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MANNED SUBMERSIBLES AND SOPHISTICATED INSTRUMENTATION:  
TOOLS FOR OCEANOGRAPHIC RESEARCH

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INTRODUCTION

The development of SONAR, SCUBA and submersibles since the 1950's has permitted man to greatly intensify his exploration of the sea to search for economical harvests of natural resources such as food, minerals and oil. Scientific observations with submersibles actually began with the tethered BATHYSPHERE in 1932 when William Beebe and Otis Barton dove to 900 m in the waters off Bermuda (Ref. 1). Their technical success and biological reports encouraged the design and use of other surface-connected as well as free-roaming vehicles for undersea investigations, e.g., FNRA III (Refs 2, 3) SOUCOPE SP 350 (Ref. 4), Deepstar 4000 (Refs 5, 6), ALVIN (Refs 7, 8, 9), TURTLE and SEA CLIFF (Ref. 10), JOHNSON-SEA-LINK (Refs 11, 12) and PISCES IV (Refs 13, 14). Today, only two of these vehicles regularly conduct oceanographic research. ALVIN continues, as it has since 1963, to focus on phenomena near the sea floor at depths reaching 4000 m, e.g., the physical-chemical processes and biological communities near hydrothermal vents. The JOHNSON-SEA-LINK submersibles, second generation vessels operating since 1971, have logged over 2000 dives to conduct studies as deep as 600 m in the water column and along the bottom.

The instrumentation and tools that have been developed or adapted to support in situ observations and collections of marine life and to measure environmental factors from the JOHNSON-SEA-LINK are presented in this paper. Emphasis has been given to equipment developed for studies of fragile, soft-bodied animals that inhabit the water column. This gear represents only a few of the devices that could be created to facilitate our understanding of marine food webs.

JOHNSON-SEA-LINK SUBMERSIBLES

JOHNSON-SEA-LINK submersibles I and II are owned and operated by the Harbor Branch Foundation, Fort Pierce, Florida U.S.A. (Refs 15, 16). They were constructed in 1971 and 1975, respectively and are virtually identical.

Each submersible has two, physically separated two-man pressure hulls supported by aluminum framework. The forward pressure sphere (10 cm thick x 1.5 m ID) is made of acrylic plastic. The aft diver lock-out compartment (8.4 cm thick x 1.1 m ID x 2.4 m long) is a welded aluminum cylinder with hemispherical ends. The vessels can dive to 800 m. They are maneuvered easily in any direction and can be propelled at speeds up to 1 m/s with the use of eight thrusters. The buoyancy of these submersibles can be controlled rapidly to regulate descent and ascent rates or to float at any depth. The environment outside the vehicles can be illuminated with ten, 375 watt incandescent lights (Birns Snooper) which may be switched

individually on and off or dimmed to a desired brightness. The visible field in clear waters extends outward to at least 15 m from the submersible. An even broader range, up to about 25 m, can be surveyed by a short-arc, xenon light with 30,000 lumen output.

The two viewing stations of the submersible provide quite different perspectives of the marine environment. The angle of view from the two, 18 cm OD ports of the lock-out compartment is limited to about 60° which is typical of most submersibles. The nearly 180° of undistorted view from the sphere is panoramic in comparison and allows both pilot and observer to view aspects of the marine environment simultaneously. This feature is particularly important in that it permits the observer to direct the pilot to move the submersible in position for observation, photography or collection and allows the observer an uninterrupted opportunity to record information independently.

### PHOTOGRAPHIC GEAR

Photographs of marine life are taken routinely in situ using a 70 mm Hasselblad camera fitted with a 40 mm Distagon lens, a 2-diopter Tiffen, close-up filter and a 70-frame magazine. This system was mounted outside the sphere in a pressure-resistant housing (1 cm thick x 21.6 cm OD x 46.3 cm long). The aluminum (6061-T6) housing features a teflon impregnated, anodic coating and an optical quality, spherical dome port (1.3 cm thick,

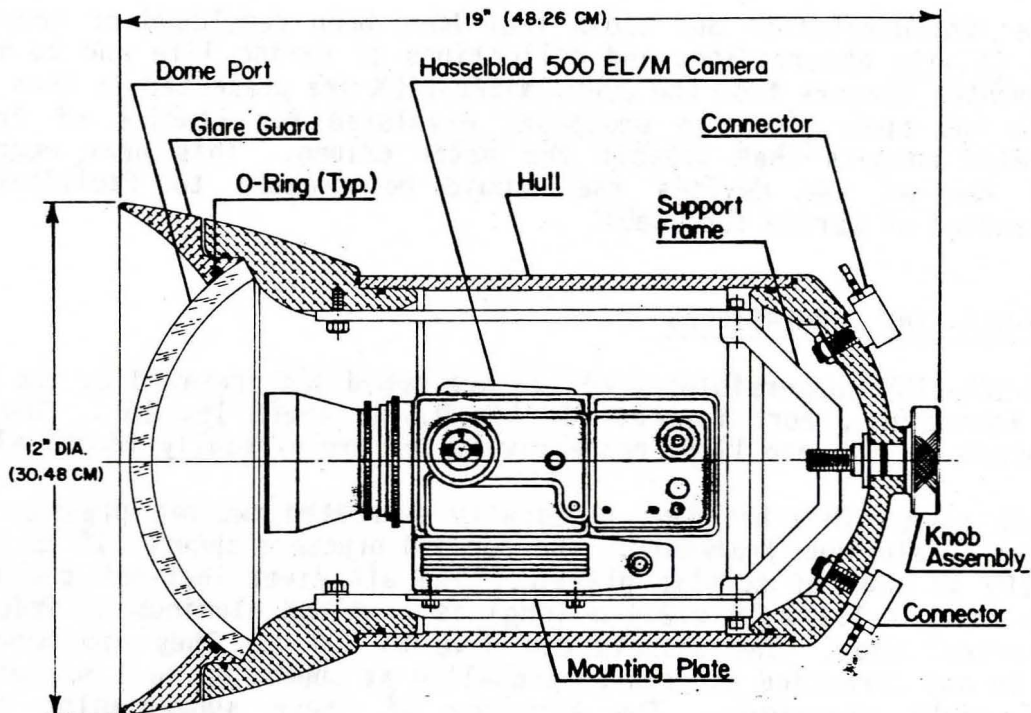


Fig. 1 Cross section of pressure resistant housing for Hasselblad 500 EL/M camera.

120° inclusive angle with a 12.3 cm internal radius, 20.3 cm OD) with a floating O-ring seal (Fig. 1). All other mating surfaces are secured by double O-ring arrangements. A flared retaining lip circling the dome port acts as a glare guard and dome protector.

Light for the camera is provided by four, 400 watt-sec Lumedyne strobe lamps situated above, below and to each side of a 43.2 cm square target zone in front of the camera system (Fig. 2). This configuration suitably illuminates semi-transparent animals creating a darkfield effect.

Underwater inspection and surveillance is performed currently with a high definition, video camera (Marine Optical Systems MOS 3000Z). This system delivers broadcast quality images and has superb color rendition. The more notable features of the camera include: a horizontal resolution of 400 lines, extreme depth of field with Fujinon 6.5-23 mm wide angle zoom lens, minimum focus distance of 5 cm, auto iris range of lens f1.7-f16, minimum illumination of 90 lux at f1.7, compact stainless steel housing (1.3 cm thick x 16.6 cm OD x 60 cm long) fitted with Plexiglas dome window, maximum operating depth of 1000 m. Three lamps (Birns snooperette) are mounted around the dome window to provide illumination (Fig. 2).

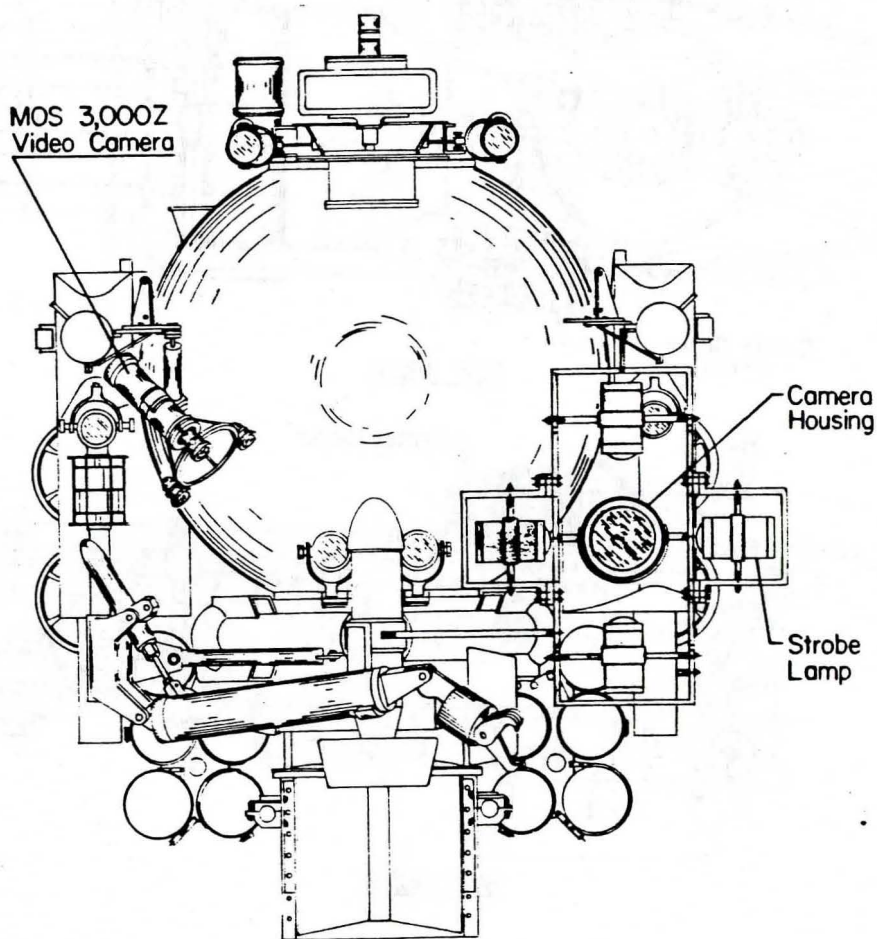


Fig. 2 Front view of JOHNSON-SEA-LINK submersible illustrating the configurations of still and video camera systems.

## COLLECTING GEAR

Animal plankton are collected alive with two types of sampling devices. The first of these systems is composed of two sets of 12 containers (0.64 cm thick x 17.8 cm ID x 20.3 cm high) which are turreted in an oval array within a protective rectangular framework (Fig. 3). A fastener mounted midway up the outside of the cylindrical containers permits each of the sample chambers to be attached to a Delrin drive chain with a removable bolt. The entire arrangement of containers is rotated by a hydraulic-drive cylinder (Allenair SSA) around two sprocket wheels and indexed to stop after a fixed distance. A small incandescent light (Birns Snooperette), situated and directed upward just below one end of the sampling device, can be activated to illuminate the interior of each container as it is rotated over this position. During operation of this tool, a proportionally-controlled, hydraulic pump powered by another pump acting as a motor (Gresen PGG 20010) is used to draw individual organisms into the 3.5-l container through an acrylic tube (7.6 cm OD x 1.5 m long). A 30 cm funnel, attached at the distal end of the tube, enlarges the intake zone and increases the chance of

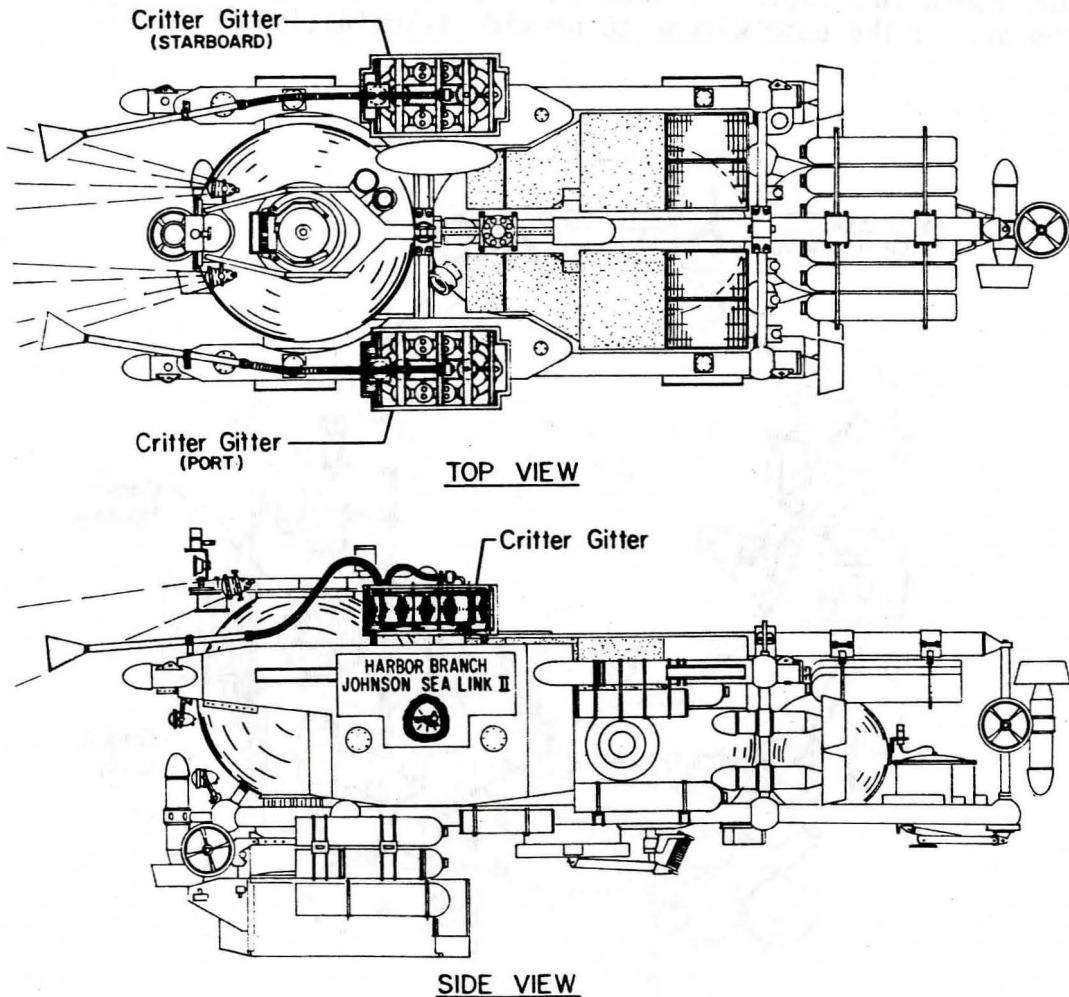


Fig. 3 Diagrammatic views of turreted suction samplers (=critter gitters).

catching a given animal. Suction pressure can be varied with the servo-hydraulic proportional control valve in relation to the fragility of the specimen being collected. Light from the lamp exposes each animal as it enters a container, at which time the pump is turned off and the next container is moved to the sampling position. A snugly fitting lid capping each chamber contains two, 7-cm openings to allow water to enter and exit. Below the intake hole is a baffle (7.6 cm long) to mitigate escape by the specimen collected. The outflow opening is covered by netting (202  $\mu\text{m}$  mesh). A Plexiglas plate (63.5 cm wide x 127 cm long) is situated 0.64 cm above the entire turreted array of containers to prevent any lid from drifting off the top of a container.

Extremely delicate animals or aggregates of marine snow are obtained with eight, specially designed, 6.5-l bottles (Fig. 4). These bottles are clear acrylic tubes (0.64 cm thick x 17.6 cm OD x 35.4 cm long), the ends of which are sealed by a pair of lids that glide horizontally across the openings. Around the inner perimeter of each lid is a rubber gasket. When the lid is moved to the closed position, the gasket is forced against the rim of the tube by a locking arm that pushes a circular disk (10.2 cm OD) against the outer, central section of the lid. The mechanical assembly which moves the lids and locking arms simultaneously is driven by a hydraulic cylinder (Allenair SSA).

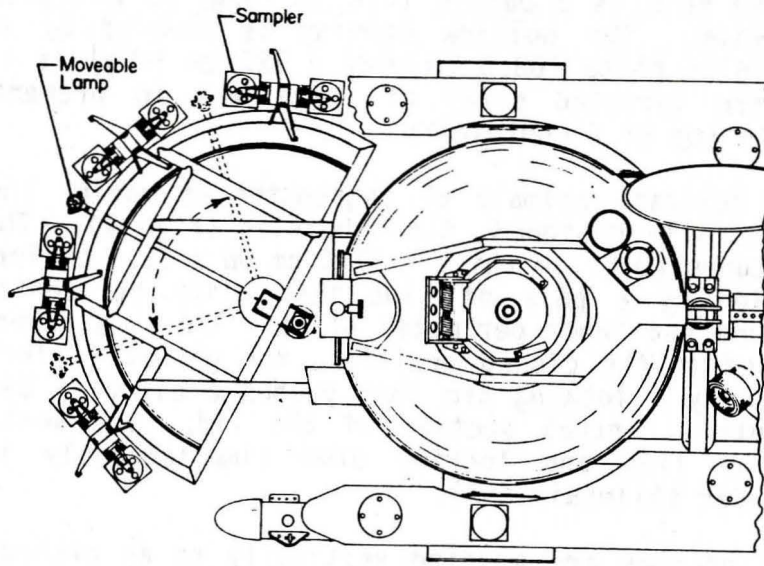
The eight bottles are mounted vertically to an arched framework just forward of the sphere. A small incandescent light (Birns Snooperette) attached to the end of a movable arm can be situated directly underneath each bottle.

To use these sampling units, the lamp is rotated below a given bottle and turned on. The cone of light passing upward and through an opened bottle provides a reference area. The submersible is then advanced to place the animal to be collected within the conical light field projecting above the bottle. Once this task is accomplished, the submersible is propelled upward until the animal passes into the bottle. The closing lids are moved subsequently into place.

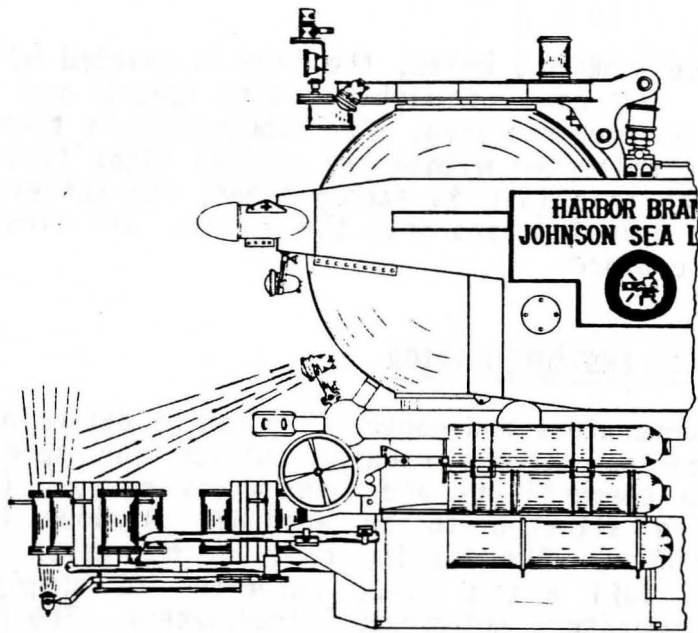
#### ENVIRONMENTAL DATA INSTRUMENTATION

Conductivity, temperature and depth (CTD) can be determined with a compact, real-time monitoring package mounted outside the sphere. The unit is composed of the conductivity and temperature sensors (Seabird SBE-4 and SBE-3) which are attached to an anodized aluminum housing, pressure-resistant to 1000 m. The housing contains the depth (=pressure) sensor (Sensotec Super TJE) and a DC-DC converter to supply voltage to the conductivity, temperature and pressure transducers. The pressure transducer is energized by voltage from the submersible battery.

The three environmental parameters are displayed inside the sphere on three, 4-digit light emitting diode (LED) readouts. The display panel is driven by a stable 1-MHz crystal oscillator and other electronic circuitry that scale and format the waveform data output from the sensors (Ref. 17).



TOP VIEW



SIDE VIEW

Fig. 4 Diagrammatic views of the arrangement of bottles designed to collect fragile planktonic organisms.

Plans are underway to upgrade this simple CTD package into a sophisticated system capable of handling many environmental factors (Fig. 5). At the present time, water samples can be collected in the lock-out compartment of the submersible by opening a pressure relief valve. Water parameters such as turbidity, chlorophyll content, dissolved oxygen and inorganic nutrients must then be determined in shipboard or shore-based laboratories. The second generation data acquisition system proposed would eliminate many of these time-consuming and labor intensive analyses. More importantly, the presence and variability of environmental factors could be obtained at sea in time to alter the course of work or to conduct additional studies to satisfy the objectives of a given mission. The system under development will have four principal components: 1) multiple sensors to measure any parameter desired (e.g., those mentioned above as well as downwelling light, bioluminescence and water current speeds), 2) data logger, 3) data reader-microcomputer with digital storage and 4) hard copy

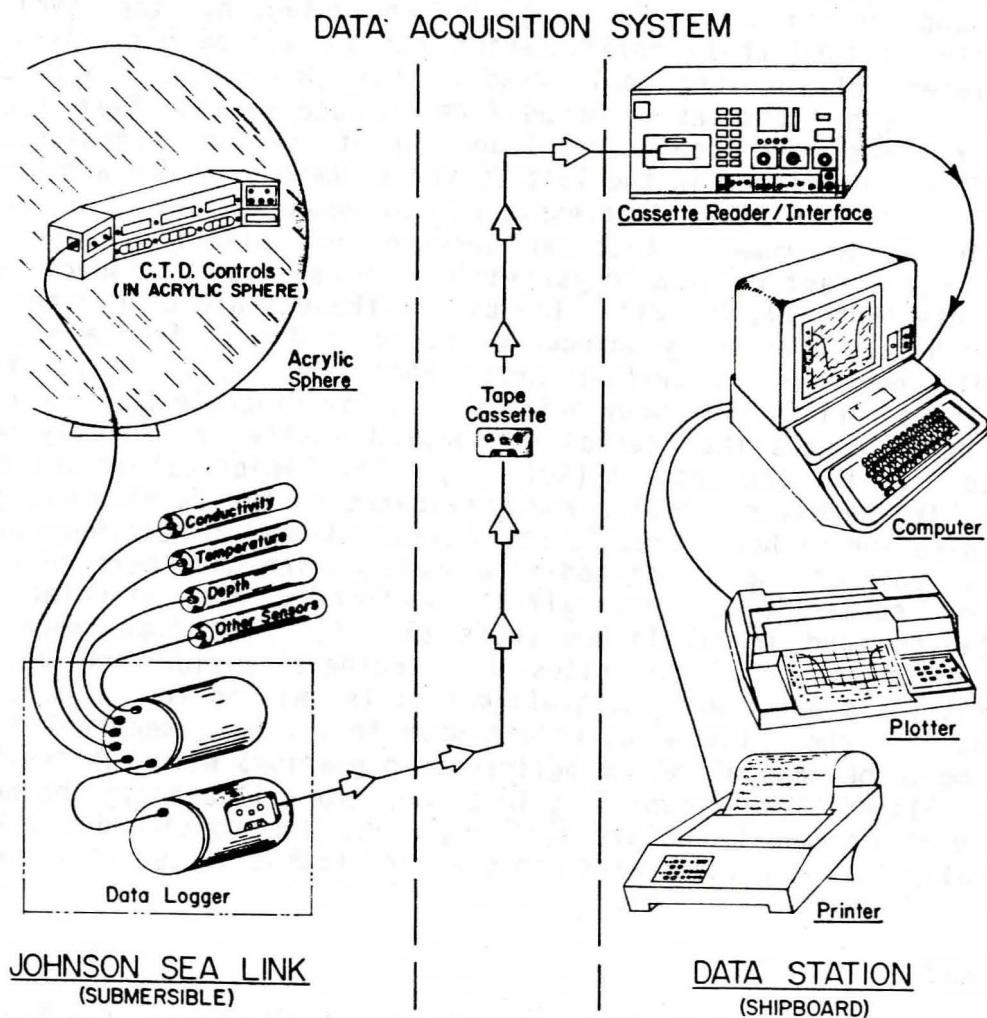


Fig. 5 Rendition of instrumentation assembled to monitor environmental data.



output devices such as printers and plotters. In the envisioned system, items 1 and 2 would be packaged for attachment to the submersible. Real-time display of the data being recorded on the logger would also be presented via LED readouts to observers within the submersible. Items 3 and 4 will be located aboard the surface support vessel to allow information to be processed immediately following the completion of a dive. This retrieval would include data reductions, statistical analyses and graphic displays. The majority of the components needed for the entire system are marketed. The primary challenge for development is to interface the sensors to a common data logging system in ways that permit near-simultaneous collection and storage of data. Note also that the in situ assembly could be attached to unmanned submersibles, tethered to a buoyed array of current meters or moored on the ocean bottom.

## IMPORTANCE OF SUBMERSIBLE TECHNOLOGY

Biological oceanography is a discipline that encompasses investigations of the distribution, abundance and behavior of marine life inhabiting the water column and sea floor. Progress in understanding the evolution and complexity of food chain relationships can be linked historically to the effectiveness of sampling tools used at sea (Ref. 18). Collections from trawls, pumps and bottles tethered from surface vessels have supplied the basis for most of man's knowledge about marine organisms. Modern submersibles, developed in the last 20 years, have provided another means of entering many of the inaccessible environments in the ocean with sophisticated instruments that can observe and collect organisms, measure environmental factors and physiological rates, and conduct short-term experiments (Refs 19, 20, 21). The use of these vehicles has revealed that several animals previously unknown or recognized only from a few specimens are quite numerous in certain areas (Refs 10, 22). Observations from submersibles confirm that many animals occur in discrete aggregations within narrow depth ranges that cannot be sampled easily or reliably with tools deployed from surface vessels (Ref. 22). The biological impact of fragile animals like herbivorous salps and larvaceans or the carnivorous jellyfish, ctenophores and siphonophores is still poorly known in nearshore and oceanic regions. Some of these soft-bodied animals, which have been collected with SCUBA or submersibles, may affect profoundly the standing crops of phytoplankton and larval fishes (Refs 23, 24). The importance of marine snow aggregates as active sites for remineralization and as transport platforms for organic and inorganic materials, within the productive photic zone and throughout the water column down to the deep sea benthos, is just beginning to be recognized and defined by operations with submersibles (Refs 9, 22). All of these recent in situ explorations illustrate the benefits of the "diving approach" and argue strongly for the continued development of technically advanced underwater vehicles and sophisticated instrumentation.

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