixed in situ

• Analysis of organic and inorganic samples can be given special treatment and care

• Physiological measurements can be made in situ by the diver

Assessing the suitability and the scientific research support potential of the MARITALIA 3GST9 is based on the above advantages to the individual investigator. From this assessment it has been determined that the desirable characteristics offered by the MARITALIA 3GST9 submersible technology are:

• Sufficient range to operate from a harbor vice a surface support ship.

• Three-dimensional mobility.

• Supports one time measurement needs; e. g. bathymetric surveys.

• Supports transient measurements at selected fixed location(s), e.g. water currents, chemistry, tides and waves.

- Supports long-term measurements at one location

- Flexible platform for accommodating a variety of sensors, instruments, and tools.

- Controllable transit path or hover positioning within a large water column.

- Good horizontal range.

- Offers optional and new methods for data acquisition.

- Navigational and positioning accuracy.

- Real-time imaging and recording.

- Platform for self-contained oceanographic sensors and instruments.

- Capability to gather data throughout a full 24 hours and more under planned conditions

Diver Support

There is significant variation in function and task performance requirements associated with scientific research projects. Inherent to these operations are non-task specific (unstructured) activities that are best accomplished by the dexterous human diver improvising to meet each situation. By integrating the vehicle into a divers work program, it has been shown that saving diver in-water time can be achieved (40 to 50 percent) in key areas:

- Reduction in non-task-specific activities associated with setting up the work site such as deployment of equipment and setting up of equipment.

- Increase in diver efficiency and speed through use of vehicle facilities such as:

- A stable and readily available diver support platform possessing the necessary support to tackle tasks with relative ease in any location in the vicinity of the vehicle

- An on-site hydraulic power supply

- A carrier of equipment and hand tools, resulting in reduction of tool deployment times

- A fixed platform integral winch, making rigging and lifting tasks easier, safer and faster.

Other attributes of saturation diving:

- Direct human observation, maneuvering and manipulation

- Increased depth capability over scuba

A system that combines the functions available from scuba, saturation diving, submersibles, remotely operated vehicles, and on-board laboratory offers desired features:

- Precise placement and adjustment of instruments to be used for longer-term data collection

- Higher degree of resolution or accuracy of measurement without disturbing the sampling site

- Extended endurance for direct observation of complex interactions

- Adequate navigational accuracy to revisit sites for replicate sampling

- Logistics support for a broad spectrum of equipment that can be deployed from the submarine by a diver
- Extended horizontal range
- Mid-water and on and near sea-floor operations
- Independence from surface support
- Three dimensional maneuvering

Some scientists are already qualified saturation divers and may choose to do their own diving. However, in the case of the MARITALIA 3GST9 the principal investigator and his scientific colleagues do not need to be saturation diver qualified. When using the MARITALIA 3GST9 the above list of functions will likely be performed by a military diver and the MARITALIA 3GST9 will be operated by a military crew. Accordingly, the scientific party will coordinate diver operations in lieu of entering the environment themselves. If direct observations are required by the scientific party, the diver can perform his tasks in front of the viewing port or in front of a video camera. Communications with the diver can be maintained acoustically or by hard-wire. Task difficulty is not expected to exceed the capability of the saturated diver.

The National Academy of Sciences Subcommittee of the Ocean Sciences Board, National Research Council, established to review the diver lockout Oceanlab Concept, declared that to be useful to science the saturation diving facility should possess:

- Instrument versatility
- Long operational endurance (8-72 hours)

• Fine positioning capability (precise sampling and measurements of the sediment-water interface is not possible with conventional sampling devices operated from surface vessels).

• An operational range in terms of operating depth and geographical distance from port facilities so as not to restrict choice of study areas unduly.

• Precision navigation (it should be possible to implant instruments and return to them over a period of years).

The MARITALIA 3GST9 represents a state-of-the-art direct support facility that meets the above requirements.

The MARITALIA 3GST9 can serve both as a mobile habitat (extended duration on-site facility) or as a diver lockout submersible. A lockout submersible, such as the MARITALIA 3GST9, can operate locally as a free-roaming transfer capsule to support both short and long-term saturation diving excursions. This combination allows for the delivery of divers and the scientific party into more complex topographic situations and with minimal alteration of the natural environment.

Personal communications (with Orzech and Askew) during this study indicate that practical use of saturated diving technology will be limited to a maximum depth of 122 meters (370 ft). Although limiting, this maximum depth opens new horizons to most scientific disciplines between 30 m and 122 m where direct observation and complex manipulations have not been possible. Collaborative operations between saturation divers and unmanned remotely controlled observation vehicles have become a preferred operating mode in most offshore oil situations. Assuming that U.S. Navy personnel will conduct all of the saturation diving, collaboration protocol will only need to be extended to include scientist-to-saturation diver.

This autonomous submarine has the advantage of weather independence, at least for the duration of its underwater endurance and could serve as an on-bottom or hover habitat for direct diver access and ROV operations. ROVs can not only be operated from the MARITALIA 3GST9, but many ROVs are of a size that could be taken aboard internally for dry data transfer, instrument changes, repair and maintenance. Divers have found ROVs to be an excellent on-site companion technology.

OCEANLAB Concept

A saturation diver lockout facility offers significant scientific support potential to those research topics involving direct observation and complex manipulation. In 1979 a variety of research topics were identified by attendees at an "Oceanlab" Scripps Institution of Oceanography workshop. The scientific applications list developed (shown below) for the proposed NOAA Oceanlab remains germane and relevant to this assessment.

The proposed projects were evaluated by the National Research Council "Oceanlab Concept Review" as to whether it was good science and whether it required a person (or his surrogate) in the sea.
The surviving "good science projects" list indicates, on assessment, that the MARITALIA 3GST9 submersible, with diver lockout, is similar enough to Oceanlab to be fully applicable to supporting science in the following areas:

Changes in the bottom
Soft bottom biology
Bioturbation
Nepheloid layer
Chemical measurements
Hard bottom biology
Burrow and borer biology
Artificial reef studies
Environmental impact statements

General observation reconnaissance
Bottom-vent exploration and observation
Under-ice biological/geological studies
Spawning and reproduction studies
Sediment transport dynamics and boundary-layer conditions
Slope dynamics
Archaeology
Gelatinous zooplankton
Macroscopic aggregates
Deep-scattering layer
Bioluminescence
In situ fixation for microscopy
Microscale (physical) processes
In situ organic/inorganic chemical oceanography
Planktonic patchiness
Variability in the benthic boundary layer
Bed-shear stress and eddy-diffusion coefficients
Determination of fluxes of momentum and heat
Geotechnical properties of benthic layer
Benthic boundary layer flows
Sediment erosion
Biological factors influencing sediment cohesion
Chemical and biochemical reactions in sediments
Metabolism of benthic communities
Benthic community succession

Clearly there exist then numerous scientific projects that would benefit from the functional attributes that are available from the MARITALIA 3GST9

In the National Research Council report the cost of designing and developing a mobile saturation diving facility was viewed as a major hurdle. As the MARITALIA 3GST9 now exists, that capital investment obstacle has been overcome, assuming that the acquisition cost and perhaps all operational funding will be provided by the U.S. Navy. Therefore, the costs associated with scientific use of the MARITALIA

3GST9 should be nearly zero or well within the budget of scientific projects.

The southern California shelves and upper slopes are excellent areas for application of MARITALIA 3GST9 capabilities. Investigations on the local continental shelf (or margin) are important because (1) the intensity and complexity of the phenomena involved give rise to a wide variety of scientific questions requiring both basic and applied research, (2) the impact of nearshore phenomena on human activities is more immediate than for more distant environs, and (3) much of the equipment required to make a new beginning already exists in the MARITALIA 3GST9 and state-of-the-art instrumentation and techniques.

Concentrated attention and extended diving time is expected to increase efficiency of information gathering. Earle states "The 86 hours I spent in the water during two weeks saturated would take at least two months to accomplish if I worked from the surface, assuming dives to full no-decompression limits, perfect weather conditions and no equipment failures. Concentrated round-the-clock observations, difficult or impossible to arrange from the surface, could readily be made from the habitat." (S. Earle, California Academy of Sciences, undated). Here "diver lockout submersible" could be substituted without reservation.

Staying on site is one of the most significant attributes of the diver lockout submersible approach to scientific research. Long, unhurried observations comparable to the approach possible on land can be applied underwater; this is a particularly valuable feature for marine ecologists concerned with comprehension of the whole environment, and complex patterns and interactions that only begin to emerge with long, thoughtful, relaxed exposure such as is possible when diving from a diver lockout submersible.

The freedom of the diver lockout submersible to move freely from one location to another is important for serial measurements with a short time-frame and for those projects that require area coverage vice a single location.

Dive tables developed for decompression dives from undersea habitats show that decompression back to the equivalent of 15 m requires significantly less time than for returning the diver to atmospheric pressure. Applying this knowledge to the saturated divers working from a diver lockout submersible would permit greater work time on site than could be effectively conducted from the surface.

Manned submersible designs often include provisions for both permanent and temporary installation of instrumentation required for the vehicles' basic operation and for add-on instrumentation payload for mission specific projects. Once outfitted with instrumentation they are likely to maintain a basic configuration for most of their useful life. Provisions can be made for quick equipment changes on any new construction. (See Appendix E, Instrumentation).

Present oceanographic research facility capabilities do not effectively provide adequate direct human access to midwater and benthic locations where direct observation and complex manipulation is required. For each of the following disciplines the physical access for direct human intervention provided by the MARITALIA 3GST9 is expected to provide new knowledge and understanding presently unavailable from traditional facilities.

OCEAN DATA ACQUISITION

The diver lockout feature of the MARITALIA 3GST9 can support scientific research in Geology, Physics, Biology and Chemistry, for example:

Photochemistry and Photobiology
Mixed Layer Dynamics
Bio-Optical Oceanography

Eddies and Jets in the California Current
Shelf/Slope Processes: Sediment
Global Ocean Flux Study
Vertical Transport and Exchange

Some annotated descriptions are offered here as examples:

BIOLOGICAL OCEANOGRAPHY

Gelatinous zooplankton

Many of the soft-bodied, transparent animals can only be successfully collected by an in situ human diver. The groups included Hydromedusae, Siphonophora, Ctenophora, Scyphomedusae, Pteropoda, Appendicularia, Thaliacea and many macroplanktonic larvae. Collecting techniques involving nets and pumps easily destroy many of these organisms. Consequently little is known about their distribution, relative abundance and role in the ecosystem structure (Hamner, et al., 1975). Many of the gelatinous zooplankton are essentially structureless (lacking normal integuments to hold them together). Slight mechanical disturbance is enough to cause extreme damage and often disintegration of the living creature.

Macroscopic aggregates ("marine snow")

These aggregations of small particles (algae, foraminifera, bacteria, detritus, etc.) in a mucous matrix originate from the secretions of gelatinous zooplankton. Due to their extreme fragility, they cannot be adequately sampled by conventional gear such as towed nets (Hamner, et al., 1975), but can be successfully collected by divers equipped with hand-closed sampling bottles. Closely allied aggregates are sediment "fluff", the upper millimeter of sediment that is usually destroyed by classical mechanical corers. "Fluff" can be readily observed, but is virtually impossible to collect other than by dexterous human hands.

The deep scattering layer(s)

Access to the deep scattering layer for direct observation and sampling has been limited. Little is known about the life history, behavior and physiology of groups that are believed to make-up the migratory layer that effectively reflects acoustic energy. Observations and selective sampling can be accomplished by a saturation diver to depths of 122 m.

Bioluminescence

Below the deep scattering layer 90 percent of the animals are luminescent and light sensitive, cutting across all taxonomic lines. The sampling of these species in nets has given information on their structure, but other factors such as the role of luminescence on behavior and physiology have necessarily been inferred. The observation and photography of these animals in situ, and the capture of intact healthy specimens from depth has not been successfully accomplished.

"Fixation for microscopy in situ"

In many cases when studying the microbial life in the sea, it is preferable to fix these organisms "in situ" in order to prevent their distortion and/or alteration during retrieval. Once collected, at depth, they can be subjected to electron microscopy and analysis. Fixation can be done by divers with the advantage of being able to better observe, select and care for samples.

Microscale physical processes

Techniques developed for scuba diver studies of shear, turbulence and advective processes can be applied to deeper water masses by saturation divers.

CHEMICAL OCEANOGRAPHY

Organic/inorganic analysis"in situ"

Many substances undergo chemical change when removed from their natural deep-sea environment due to pressure or temperature changes or due to contamination during sampling. Techniques for in situ analysis will permit improved identification as they appear in nature. The interdiction of the diver will improve observation, selection and processing of samples.

PHYSICS

High energy physics

Cosmic ray muons can be detected by sensitive emulsion stacks prepared within a submersible and then placed in the environment by a lockout diver. Preparation at depth is essential as to do so other than "in situ" would result in contaminated emulsion. From the moment it is manufactured, an emulsion begins to collect random particle tracks from cosmic rays (and terrestrial radioactivity, if any). Exposures undersea are relatively free of background noise so that particle tracks are credited to neutrino-generated muons (Stehling, 1979)

INTERDISCIPLINARY

Patchiness

Patchy spatial relationships take place both vertically and horizontally in the finest to the largest scales. Physical discontinuities such as thermoclines, current boundaries, micro-scale gradients give rise to patchiness of many biological and chemical products. Patchiness is not limited to chemical and physical parameters. Zooplankton patchiness, for example can occur in an otherwise homogeneous water mass. Direct observation by divers of micro-scale patchiness as well as macro-scale studies would do much to quantify the extent of patchiness and to characterize the physical, chemical and biological relationships.

SHIPWRECK SURVEYS

Detailed and efficient surveys of sunken ships in water depths greater than 150 feet requiring the capabilities of a human diver would benefit from the availability of a mobile diver lockout vehicle. Connors, 1988 describes the joint U.S. Navy/U.S. National Park Service Project SEA MARK, an endeavor to establish the ecological condition and physical status of Pacific Basin shipwrecks; particularly U.S. warships sunk in World War II such as the UTAH and ARIZONA in Pearl Harbor, using U. S. Naval reservists of Mobile Diving Salvage Unit ONE (MDSU ONE). Project SEA MARK has been extended to the waters of Guam and Palau. The functions of the divers is to establish through exact measurements and drawings the present wreck features.

Much of the underwater survey work relied on a process of "trilateration"--taking measurements in distance and degrees of angle from known locations on the baselines out to other points on the wreck. The process sharpened the underwater surveying and drafting skills needed by Navy divers, skills essential for effective salvage. The divers also improved their underwater still photography and video techniques.

The inherent and learned capabilities of a human diver are difficult to replicate with instruments or other devices, e.g., human ability to observe and decipher subtle clues, such as finding the source of a small oil leak that has released a few drops of oil every few minutes since it was sunk and to assess the status of biofouling and corrosion.

The scientists aboard the MARITALIA 3GST9 need not be divers. Cooperative efforts between scientists and U.S. Navy have clearly indicated that saturation divers can be effectively trained to accomplish, with alacrity and precision, specific (scientific) tasks in support of and under the direction of a scientific investigator. Such coordination is facilitated by the use of underwater communications and video systems. Working closely with scientists from the Scripps Institution of Oceanography, Navy divers collected samples of marine snow at all depths (Orzech, J.K., 1983). The divers collected intact specimens of gelatinous zooplankton (salps and siphonophores) and with lights out at 260 m, observed bioluminescence phenomena for the investigator (Orzech, J.K., 1984).

GEOLOGY

Seafloor observations and selective sampling of sedimentation and lithofied materials can be accomplished by hand and by hand operated sampling devices to a high level of exactness. Relationships among the physical, biological and geological parameters active at a given site become available to the diver and the scientific investigator. Precise positioning of measurement instruments and sampling devices are additional advantages.

SCIENTIFIC INSTRUMENT SAFETY CERTIFICATION

All add-ons to a U. S. Navy manned submersible, such as oceanographic instrumentation, must be certified according to specifications provided in NAVMAT (Naval Material Command) MANUAL P-9290, June 1976. The Manual presents a set of guidelines for the designer and/or builder of a Manned Submersible Systems (DSS) that is intended for Naval use. The objective of the Certification process is to verify that a Deep Submergence System provides acceptable levels of personnel safety throughout the specified operating range of the DSS when used in accordance with approved operating and maintenance proceudres.

Subsystems, such as scientific instruments using pressure resistant containers, are of particular concern because of possible implosion of the container and sympathetic implosion implications.

Accordingly, instruments must be adequately tested and certified for use aboard and must have acquired certification documentation acceptable to NAVMAT. The time and cost required to certify each piece of equipment depends on the characteristics of each item.

The principal participants in the System Certification process area: (1) the Deep Submergence System Sponsor which is applying for or sustaining System Certification; and (2) the System Certification Authority (SCA), Naval Sea Systems Command (NAVSEA), or Naval Facilities Engineering Command (NAVFAC), which implements the System Certification Process. The Naval Material Command (NAVMAT) maintains cognizance and effects priorities.

Many instruments are manufactured to meet U. S. Navy safety certification requirements. Examples and names of specific sources are offered for information only and do not reflect endorsement of the product described over that available from other sources. Many commercially available scientific instruments have already satisfied U. S. Navy safety certification requirements and are being used aboard manned submersibles..

CONCLUSIONS

1. There exists a broad spectrum of scientific research projects in every major oceanography discipline that can be significantly advanced by a closed-cycle, diesel-powered, lockout submersible facility.

2. New knowledge and understanding can be expected in every major oceanography discipline from the application of a diesel-powered lockout submersible, with its saturation diving capability, to access regions beyond the effective reach of other techniques.

3. Scientific knowledge voids exist within the vertical depths of 30 m to 122 m that can be filled in by a saturation diver operating in the water column and on the seabed. The availability of a diesel-powered

lockout submersible that can support saturation diving to, at least, 122 m can effectively fill an existing void in research data acquisition methodology.

4. The operational performance attributes of the MARITALIA 3GST9 are unique and offer field investigators many advantages not available from other sea-going facilities.

5. Scientific personnel desire to use a diver lockout submersible for research in each of the major oceanographic disciplines.

ACKNOWLEDGEMENTS

The volunteered assistance of scientists from local academic institutions is gratefully acknowledged (their names and affiliations are listed in Appendix B). Thanks to Mr. James R. Stewart for inviting Scripps Institution of Oceanography personnel members to attend the workshop and for making meeting place arrangements. The special assistance of Dr. J. K. (Otto) Orzech and Dr. Sylvia Earle included access to their personal libraries. Sharing information gained from their first-hand experiences as saturation diver scientists pioneering in observation and sampling using this technology was most valuable. Mr. Tim Askew, Harbor Branch Oceanographic Institution kindly supplied data on experience with the diver lockout submersibles Johnson-Sea-Link I and II. The author appreciates the time and the technical information about the MARITALIA 3GST9 provided by Mr. Charles Duchock, Honeywell Advanced Marine Systems and Mr. Joe Hughes, Consultant. Captain Charles B. Bishop, USN (Ret.) provided logistics assistance related to staging the Scripps Institution of Oceanography Workshop, offered counsel and guidance, and monitored the study contract.

REFERENCES

Anonymous, Manned Undersea Science and Technology Fiscal Year 1976 Report, Department of Commerce, Washington, D. C. March 1977.

Anonymous, "Oceanlab Comparative Concept, Cost and Effectiveness Studies of Alternate Oceanlab Systems", U. S. Department of Commerce, National Oceanic and Atmospheric Administration, July 1978.

Anonymous, National Academy of Sciences, Oceanlab Concept Review, Report of a Study by a Subcommittee of the Ocean Sciences Board, National Research Council, Washington, D.C. 1980.

Boyd, J. H. (ed.), U.S. Navy Diving Manual Volume 2: Mixed Gas Diving, Naval Sea Systems Command, Washington, D.C. 1973.

Conners, Lt. Cmdr. Tracey, Project Sea Mark, ALL HANDS, Feb 1988 pp. 18-25.

Earle, S., California Academy of Sciences, undated.

Hamner, W.M., L.P. Madin, A.L. Alldredge, R.W. Gilmer, and P.P. Hamner. "Underwater observations of gelatinous zooplankton: Sampling problems, feeding biology, and behavior." Limnology and Oceanography, 20:907-917, 1975.

Miller, James W. and Ian G. Koblick, Living and Working in the Sea, Van Nostrand Reinhold Company, 1984.

Orzech, J. K. and Smith, K. L. Report of the Water-Column Group of the NOAA Oceanlab Study Panel. July 1979, 23 pp.

Orzech, J.K., Navy Saturation Divers Collect 'Marine Snow' for Science," Faceplate 1984.

Orzech, J.K., "U.S. Navy Saturation Diving Aids Oceanographic Research," Sea Technology, Vol. 24 (12), pp. 19-21. 1983.

Stehling, K., A Submersible Physics Laboratory Experiment, U.S. Department of Commerce, NOAA Technical Report OOE 1, 1979.

APPENDIX A, OCEANLAB CONCEPT REVIEW

The contents of this Appendix was excerpted from: National Academy of Sciences, Oceanlab Concept Review, Report of a Study by a Subcommittee of the Ocean Sciences Board, National Research Council, Washington, D. C. 1980.

(1) Terms of Reference for the study :

1. Oceanlab was defined as a program to make available facilities (primarily a mobile diver lockout vehicle) to carry out complex undersea observational and manipulative tasks in support of ocean research activities.

2. Emphasis was to be on research of the type normally conducted by academic institutions, although use of these facilities would be open to qualified scientists, irrespective of affiliation.

3. Account was to be taken of the important role played by the man-in-the-sea concept in developing the initial Oceanlab program.

(2) Working Group Participants

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APPENDIX B, SIO MARITALIA 3GST9 WORKSHOP April 13, 1989

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MR. ROBERT VAN SYOC, UCSD/SIO, A-008, LA JOLLA, CA 92093

APPENDIX C, SCIENTISTS INTERESTED IN USE OF 3GST9

This is only a partial reference list of California scientists interested in the availability of a diver lockout submersible, such as the MARITALIA 3GST9, to support their research efforts:

Arrhenius, G., University of California, San Diego

Berry, R.W., San Diego State University, San Diego

Boudrias, M., University of California, San Diego

Casey, R., University of San Diego, San Diego

Childress, J. J., University of California, Santa Barbara

Clifton, M., University of California, San Diego

Dayton, P.K., University of California, San Diego

Earle, S., California Academy of Sciences, San Francisco

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McConnaughey, R., University of California, San Diego

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Van Andel, J., Stanford University, Palo Alto

Van Syoc, R., University of California, San Diego

Wilkie, D., University of California, San Diego

Wyman, C., University of California, San Diego

APPENDIX D, SCIENTIFIC RESEARCH AREAS

Among the principal scientific knowledge voids that can be filled using the MARITALIA 3GST9 are in the ocean regions between 30 m and 130 m. The MARITALIA 3GST9 is well suited for oceanographic investigations off San Diego and the Channel Islands. Research areas wherein a diver lockout submersible could be effectively used for data collection and in situ observations are many. The following new scientific thrusts were provided to the SIO MARITALIA 3GST9 Workshop attendees as a starting point for identifying their own research projects.

Global Oceanic and Climatic Processes

- Understanding global scales of oceanic circulation; circulation patterns that contribute to phenomena like El Niño and other interannual climatic variations

- Understanding and providing the scientific basis for predicting the biological productivity of the oceans

- Understanding the carbon balance of the global earth

- Understanding the physics, chemistry and geology of ridge-crest processes and convergence zones

- Aid in the precise placement of bottom mounted instrumentation

- Assist in the maintenance, repair and recovery of moored data collection systems

Underwater Acoustics

- Facilitate the survey of underwater sites, including examination of topography and bottom-bearing strength prior to the installation of test instrumentation

- Aid in the precise placement of bottom mounted instrumentation

- Assist in the maintenance, repair and recovery of moored data collection systems

- Serve as target source, in either an active or passive role

- Work in consort with other platforms, e.g., FLIP

Estuarine and Near Estuarine Studies

- Water management and its relationship to estuarine productivity

- Sediment management and estuarine productivity

- Nutrient inputs and other contaminants and control of primary productivity

- Coupling of primary and secondary productivity

- Habitat requirements for fisheries production

- Aid in the precise placement of bottom mounted instrumentation

- Assist in the maintenance, repair and recovery of moored data collection systems

- Scientific investigations at depths between 30 meters and 130 meters.

- Extending the oceanographic, geological, chemical, and biological characterization of 30/130 m region.

- Canyon studies.

- Extending studies of species composition, chemical, and biological characterization of the 30/130 m region.

- Sampling transects from 30 m to 130 m.

- Macro-photography.

- Equipment test and evaluation, e.g., embedment anchors, fish traps, and in situ soil testing devices.

- Observations and sampling of reefs and reef biota on reefs below scuba depth.

BIOLOGY

- Ecological studies both at midwater boundaries and at the seafloor boundary.

- Life history studies of various marine animals.

- Animal behavior studies.

- Collection of fish by poisoning. Diver lockout capability required in order to make poisoned fish collections in deep rocky areas and other areas inaccessible to other techniques.

GEOLOGY/GEOPHYSICS

- Investigations of primary geological processes and their impact on the formation of the Earth's crust and the marine environment.

PHYSICS

- Study of ocean stability, ocean floor, and subfloor characteristics, biological populations, and ambient noise as related to acoustics.

- Ocean currents and other motion phenomena.

CHEMISTRY

- Determine the chemical oxygen demand of the water column and the sediments.

- Determine the role of sediment/water and water/water interfaces in the energy and nutrient budgets.

- In-situ benthic metabolic measurements.

- Studies to assess the effects and disposition of oceanic disposal of metabolic wastes, hazardous materials, and dredge spoils, and evaluation of toxic substances with regard to removal/abandon decisions.

- Outfall plume studies.

ENGINEERING

- Implant, observe, maintain, test and evaluate performance of in-situ bottom-mounted and mid-water anchored scientific equipment for the collection of oceanographic data.

- Engineering survey transects.

APPENDIX E, INSTRUMENTATION OPTIONS

It is the add-on sub-systems that provide much of the quantitative data collection capability, operational effectiveness and versatility needed to meet both general and specific scientific research requirements. Using state-of-the-art sub-systems it is possible to configure a manned submersible to meet many scientific research project requirements. The following sub-systems are now available from U.S.commercial sources and are included here as a reference resource.

Obstacle avoidance sonar
Gyrocompass
Depth sensor
Altitude sensor
Current meter
Acoustic velocimeter
Pipe/cable tracking systems
Transponder/interrogator Transponder/responder
Side scan sonar
Conductivity potential probe
Transponder place/replacement tool
Hydraulic tool package
Still cameras
Video cameras
Flood and strobe lights
Fiber optics
3-function grabber
7-function manipulators
High pressure water jet (cavitation jet)
Low pressure jet for silt removal
Alignment measurement tool
Specialized lifting tools

Hydraulic power pack
Conductivity-temperature-depth sensor
Sound velocity
Waves and tides
Water current
pH
Redox
Oxygen sensor
Corrosion potential monitoring
Specific substances sensors
Radiographic instruments

Oceanographic instruments, available as off-the-shelf units, can be installed aboard most manned submersibles as extra payload. Buoyancy can be added to compensate for instruments that exceed the normal manned submersible payload. It is fortuitous that many newer versions of oceanographic instruments have built-in recording capability for unattended use. These systems can be mounted on a manned submersible quickly and without concern for telemetry links or power connections. In most instances hardwire telemetry is an optional mode of operation for these off-the-shelf oceanographic instruments.

SALINITY /TEMPERATURE/DEPTH/SOUND VELOCITY GRAPHIC RECORDING PROFILER

Oceanographic instrumentation that is immediately compatible and amenable to simple installation aboard a manned submersible includes a model that is self contained, self recording, and simultaneously measures: salinity and temperature as a function of depth; sound velocity; dissolved oxygen; pH; and turbidity with automatic switching circuit. Redox and specific ion measurements are also included in this profiler model. It is convertible to self contained digital recording or remote readout profiling system. Neither electrical cable or shipboard electronics is required. The instrumentation package is portable and its in-water weight can be easily offset to neutral buoyancy for installation on a manned submersible by the addition of fixed buoyancy.

The researcher has the option of using the instrument in several configurations. With the analog module attached it can be used as a self-contained graphic profile recorder. By disconnecting the analog recorder module and adding an appropriate length of cable and remote data display, the system can be used as a remote readout real-time data display acquisition system. Alternatively, a self-contained digital magnetic tape cassette data recording module may be attached. In this configuration the researcher may obtain high accuracy digital recordings of all parameters simultaneously while profiling or while the system is installed on a mooring (specific placement by a diver).

CONDUCTIVITY/TEMPERATURE/DEPTH SENSOR

An available oceanographic data acquisition system is designed for deep water operation where extremely high precision and reliability are required. The probe continuously and simultaneously measures conductivity, temperature and depth, with optional sound velocity or dissolved oxygen sensors. Data transmission to the support platform, if desired, is done in digital mode. Frequency shift key, serial ASCII code is used at a rate of 7200 BAUD. This provides for 30 data scans (of four parameters per scan) each second. At a profiling rate of about one meter per second a set of measurements of conductivity, temperature, depth and sound velocity would be obtained for each centimeters of a vertical or horizontal profile. This model has an in-water weight of 34 kg and has a standard depth rating of 6,000 m.

Individual sensors can be installed on a manned submersible to measure selected parameters. The above illustration indicates that a combination of sensors can be added to almost the entire range of manned submersible sizes and payload capacities. Installation of but one or two oceanographic sensors should not be a problem. Vehicle thrust capacity will determine horizontal range and maneuvering response. Most oceanographic instruments can now be operated, at the researchers option, as a direct readout system or in a remote recording mode. The manned submersible or diver can be used to install long duration implants for later recovery.

WATER CURRENT METERS

Water current measurement instrumentation suitable for installation on a manned submersible are available from several sources. The following products are used as illustrations of compatibility:

WATER CURRENT METER--DIGITAL MAGNETIC TAPE RECORDING TYPE

A self-contained recording current meter of low cost, with digital magnetic tape cassette recording for current speed and direction with optional temperature, conductivity, and depth. It contains a duty cycle programmer so that the researcher can select either continuous recording or periodic reading for 2 to 30 minutes every l to 5 hours. With a data capacity of 300,000 words the instrument is capable of recording speed and direction every 8 seconds for l0 minutes duration every three hours for 250 days. The instrument package can be installed on a submersible or implanted and retrieved by a manned submersible. Its in-water weight is 4.5kg and has depth ratings of 0-l,000 m and 0-6,000 m.

WATER CURRENT METER--ELECTROMAGNETIC TAPE RECORDING TYPE

An available electromagnetic current meter is a self-contained, digital magnetic tape cassette recording instrument with switch selectable programming of data rate, recording duration, and recording periodicity. The sensor has no moving parts, is resistant to mechanical damage, possesses excellent direction and tilt responses, is insensitive to vertical motion, maintains long term stability and has low maintenance requirements. The fast data rate acquisition of the recorder suits the rapid response of the electromagnetic sensor and flux gate compass. Data capacity is 300,000 data words which permits the acquisition of high density data or very long term deployment. Its in-water weight is 2.7 kg and it has a depth rating of l,000 m.

WATER CURRENT METER--SOLID STATE TYPE

An available current meter is a spherical solid state sensor, microprocessor driven instrument which records data in any manner desired with high accuracy and reliability in a sealed easy-to-use housing. It has no moving parts or fragile sensors. The sphere is made of high strength dimensionally stable plastic with a titanium main load bearing shaft. The compass and all electronics including data storage and power supply are sealed within the sphere. Information is stored in a solid state memory and is retrieved through an RS232 port to the user's terminal, computer or other storage device. This sensor represents a breakthrough in water current meters and is probably the best choice for installation on a manned submersible. It functions well near the surface where excellent horizontal and vertical cosine response is needed. In low current regimes, such as can be expected in deep ocean regimes, this sensor has exceptional stability and resolution. Flow rates and mechanical forces such as those generated by a moving manned submersible can be accommodated by its low drag and lack of moving parts. The internal fluxgate compass operates within specification when the sensor is tilted a full 25 degrees. The recorder memory is included within the sphere (CMOS static RAM 64 Byte (Optionally l28 Byte) 40,000 N, E Vector averaged pairs>l year using l5 minute samples (l28 Byte Option). Its in-water weight is less than 2 kg and has a depth rating of l000 m.

ULTRASONIC THICKNESS

A non-destructive test instrument for measuring the in situ condition of marine structures is being effectively used on manned submersibles. Thickness of structures is being measured from manned submersibles using ultrasonic techniques. This involves placement of a small acoustic transducer against structure cleaned of bio-fouling and any corrosion deposits. The induced vibration is received by the same transducer for display and analysis. Several commercial ultrasonic systems are suitable for this manned submersible application.

CORROSION POTENTIAL (c-p)

Instruments to measure corrosion potential have been successfully applied to monitoring the performance of cathodic protection systems. Commercially available c-p systems are available for manned submersible applications.

RADIOGRAPHY

Radiographic testing is used for flaw detection in metals. There has been limited manned submersible application of this technology. A radiation (gamma) source is placed on one side of a specimen. A photographic film plate is placed on the opposing side. The results appear as a shadow that can be interpreted for flaws and plate thickness.

BIO-FOULING REMOVAL

Cleaning of bio-fouling and corrosion removal for maintenance and repair is being accomplished by several techniques: rotary brush and grinders; high pressure water jets; and very high pressure hydraulic cavitation 1,054 kg/cm2 (15,000 psi). Manned submersible application of these devices requires the capability to maintain a fixed position reaction force. Due to the high power consumption rate of these devices, the prime power source is on the surface.

MAGNETIC SENSING

Magnetic sensing instruments are being added to manned submersibles for determining the thickness of overburden covering a pipeline or cable. These instruments are used to locate and track buried or exposed cables on the seafloor under zero visibility situations. They usually consist of two fluxgate magnetometers that are coupled to act as a magnetic gradiometer. Peak amplitude signals occur when the system is directly over the buried object. Detection depths to 3 m (10 ft.) and a depth accuracy better than 10 cm (4 in.) are possible.

BOTTOM PENETROMETER

An expendable Doppler penetrometer system, is designed to acquire data on bottom soil characteristics by methods faster than conventional sampling with a grab or coring device. Applications include site surveys and exploration of very deep ocean areas where bottom characteristics have scientific importance. The penetrometer consists of a precise CW sound source and a platform receiver. The sound source can be launched from a manned submersible; it then falls through the water column at speeds up to 100 feet (30.5 m) per second, and penetrates the bottom to as much as 90 feet (27 m). The signal it transmits to the receiver is recorded and analyzed. The Doppler shift caused by the deceleration upon impact provides data relative to the undrained shear strength of bottom soils. The system operates to depths of 6,000 meters. This device could be transported by a manned submersible to precisely known locations and launched on command; thus providing cost-effective access to remote areas.

Profiling acoustic velocimeters designed for measuring sound velocity vs. depth are available as free-fall recoverable units. These can be customized for installation aboard a manned submersible.