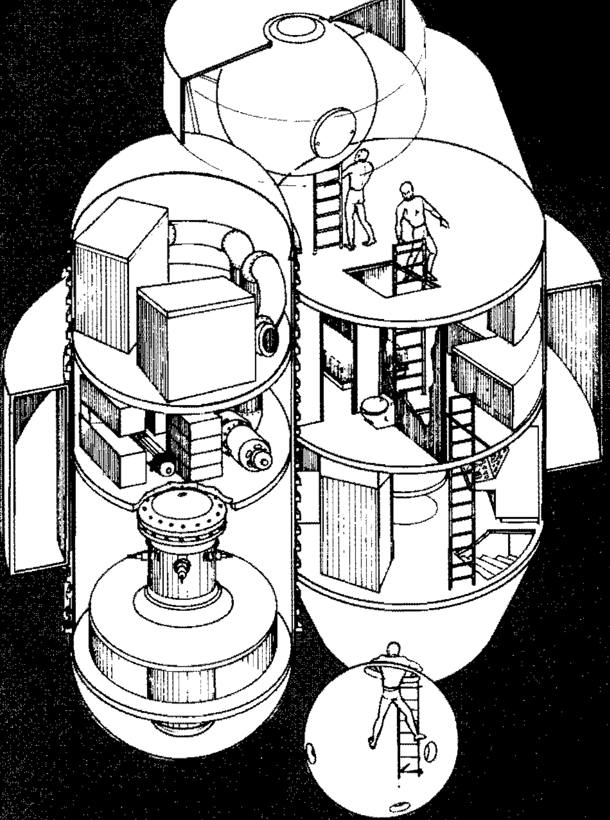


UNDERWATER

report of concept

The Naval Facilities Engineering Command is responsible for (a) Material support functions with respect to: . . . fixed surface and subsurface ocean structures . . .

This extract from the United States Government Organizational Manual, 1967-68, explains why NAVFAC is systematically preparing to get itself into deep water.

The "subsurface ocean structures" aspect of the command's mission promises to be perhaps the most spectacular project it will be carrying on in the next several years.

As a first step, the development of a manned underwater habitation emerged as the logical approach to permit the command to fulfill its deep ocean (sometimes termed 'hydrospace') mission. In order to perform Civil Engineering activities in the underwater environment, the command must gain supporting technology for future underwater construction needs. To do this they must develop the underwater structure for test and evaluation of deep ocean construction tools and equipment, including the integrated operation of the manned station as part of the system. This approach has been determined to be the best means of acquiring the needed knowledge in reasonably acceptable stages.

National Goals Undersea

Beyond this basic necessity for developing and building a Manned Underwater Station, there are several decisive needs that can be met with such structures. First, it will help gain the national objective of exploration, occupancy and possession of the seabed to establish our sovereign rights to certain of its strategic and economic regions.

This use of the seabed by individual nations was established by the 1958 Geneva Convention for the Continental Shelf, which recognized the sovereign rights of coastal states to exploitation and use of contiguous waters and seabed zones to a depth of 200 meters (656 feet) for mineral and oil deposits. Beyond this continental shelf, anyone with the capability can explore, occupy, exploit and possess bottom areas of the deep oceans.

This international agreement makes it essential that the United States develop a Manned Underwater Station, in order to establish such rights.

Further justification for a Manned Underwater Station has been presented by the Interagency Committee on Oceanography, official representative to the White House for all government agencies having an interest in the oceans. The committee has urged the development of manned underwater installations as one of five essential

STATION

development

systems required to further the national commercial interest, as well as serving the needs of the agencies.

Development Task to NCEL

Research, development, testing and evaluation of a first generation habitat was assigned by NAVFAC to the Naval Civil Engineering Laboratory, Port Hueneme, Calif. Commencing nearly two years ago, the program has been carried out by the Ocean Engineering Division, under Joseph J. Hromadik, director.

Specific conduct of the program is carried on by a project group led by Robert A. Breckenridge. Manpower in the group is supplemented by assignment of personnel in the division as well as other divisions and department, as needed for specific tasks. At this time, Breckenridge is assisted in the current concept development phase by Martin Snoey, handling development of the full-scale windows, and Dr. Cheng Lung (Francis) Liu, investigating the hydrodynamic stability aspects of the system.

Functional Requirements

It was determined that the functional requirements can best be achieved with a tethered, manned station having a self-contained, one-atmosphere habitat to provide a "shirt sleeve" environment for a five man crew for a period of thirty days at a 6,000-foot operating depth. The station will not require support from surface vessels or external connections after it is emplaced. It will have a self-contained power source, life support systems and a mating capability with deep submergence vessels for resupply, emergency or rotation of personnel. A back up system allows five day emergency operation.

The hull is to be positively buoyant with controls to enable the crew to position the station anywhere in the vertical water column or on the seabed.

Finally, it is to be recoverable and capable of being moved to another location on completion of its mission.

"These requirements were selected in order to develop a concept that would force technological advancement, produce a usable structure in the very near future at a reasonable cost, and produce a structure of utility that could easily serve many missions within the framework of existing defense and non-defense requirements," says Breckenridge.

Complex of Sub-systems

To limit a description of the design effort to a single "structure" would give a misleading idea of the extent of the effort being put into development of the Manned Underwater Station. More properly it should be regarded

Oceanographer of the Navy, Rear Admiral O. D. Waters, USN, discusses relative merits of different concept designs for a manned underwater station with R. A. Breckenridge, NCEL project leader.

as a system, including structure, power and life support sub-systems, towing and emplacing craft, emplacement mode, an anchoring device, undersea support craft and a variety of auxiliary equipment essential to assure successful employment of the habitat.

The hull is of primary importance however, and received first attention. Other sub-systems were developed concurrently with the development of the hull concept, and some are still being evaluated.

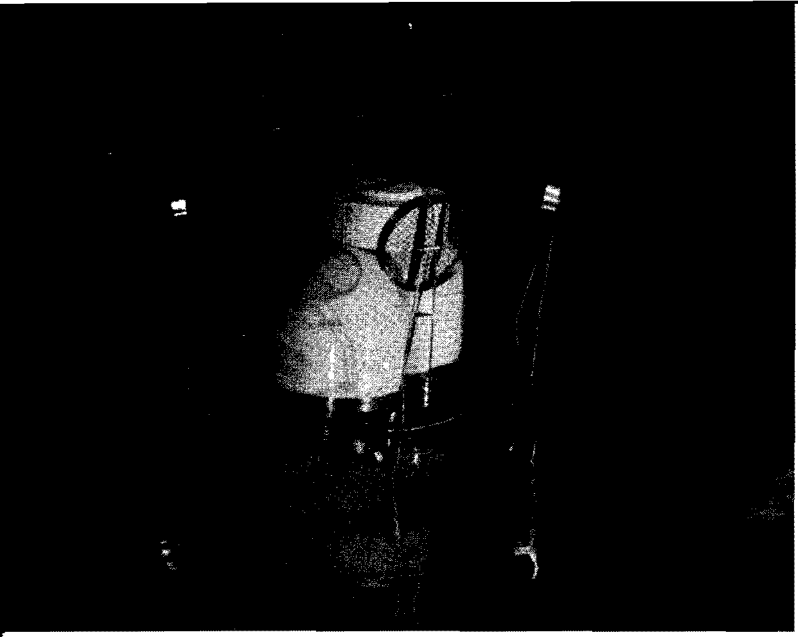
To obtain the most effective system and to develop the necessary range of sub-system alternatives, contracts for conceptual studies were awarded to three firms: General Dynamics, Electric Boat Division, Groton, Conn.; Westinghouse Electric Corp., Undersea Division, Baltimore, Md., and Southwest Research Institute, San Antonio, Tex. In developing the concepts, each firm utilized the state of the art to the maximum, with emphasis on prefabrication.

System characteristics selected for further development from the conceptual studies included vertical cylinders for the pressure hulls, a nuclear reactor for electrical power, and a winch-down placement mode.

The concept that has been developed from these requirements specifies a vertical cylinder 16 feet in diameter and 40 feet high for the living area. With a top access sphere, an observation sphere beneath and stabilizing legs in place, the station will tower nearly 50 feet high.

A nuclear power generation sub-system will be in a separate 12 foot diameter cylinder and will utilize existing reactor technology and power conversion equipment to produce the 30 to 100 Kw. output anticipated for the station requirements. This system will give a high degree of reliability with simplified controls requiring only occasional monitoring.

Girding the coupled cylindrical hulls will be a hollow ellipsoid-shaped ballast chamber that will give the station about a 25-foot draft on the surface. Underwater buoyancy control will be provided with a system of ballast chambers and steel shot held in place by electromagnets and which can be released for increasing buoyancy.



—Photo by General Dynamics, San Diego

Scale model, 1/25th size, undergoes a series of towing tests at General Dynamics towing basin in San Diego. Aim is to determine hydrodynamic stability of the Manned Underwater Station while being towed on surface.

Internal Design

The habitation hull includes 200 square feet of operational area for mission functions and additional space provides "hotel" accommodations for the five-man crew. Observation ports will give an approximately 360° view around the station, as well as a view of the access sphere topside to enable guidance in mating underwater submersibles to the sphere.

Special consideration is being given to the aesthetics of the habitation interior. Recognizing the possibly negative effect of cold-steel surroundings on personnel, NCEL's researchers propose special efforts in interior design and decoration to mitigate the problems that would likely develop in a purely functional environment. For instance, crews quarters will be designed to provide each man a private retreat to enable him to seek solitude as he desires.

Textured pastel paints are recommended to soften the stark surroundings and lighting will be designed with environment as well as function in mind. Acoustic materials and techniques will be utilized to control noise levels.

Life Support System

Life support systems, are still, in the jargon of researchers, "the subject of further trade-off studies." The merits and disadvantages of various systems are being evaluated: the final choice in each case will be made after identification of the method offering optimum value. Major categories of the life support system are water, food, atmosphere and waste management.

The water management sub-system should supply each man at least six-and-a-half pounds of potable water daily, with about twice that amount for personal hygiene. Toilet flush water is the third and last requirement for water. Under consideration are: use of all-stored water, water reclaimed for washing, water reclaimed for all uses, and distillation of seawater.

The atmospheric pressure environment will require the supply of oxygen and the removal of carbon dioxide, noxious gases, hydrogen and airborne particles. Atmosphere options include either regenerative or non-regenerative system; that is, purifying and reusing atmospheric elements, or constantly generating new atmosphere. In the event of emergency, wall-mounted breathing stations will supply oxygen to the crew long enough to rescue them from the station or to bring it to the surface.

The waste management sub-system appears to be the most readily determined. Toilets similar to the ones used on commercial airliners are practical and adaptable to the stations requirements. They will be flushed with reclaimed wash water treated with chemical disinfectants for proper waste control.

Provisioning requirements are still far off, but they must be determined well in advance of actual need in order to provide equipment and space for storage and preparation. Optional food management sub-systems include: use of fresh and canned foods, freeze dried foods, dehydrated or frozen. Meals must be psychologically as well as physiologically satisfying to the crew, and they must require little time to prepare.

Current Activity

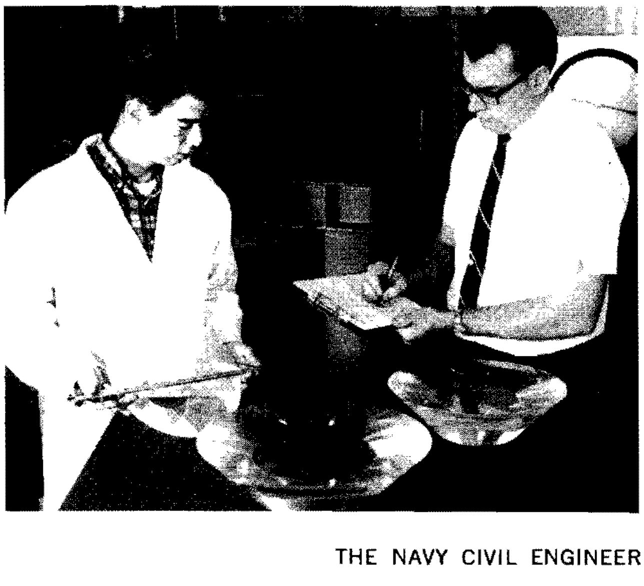
It can be seen that many determinations have been made regarding sub-systems, with life support options the major remaining area for conceptual studies.

This does not mean that the specified sub-systems are perfected. The nuclear reactor power system, for instance, is the subject of concept studies by three contractors at the present time. At the moment the status is simply that nuclear power *will* be used, subject to adaptation of a suitable power conversion system and perfection of radiation shielding for personnel and station safety.

In the hydrodynamic stability aspects being investigated by "Francis" Liu, main efforts at this time are focused in San Diego. There he is having experiments conducted with a 1/25th scale-model of the station assembly in facilities provided by General Dynamics. In their Marine Technology Center, the model is undergoing surface towing tests in the towing basin. "Drag force" stresses created by towing the upright, partially-submerged station are recorded by a strain gage attached to the tow line. Ascending and descending tests are similarly conducted in a large 16-foot deep tank at the Convair Division.

Still subject to experimental and theoretical evaluation is the tethering cable and shock forces it may transmit to the hull assembly while winching down, or tethered in the water column or on the sea floor.

Acrylic plastic windows are evaluated after pressure tests by Martin Snoey, NCEL engineer (right)and John McKay, engineering technician.



The full size windows will be of acrylic plastic material, and tentatively the plan is to use a large size—8" diameter on the interior surface, 16" on the exterior and approximately 4" thick. The resulting shape will have tapered edges to resemble the base section of a truncated cone.

Martin Snoey will repeat the experimental tests of scale-size windows, or view ports, in his studies on the full size windows. The full-scale windows will be subjected to complete stress analysis with strain gages and a theoretical analysis computer program. Other tests and experiments will answer other questions.

Similarly, diligent attention has been and continues to be given to each component in each sub-system, so that the designers can come forth with a complete system of predictable high reliability.

Personnel and Station Safety

For the purposes to which the Manned Underwater Station will be used, both personnel and station safety can be regarded as equally important in the design requirements.

"Safety and reliability are engineering design considerations that have been paramount from the inception of the concept and will remain so through the final design and proof of workability," emphasizes Hromadik.

"The considerations must be tempered with sound engineering judgment," he continues. "They must include not only the aspects of the individual components, but also the overall system, which is no safer than the weakest component.

"A high so-called 'factor of safety' cannot supplant sound engineering judgment," he concludes. "The design of any system must balance the risk of loss against the cost of a high factor of safety. Above all, consideration must be given to the manning personnel and the conditions that will be imposed on them." In conforming to these rigorous constraints, the NCEL group have doggedly pursued the objective of attaining as near 100% safety as possible.

Since the pressure hull assembly is an extremely important sub-system, steps are being taken during the concept formulation process to insure that it will be protected at all times from the catastrophic ingress of sea water. Several methods are being used to achieve this high degree of hull safety.

The pressure hull proper, because of its bulk, can not be provided with a redundant backup hull. Rather it will be designed and built with proven construction materials and techquiques, so that it will have a "safety factor" of 1.5 and a "performance factor" of 1.25—which the staff regard as more than adequate, considering the positive-controlled descent afforded by the winch-down emplacement mode. This factor will provide the added safety for possible over-pressurization due to crew error, depth gage error, winch malfunction, deep ocean swell or local corrosion of the hull. It is also an adequate factor to provide psychological assurance to the crew.

A redundant approach is utilized in assuring safety of the pressure hull sub-systems, whose malfunctioning at operating depths would be disastrous. There will be no wetted penetrations to the main hull; all penetrations through the pressure hull in the form of hatches, electrical bulkhead connectors, mechanical arms, seawater and soil samplers, windows, etc., will be backed up with redundant, water-tight, pressure-resistant bulkheads, which during operation of the individual unit under external pressure will remain closed except for passage of the operator from the main pressure hull.

Sub-system Testing

Hull sub-systems are subjected to testing in a variety of test chambers. Considerable impetus was given to the testing program with the recent installation of a big new pressure vessel at an underground site adjacent to the laboratory. The 6x10 foot inside dimension "hydrospace simulation vessel" will be pressurized with seawater and will be able to accommodate scale-model and some full-size hull components.

Finally, of course, the operational habitat will be subjected to intensive ocean-testing prior to its emplacement at the ultimate 6,000 foot depth. When the five-man crew enters the station on the target date sometime in the early 70's they will have every reason for confidence in the habitat where they will spend the next thirty days.

Reliability in Life Support Sub-systems

Safe operation of all life support sub-systems will be equally predictable while the habitat is in transit or submerged on station. Backup systems and redundancy are provided for all essential functions.

An emergency power supply can be activated to sustain life and assist in recovering personnel and the station itself in the event of main power breakdown. The emergency power source will sustain the station for five days. A special battery pack will be available for operation of the electromagnets powering the ballast shot release.

(Continued on Page 28)

Big hydrospace simulation vessel, with 6 by 10 foot internal dimensions, was recently installed near the laboratory to enable exhaustive testing of station subsystems and full-scale components.