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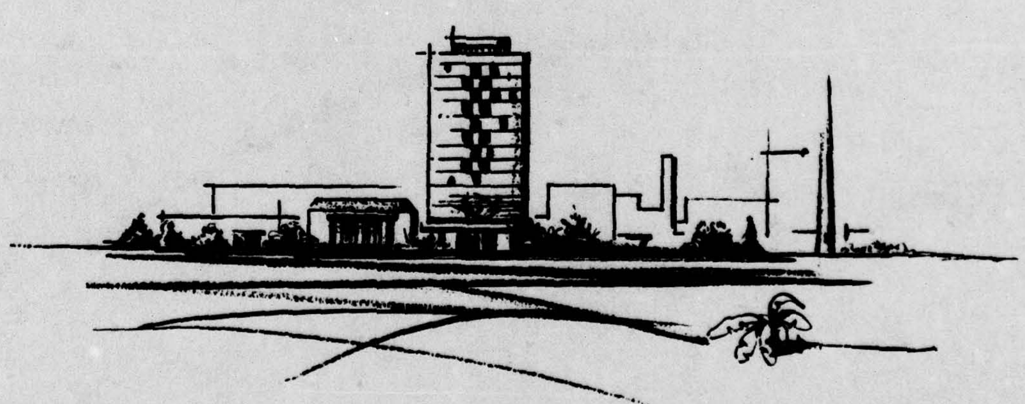

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(6) TECHNICAL ASSISTANCE IN CONNECTION WITH TEKTITE I

to

DEPARTMENT OF THE NAVY

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(10) D. E. Adkins [redacted] A. J. Coyle

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SUMMARY REPORT

on

TECHNICAL ASSISTANCE IN CONNECTION WITH TEKTITE I

to

DEPARTMENT OF THE NAVY

August 20, 1969

INTRODUCTION

Tektite I was a cooperative program between government agencies and industry conducted to determine the capability of a small group of men to satisfactorily perform a scientific research mission while living isolated on the ocean floor for a long period of time.

The program was cosponsored by the Navy, National Aeronautics and Space Administration, and the Department of Interior, with participation by the U. S. Coast Guard. The prime contractor was the General Electric Company, which furnished the undersea habitat and assisted in program planning and scientific-mission coordination. Battelle-Columbus participated in the program under Navy/Industry Cooperative Research and Development Agreement Number R-485-91. Battelle-Columbus responsibilities in Tektite were to:

(1) Provide technical and engineering assistance to the Office of Naval Research

(2) Coordinate acquisition and deployment of a decompression complex

(3) Review habitat systems and subsystems to assist in assuring proper performance

(4) Monitor habitat systems and subsystems on site to provide an unbiased evaluation

(5) Provide hardware integration and program planning support

(6) Supply the hookah system, two types of coring tools, and built-in breathing (BIB) equipment for habitat use

(7) Coordinate on-site aquanaut training

(8) Rebuild, modify and test the dated two-man wet submersible (mini sub) to be used by the aquanauts on excursions from the habitat

(9) Provide diving support during the construction and habitat deployment phase of the program and during the research studies of the three standby aquanauts performed outside their excursion limits.

(10) Assist with responsibilities associated with the control van and support equipment.

Tektite I was the first undersea program to be undertaken by a group of Federal agencies, in cooperation with private industry.

Four marine scientists from the Department of the Interior lived for a period of 60 days, beginning February 15, 1969, in the Tektite I habitat on the ocean floor at a depth of about 50 feet. During this time the aquanauts breathed a nitrogen/oxygen gas mixture where the percentage of oxygen by volume was approximately equivalent to that at the surface. The site for this pioneering saturation dive was Great Lameshur Bay, St. John, Virgin Islands, chosen for its favorable climate, clear waters, and abundant undersea plant and animal life.

The aquanauts lived in a marine laboratory, both on the ocean floor and in the habitat working spaces. This environment provided an unprecedented opportunity for intimate long-term marine investigations.

While the scientists were conducting their underwater research mission, they were continuously observed by Navy and NASA behavioral and biomedical teams. Very complete psychological and physiological data were obtained identifying man's reactions to a long-term mission performed in an isolated, hostile environment common to both undersea and manned space missions.

This report deals mainly with problem areas uncovered during the mission with habitat and support equipment hardware as well as with the evaluation of certain procedural items. No attempt has been made to describe the operation and functions of all the equipment discussed; this description has been left to those with original and ultimate responsibility in each area. Only the problem areas and possible improvements for future missions, which should be familiar to those intimately associated with the program, are expounded herein. Although the remarks are directed specifically toward the Tektite I program, they also pertain to typical areas for improvement in equipment for other experiments of this type.

CONCLUSIONS AND OBSERVATIONS

(1) Four scientist/divers can be autonomous and perform useful research for 60 continuous days at a 50-foot depth on N_2O_2 mixture, can be safely decompressed, and will exhibit no adverse physiological or psychological problems.

(2) The total aquanaut time on the bottom was divided into the following general areas, with each area assigned an approximate average percentage figure:

	Average Percent of Time
Scientific Work	32
Sleep, Rest, and Relaxation	22
Recreation	16
Self-Maintenance Activities	16
Habitat Maintenance and Repair	10
In Transit	4

(3) The scientist/divers spent 432:15 man-hours in the water during the 60-day mission. This represents an average of 7.2 man-hours per day.

(4) The Jack Brown full-face mask with communications was usable up to 200 feet from the habitat. The mask and communications package were more than adequate and were used more than 41 diving hours during the mission, about one-tenth of the total diving time.

(5) In situ habitation in strategic ocean locations at reasonable depths provides effective use of time in diurnally investigating undisturbed scientific, biological, and geological phenomena over long periods of time.

(6) Saturated swimmers, in water with average visibility of 50 to 75 feet and between depth limits of 21 to 100 feet, can perform excursion dives from the habitat to distances exceeding 1800 feet and return safely.

(7) The performance by a number of support scientist/divers of research work to no-decompression limits around the perimeter of aquanaut excursion limits significantly adds to the total scientific coverage of the area.

RECOMMENDATIONS

The recommendations listed are based on a survey of the overall program. Many of the suggestions deal with minor problems, but unless the small problems are recognized at this time, they may become major problems in future programs. The specific suggestions included in this section may be used as typical examples for consideration during retrofit and/or the design of additional habitats.

Habitat Systems

Structure and Interior Design

(1) A hatch that opens from the cupola into the engine room that remains dogged when the cupola is not in use could be installed for safety. If a cupola window were broken the hatch would seat firmly because of higher habitat pressure and prevent loss of gas and flooding of the habitat.

(2) Storage areas and work spaces could be redesigned to provide more study and laboratory space.

(3) Mechanical leveling legs could be installed to level the habitat base. A needle valve installed in the emergency hatch in the crew's quarters could eliminate pressure differential caused by poor leveling and this would allow the emergency hatch to be opened quickly.
(Note: Small differential pressures acting on the large areas of hatches can exert large forces in either direction.)

(4) Holes in the base should be screened off to prevent dangerous marine animals from entering the shark cage area.

(5) Emergency air bottles could be placed under the crew's quarters, leaving clear space in the passage under the wet room.

(6) Prime and paint habitat decks well in advance of mission start to allow complete drying and eliminate peeling and formation of rust.

Environmental-Control System

(1) The CO_2 scrubbing system should be redesigned to include an efficient canister to prevent channeling, to provide sufficient absorbent bed capacity, and to increase the dwell time of gas in the absorbent.

(2) The use of Sodasorb or lithium hydroxide as the CO_2 absorbent may be considered.

(3) The NASA mass spectrometer should be analyzed, redesigned, and completely evaluated for hyperbaric applications prior to the next mission.

(4) To eliminate the effects of layering and heavy gases collection in low points, adequate exhaust and gas removal should be provided.

Thermal-Control System

(1) The seawater switch used to control coolant flow to the compressor could be made of corrosion-resistant material and be protected by a waterproof container to reduce maintenance time.

(2) The problem of dripping condensate water may be eliminated by installing more insulation on the airflow ducts and drain lines and by more direct routing of heat-exchanger drain lines to the sump.

(3) Fuses should be protected from possible condensate formation, which causes failure, by enclosing them in a more tightly sealed fuse box.

(4) Soundproof paneling could be installed in the engine room to attenuate machinery noise.

Scuba Charging, Low-Pressure Air, and Emergency Air Systems

(1) The scuba-charging panel could be moved and plumbed in a more convenient location.

(2) Rather than using the emergency air bank to charge scuba tanks, a larger bank of receivers could be installed topside to maintain a constant supply of high-pressure air to the charging station.

(3) Low-pressure air lines could be plumbed near the 10-inch trunk to permit easy exit of the hookah hoses.

Plumbing and Sanitary System

(1) A gooseneck fitting should be installed in the sewer outfall line near the toilet discharge to trap sewer gas and eliminate introduction of methane and other harmful gases into the habitat atmosphere. In addition, an air fitting may be provided on the outfall line to permit the aquanauts to blow out the line to remove built-up material.

(2) The bilge pump in the wet room could be reoriented to allow the bilge to be pumped dry. In addition, all components known to be vibration sensitive should be locked and/or wired to prevent vibration failures.

(3) The inlet to the seawater pump could be screened to eliminate small fish from being sucked into the rotor blades and possibly clogging the pump.

Communications System

(1) The intercom sets in the habitat should be reconditioned or replaced before the next mission to eliminate speaker noise and feedback.

(2) Casings for sound-powered phones in the way stations could be redesigned to keep the phones dry, and operating procedure to receive communication from way stations should be clearly delineated.

(3) Underwater TV cameras could be repaired and evaluated before they are brought on the site. It may be possible to provide pan and tilt mechanisms for more effective use of the cameras.

(4) The sound-powered phone on the bridge should be replaced by a Bogen or equivalent.

Electrical System

(1) For future missions, habitat electricity could be grounded at the surface support facilities.

(2) The reheater circuit breaker in the crew quarters should be replaced with a less noisy model and/or be relocated in a more remote area.

(3) The clothes dryer could be replaced with a washer/dryer combination for convenience. This change will take up very little additional space.

General Recommendations

(1) The aquanaut crew consisting of four aquanaut/scientists could be expanded to include one engineer to assume responsibility for equipment maintenance, habitat resupply, and housekeeping chores, thus freeing the scientists to conduct their primary research mission.

(2) The habitat could be given a dry run in the shipyard at bottom pressure, not only to check the workability of the systems, but also to help train the new aquanauts before the start of a future mission.

Habitat Interfaces

(1) The navigation grid system was not used by the aquanauts during the mission and may be eliminated in future programs.

SUMMARY REPORT

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August 20, 1969

by
D. E. Adkins and A. J. Coyle

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(2) Provisions could be made on or in the habitat for stowing 200 feet of hookah hose and the masks in a convenient manner.

(3) More reliable, longer range, free-swimmer communications are needed for the next mission.

(4) New, noncorrosive transfer pots should be supplied.

(5) A closed-circuit, shallow-water dumbwaiter system could be designed and developed to speed up transfer of supplies.

Habitat Support Equipment

(1) Larger capacity pumps could be used to transfer water and diesel fuel to the support facilities. This would significantly reduce transfer time.

(2) A critical spare-parts inventory should be established for the crane to eliminate lengthy downtimes due to failures.

Aquanaut Support Equipment

(1) Longer range, more accurate pinger/receiver sets would be useful for underwater lobster research.

(2) Additional equipment could be used for studying lobster habits, including an underwater photocell-light-source movement detector and a phosphorescent grease or paint with a black light for identifying lobsters and landmarks at night.

(3) Development of plankton-sampling equipment should continue.

(4) Storage space could be made available in the wet room of the habitat for dry storage of the underwater electric coring tool if it is used on future missions.

(5) Research could be undertaken to develop a long-duration, semi-closed breathing device capable of lasting 4 hours at 50 feet using a N_2O_2 breathing mixture.

(6) Reliable, operational swimmer delivery vehicles could be provided for aquanaut excursions, which are capable of maintaning 3 to 5 knots for at least 4 hours.

Habitat-Deployment Procedure

(1) When using the Tektite I habitat for future missions where a Landing Ship Dock must be used for transportation, it is recommended that the same emplacement procedure be used. The LSD does not have sufficient water depth in her launch well to float the habitat out without being mounted on a sinkable barge.

(2) A more efficient method of habitat ballasting could be incorporated for future missions.

Aquanaut Training

(1) A longer, more extensive training period could be provided for future aquanauts that deals both with the habitat hardware and with aquanaut support equipment.

Logistics and Facilities for Support Personnel

(1) For future missions at the Lameshur Bay site, a stable pier could be built at Cabritte Horn Point for use as a support platform for habitat support equipment. The access road could be extended to the tip of the point.

(2) For shallow-water missions at sites other than Lameshur Bay, the economics and convenience of using a large vessel such as an APL for surface support, berthing, and messing should be considered.

(3) If the base camp at Lameshur Bay is to be used again, improvements may include a hot-water heater and improved latrine facilities.

HARDWARE EVALUATION

Hardware in the Tektite program can be divided conveniently into four main areas: habitat systems, interfaces, habitat support equipment, and aquanaut equipment. Base-camp machinery will not be discussed in this report; however, the overall concept of the base camp will be dealt with in the section on Procedure Evaluation.

A basic objective of the program was that minimum development money would be expended in an attempt to keep costs low. Each habitat system was fabricated with many off-the-shelf components; only the dual-can concept with a crossover tunnel indicated significant change from previous habitat designs. In conjunction with this structure, some of the subsystem routings had to be different to accommodate standard conditions in each cabin. In addition, the emplacement environment (shallow, warm water) allowed further simplification in design, eliminating expensive breathing gas and extensive insulation and thus further reducing costs.

Most of the hardware associated with the program is discussed below, dwelling mainly on equipment problems as an aid in planning future missions.

Habitat Systems

The habitat as a whole provided a comfortable and very livable home for long-duration, shallow-water, saturation dives (see Figure 1). As a laboratory it was not optimum, but adequate. A number of small problems occurred, some caused by human error and some by design or equipment faults, most of which required remedial action and some of which caused a large degree of concern. In pointing out problems and faults, it must be borne in mind that the majority of equipment functioned as designed and that the design success of most aspects of the habitat provided major contribution to the overall success of the program.

Structure and Interior Design

The basic structural design of the habitat was good. The brightness of the paint clouded somewhat with marine growth over the 60-day duration, but no significant external corrosion was noticed. However, paint and primer flaked off the deck in the wet room, allowing rust to form on the exposed steel. This rust and paint falling into the bilge clogged the strainer to the bilge pump and thus restricted water removal. The problem can be eliminated by priming and painting the decks well in advance of mission start.

Various comments made by the aquanauts on habitat structure and interior, including lack of effective laboratory work space and study areas, the attitude of the structure, holes in the base, and the crossover tunnel, are presented in the Appendix to this report.

The most consistant complaint involved lack of adequate work space and crowded study conditions in the bridge and the wet room. Since the habitat cannot be made larger without excessive expenditure, two avenues are open. First, storage areas and work spaces may be redesigned so that seldom-used supplies are stored in remote areas (i.e., in tanks below the crew's quarters) and seldom-used cabinets are eliminated. The resulting space may be used for separate work spaces. Second, a separate chamber (garage) could be constructed to provide wet laboratory work space having vented hoods or absorbents for use of toxic research chemicals as well as to provide a service area for charging and maintaining an excursion submersible.

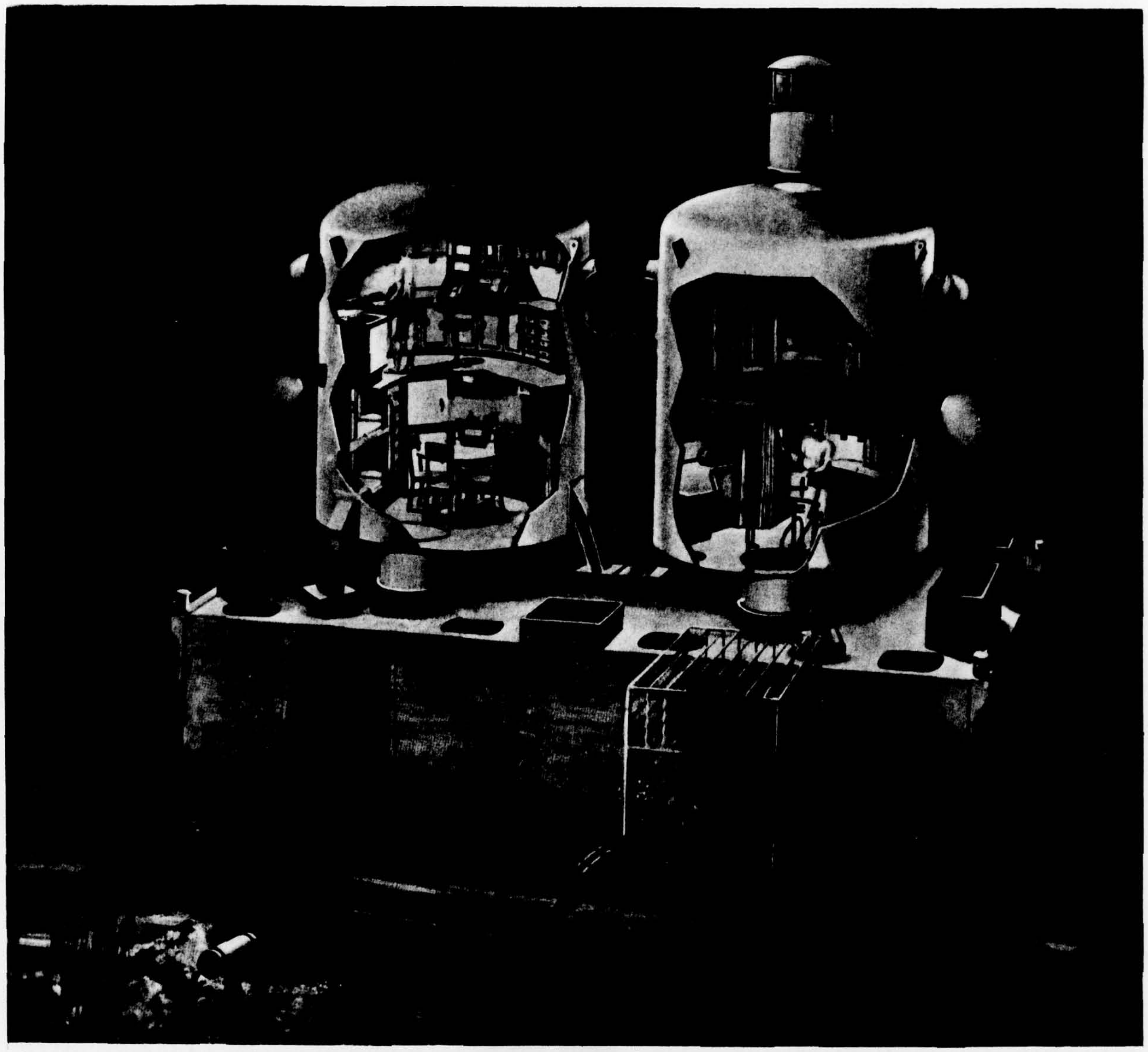


FIGURE 1. CROSS-SECTION VIEW OF TEKTITE I HABITAT

It was noticed that water collected in puddles behind the sinks in both the engine room and the wet room and the cabinet doors swung open in the same sloping direction both in the crew's quarters and in the wet room. It may be that the habitat was not level on the ocean bottom. Even though the bottom was leveled by the Seabees prior to emplacement, over the 74-day time the habitat was on the bottom, the habitat may have settled. This is not particularly important to habitation; however, if the emergency hatch in the crew's quarters is only 1/2 foot higher than the hatch in the wet room, a force of about 450 pounds is necessary to overcome the pressure on the emergency hatch. Of course the reverse could occur too. Fortunately, it was not necessary to use this hatch. Mechanical leveling legs could be installed to level the habitat and an internal needle valve in the escape hatch could quickly equalize any other pressure differentials.

Holes in the base of the structure should be either screened off or welded shut to prevent dangerous marine animals from entering the shark cage area. One moray was encountered in the trunk and was dispatched. Others were seen entering through these holes. It was estimated that, many times, morays lurked among the emergency bottles stored in the trunk. In addition to covering the access holes, the emergency bottles could be moved and plumbed for use in the area under the crew's quarters, leaving clear space in the passage under the wet room.

The crossover tunnel held up well as a structural item. The four pinhole leaks noticed in the beginning of the mission gave no trouble. However these should be repaired for future missions. In addition, inconvenience in using the tunnel was noted. The occupants must duck walk or crawl through the tunnel many times a day. Since, functionally, it proved effective, the problem of crossing is a matter for personal adaptation.

The cupola was seldom used as an observation station because of poor visibility conditions. If the water were clearer or if a sonar were available for signature studies, it would have been used more extensively in the marine sciences program. However, since the cupola was the highest point on the habitat, if a window were broken the N_2O_2 mixture would escape and be displaced by water very quickly. A hatch that opens from the cupola into the engine room could be installed that would remain dogged when the cupola is not being used. Higher habitat pressure would seat the hatch and keep water from entering the open trunk if a window were broken.

Environmental-Control System (ECS)

The environmental-control system is divided into five subsystems: gas supply, CO_2 scrubber, thermal control, scuba charging, and emergency air.

Gas Supply. No problems occurred during the initial nitrogen fill or while supplying make-up air at flow rates between 12 and 29 scfh to the habitat. However, many times during the program the dessicant container on the low-pressure compressors was not tightened or the bleed valve was loose. This results in line leakages and high pressures when the components are finally secured.

CO_2 Scrubber, Instruments, and Contaminant Gases. A significant problem developed with the CO_2 scrubber. The habitat was occupied at 1155 on Saturday, February 15, 1969. At 2350 on Sunday, February 16, 1969, the CO_2 level rose to 10.2 mm Hg or 1.34 percent surface equivalent by volume. Threshhold limits for CO_2 published by the Bureau of Medicine and Surgery are 3.8 mm Hg or 0.5 percent. In addition, it is generally accepted that the CO_2 level should not rise above 1 percent surface equivalent in closed hyperbaric environments. As seen in Figure 2, both blowers were used, and eventually a vacuum cleaner was connected to an auxiliary canister to supplement scrubbing, but still the Baralyme had to be changed twice as often as planned to keep the CO_2 level under control. Habitat design specifications indicate that the ECS canister, holding 15 pounds of Baralyme, should hold CO_2 at a nominal operating level of 2 mm Hg with changes every 12 hours. The aquanauts used from 40 to 45 pounds of Baralyme daily, changing Baralyme more often to keep the nominal level at about 6 to 7 mm Hg. At no time during the project did the CO_2 come down to the projected nominal operating value of 2 mm Hg even with small auxiliary scrubbers helping out. Incidentally, both blowers were forcing air through the single canister and this was probably more harmful than helpful. Increased airflow detracts from scrubbing in that it promotes channeling through the absorbent and reduces dwell time, thereby reducing Baralyme efficiency. This can be noticed in Figure 2. Baralyme was changed more frequently, but the CO_2 level continued to increase.

On the fourth day of the mission the aquanauts asked to be notified when the CO_2 level reached 7 mm Hg so Baralyme could be changed. They had noticed symptoms resulting from a high concentration of CO_2: shortness of breath, increased respiration, and uncomfortable feelings.

It is a foregone conclusion that the CO_2 scrubbing system should be completely redesigned. In addition, prior to shipping the habitat for new missions, the habitat could be given a dry-run in the shipyard at bottom pressure, not only to check the workability of the systems, but also to help train the aquanauts before mission start.

On March 1, 1969, an auxiliary scrubber from the U. S. Navy Experimental Diving Unit was installed in the engine room. Later in the program a scrubber from Duke University replaced the EDU scrubber. These helped to keep the CO_2 level in check, allowing longer time periods between Baralyme changes for primary mission research. A comparison, made by the aquanauts on the 17th day, of the effectiveness of the ECS scrubber and the EDU scrubber is shown in Figure 3. Both scrubbers use a 15-pound absorbent charge, but the EDU scrubber quickly reduced the CO_2 level to 1.5 mm Hg, while the ECS scrubber gradually lowered the level only to 1.0 mm Hg.

At two different times during the project, samples of Baralyme were analyzed at Battelle to determine CO_2 per pound of absorbent. The results are given in Table 1. Reasons for subpar performance include inefficient canister design, insufficient Baralyme-bed capacity, high flow rate of atmosphere gas through the canister giving rise to channeling in the absorbent, and low dwell time of gas in the bed.

Three days into the mission the mass spectrometer malfunctioned. The fault was determined to be an overheated transformer. It was disassembled into two parts by the aquanauts and sent topside for repairs. The fact that this complicated instrument could be taken apart, sent up, and reinstalled is significant not only to underwater research, but also to space exploration. If equipment is even partially serviceable by inexperienced researchers in isolation, then astronauts can perform similar work under analogous space conditions.

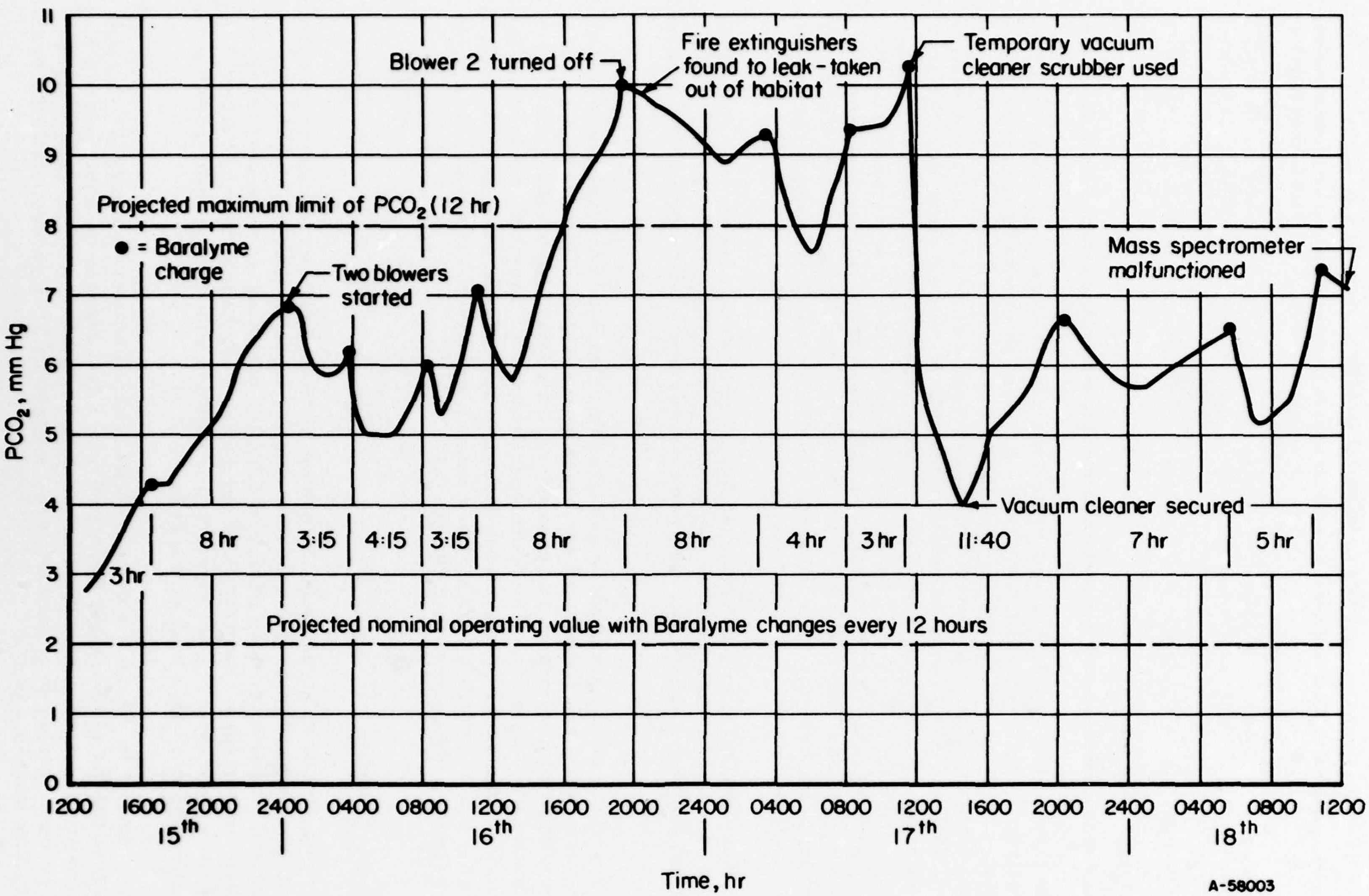


FIGURE 2. GRAPH OF CO_2 SCRUBBING UNTIL FAILURE OF THE MASS SPECTROMETER

TABLE 1. BARALYME ANALYSIS

Sample Taken From Habitat	EDU Scrubber		ECS Scrubber		Manufacturers Suggested Performance	
	Weight Percent	Lb CO_2/ Lb Baralyme	Weight Percent	Lb CO_2/ Lb Baralyme	Weight Percent	Lb CO_2/ Lb Baralyme
February 20, 1969	Not in use		11.6	1/8.62	39.0	1/2.56
March 25, 1969	13.2	1/7.6	14.9	1/6.72		

While the mass spectrometer was being repaired (11 days), colorimetric tubes, infrared analyzers, and a gas chromatograph were used to monitor gas partial pressure in the habitat. This equipment provided adequate, but not continuous, gas analysis, although some discrepancies were noticed in the gas values among the different analyzers. Most significant, however, were the readings taken first near the floor and then near the ceiling of different rooms. These showed that CO_2 stratified in the cabins, i.e., on February 22, 1969, there was 7.6 mm Hg at table level and 5.3 mm Hg at the ceiling in the crew's quarters. The partial pressure of CO_2 also varied between two rooms in the same cylinder, i.e., on February 24, 1969, it was 6.1 mm Hg in the crew's quarters and 3.8 mm Hg in the bridge. This indicates that ECS circulation in the cabins was not adequate to eliminate stratification of heavier gases.

The mass spectrometer malfunctioned again on the 46th mission day. This time the fault was attributed to failure of the ion pump. It remained out of service for the duration of the program. The mass spectrometer was down for 25 days of the 60-day mission.

Samples of the closed atmosphere gas from the 13th day of the mission were taken back to the Naval Research Laboratory for breakdown analysis. Results showed the following quantities of undesirable gas present: 2.1 mg total hydrocarbon/meter^3, 8.4 ppm methane, 9.3 ppm CO. The NASA specification for breathing air in hyperbaric chambers lists maximum allowable contamination to be: 50 ppm gaseous hydrocarbons (e.g. methane) and 20 ppm CO. Bu Med has become even more stringent, allowing no detectable gaseous hydrocarbons and 20 ppm CO.

Thermal-Control System

This system is used to maintain the habitat air temperature and humidity by cooling the gas flow in a heat exchanger and removing condensate, then passing the gas through charcoal filters to remove odors, and finally reheating it, when necessary, to nominal cabin temperature. Seawater was pumped into the habitat to remove heat from the Freon compressor. Cool glycol/water solution was then pumped from the compressor to the separate cabin heat exchangers.

The thermostat in the crew's quarters was lowered only once during the mission and the average habitat temperature fluctuated only a few degrees on either side of 80 F. Relative humidity averages varied from cabin to cabin (wet room 50 percent, engine room 55.4 percent, bridge 48.2 percent, crew's quarters 57.3 percent), and the average relative humidity was 52.1 percent.

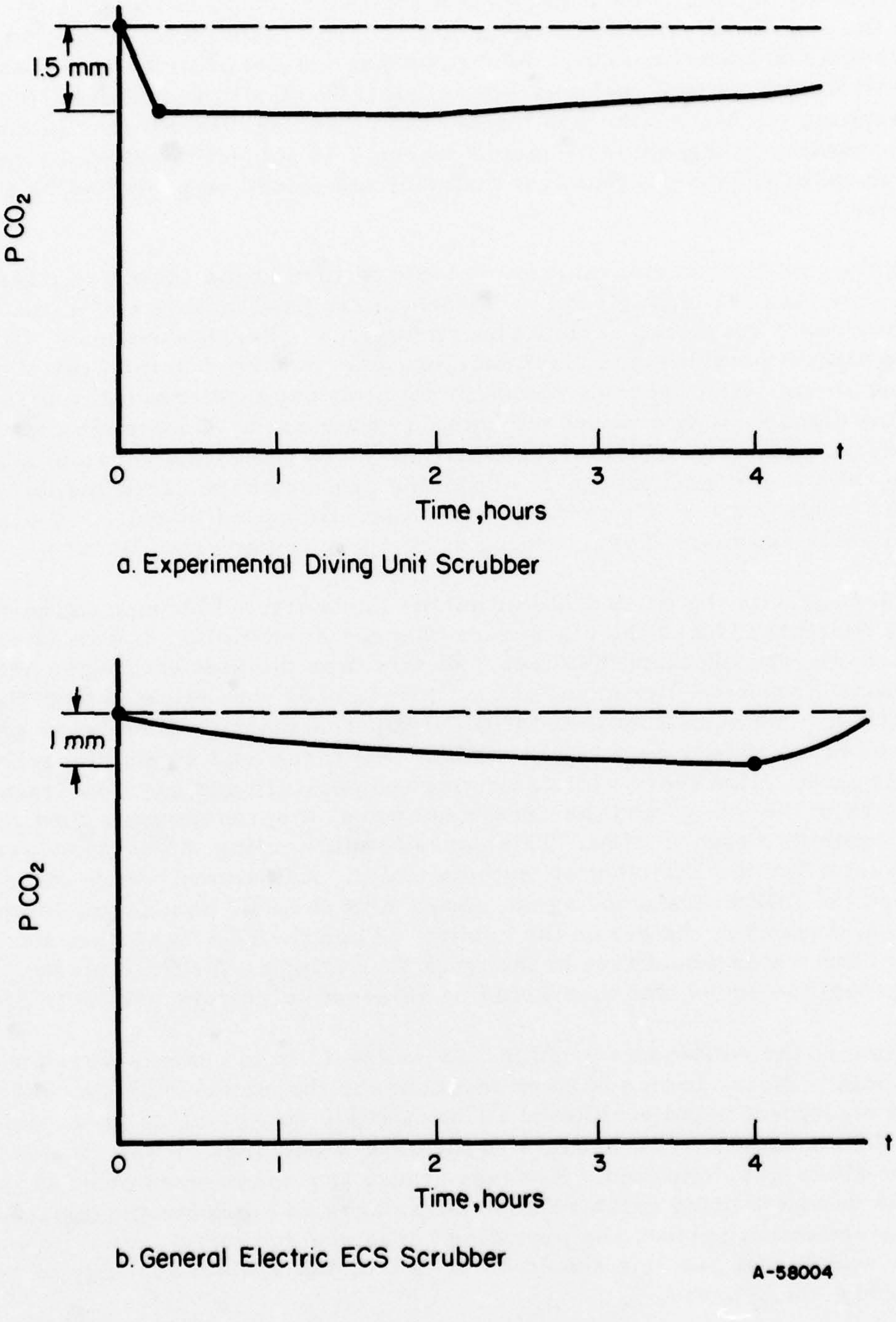


FIGURE 3. COMPARISON BETWEEN THE EDU AND THE ECS SCRUBBERS

Two times during the mission the seawater flow switch located in the wet-suit cabinet shorted out, blowing a fuse and automatically turning off the ECS. The first time, while investigating the failure, one of the aquanauts received a minor shock. The shock was not at all harmful, but it shows that the switch could be dangerous. After each failure the switch was replaced with a new, copper-diaphragm switch. A third time the aquanauts noticed the copper diaphragm was getting badly corroded and eaten through by salt water. It was replaced before failure with a flow switch having a stainless steel diaphragm. Much time was involved in replacing this switch. In the future, if the switch remains in the wet-suit cabinet where it is subject to saltwater corrosion, it should be made of corrosion-resistant material and should be protected by a waterproof container.

During the mission considerable condensate formed in the crew's quarters, the crossover tunnel, and the engine room. Condensate formed at a rate of about 3 gallons per day in the crew's quarters, at times becoming a considerable nuisance. It is noticed that the highest humidity and maximum heat load occurred in the crew's quarters and the engine room. When periods of maximum heat load occurred (all four aquanauts aboard cooking dinner), temperature and humidity increased. Cooler air coming through the ducts seemed to condense moisture in the warmer, more humid air surrounding the ducts, allowing condensate to run down the outside of the ducts and into cabinets or through the acoustic tile. This problem could be eliminated by better insulation of air and drain ducts and more direct routing of heat-exchanger drain lines.

While dealing with the condensate problem, fuses started blowing in the reheater in the crew's quarters. After the fuses were changed a few times, it was determined that the condensate was shorting the fuses. At this time the heat exchanger drain ducts were repositioned for better drainage, the airflow damper was adjusted, and the fuse plugs were dried. The aquanauts then turned all the thermostats down below ambient temperature and then raised them one at a time. All fuses held up and the reheater was functional again. However, while adjusting temperature and gas flow from the heat exchangers in the bridge and the crew's quarters, disproportionate flow conditions resulted and humidity began to rise. This caused rapid cycling of the compressor solenoid until, eventually, the ECS shut off automatically. Adjustments were made for 30 minutes before the ECS was started again. Each time the ECS shut down, temperature would increase, expanding the gas in the habitat. When the ECS was again started, the gas would cool and water would rise in the trunk thus tripping the flood alarm. High-pressure air from the scuba line then would be released to restore habitat pressure.

In addition to the condensate problem, noise levels in the cabins were annoying (see the appendix). Noise from auxiliary scrubbers in the engine room in conjunction with installed equipment noise prohibited all but shouted conversation in the engine room. When the reheater circuit breaker in the crew's quarters closed, it was annoying to the extent that sleep was disturbed. However, there is a break-even point in system design where the designer must weigh relative advantages and disadvantages between creating a cost-effective system and providing "creature comforts". In the case of the engine room, soundproof paneling should be installed, but system redesign to reduce noise is probably not in order.

Scuba-Charging, Low-Pressure Air, and Emergency Air Systems

A suggestion was made (discussed in the appendix) to provide more utility and increase available space by reorienting the scuba-charging and low-pressure air station. It was mentioned that gages and hose reels be mounted near the ceiling of the wet room over the trunk with valves mounted on the trunk railing. The hoses would be reeled down and attached to bottles for charging, and reeled back up when not being used. In this manner the hoses would not block the trunk when bottles are being charged. From an engineering standpoint, it would be difficult to reel high-pressure charging hose, but the charging panel could be moved and plumbed in a more convenient location. In addition, rather than permit emergency air to be used for normal charging purposes, a larger bank of receivers should be installed topside to provide a constant supply of high-pressure air to the charging station. The emergency air bottles could be moved under the crew's quarters to keep the lower trunk under the wet room clear of hiding places for Morays and fish.

Low-pressure air lines could be plumbed near the 10-inch trunk to permit easy exit exit of hookah hoses.

Plumbing and Sanitary System

Each time the toilet was flushed, gas bubbles backed up through the water. The gas was described as sewer gas (see the appendix). Complete gas analysis performed 13 days after the mission began showed 8.4 ppm methane in the closed atmosphere, indicating that sewer gas was clearly detectable early in the program. Methane, formed by decomposing organic material, is only a part of a group of gaseous hydrocarbons that NASA specifications indicate should be less than 50 ppm in hyperbaric applications and that Bu Med indicates should be undetectable (letter 7 June, 1968). Before the habitat left Philadelphia, and again during the construction phase, Battelle recommended that a gooseneck be installed in the sewer line to trap gas and that an air fitting be attached downstream to enable the divers to blow air into the outfall line to remove built-up material. This would eliminate the problem on future missions.

The bilge pump in the wet room did not pump the bilges dry because the inlet orifice was situated on the side of the pump. In addition, early in March, the allen screws that hold the pump impeller tight vibrated loose. Before the problem had been diagnosed and rectified, it was necessary to hand pump the bilge. A similar problem developed with the blower impeller on the Duke CO_2 scrubber. All components known to be vibration sensitive should be locked and/or wired to prevent such failures.

The inlet of the seawater pump should be screened to prevent small fish from being sucked into the rotor blades and possibly clogging the pump.

Communications System

The intercom was the most critical communications system in that it was the primary means of communication between the aquanauts and the test director. Of course, it was backed up with the sound-powered phone in the bridge and the Bogen in the crew quarters. However, if the intercom were lost, verbal interaction would greatly decrease, impairing safety as well as data collection. Five times during the mission the intercom went out of service unexpectedly. In three of these cases the circuit breaker had snapped open. In the first case the batteries ran down, providing a voltage too small to hold the breaker in. The breaker was set again after the batteries were recharged. In the second case, the wet-room trunk alarm shorted out, throwing the circuit breaker in the bridge again. The alarm was bypassed to restore intercom communications. In the third case, the breaker went out for no apparent reason; when the breaker was reset, communications were restored. The other two intercom failures did not involve the habitat breaker. One occurred when the press-to-talk switch in the van malfunctioned. It was replaced with a hand microphone. The other involved loss of communication from the habitat for 90 minutes while communication from the van to the habitat remained in service. It was found that the habitat console microphone was turned off to increase the clarity and volume from the bridge speaker.

The closed-circuit TV monitors were equally as important as the intercoms. The test director could monitor the aquanauts' activity and record data which were not verbally reported. In addition, the TV monitors, as well as the open microphones, provided the major input to the very successful behavioral program. The cameras functioned well throughout the mission, with occasional replacement of the Videcon tubes. The engine room camera failed twice. After the second failure, all cameras had to be turned off for 24 minutes while repairs were made to the panel.

The sound-powered phones in the way stations were used more by the surface support divers for communications checks than they were by the aquanauts. These phones were seldom in working order. The protective casings, open at the bottom, were makeshift and in many cases admitted water to the phone components. Conversations from the phones that worked after emplacement were garbled and not easily understood. Halfway through the mission, all phones were removed from the way stations to determine the reason for their failure. They were replaced, but they still did not work. Near the end of the mission it was found that Intercom Key 8 must be depressed to receive the way-station phones. Following this discovery, occasional repairs had to be made to keep the phones working in a nominal fashion. In future programs, the cases should be redesigned, and operating procedure clearly delineated.

Although not specifically a habitat subsystem, the underwater cameras should be mentioned here. One underwater TV worked for a short while near the middle of the mission, and the other was never put into service. When the camera worked, it was not positioned correctly to monitor diver egress and entry, and it was of marginal use in the marine science program. The shark cage was adequate for determining whether dangerous animals were near; the camera was not needed for this purpose. If the underwater cameras are to be used in future programs, they should be repaired and evaluated before shipment. Furthermore, it may be possible to provide the cameras with pan-and-tilt devices for optimum usefulness.

The intercom, the sound-powered phone, and the Bogen should be discussed from a habitability standpoint. Much whining and screaming was reported coming through the intercom on the bridge, and the intercom in the engine room was ineffective unless earphones were used to reduce noise and feedback. This equipment probably should be tuned or replaced before the next mission.

The sound-powered phone on the bridge was not as easy for communications as was the Bogen in the crew's quarters. The Bogen was intended for use primarily for personal outside telephone calls. Since the commercial telephone link was never completed, it served as a supplementary habitat/topside communicator. One must speak in a loud voice to talk over the sound-powered phone and communications were not clear.

If it is not cost restrictive, the sound-powered phone could be replaced with a Bogen type for future missions.

Convenience items, i.e., the commercial TV, the AM/FM radio, and the tape recorder, did not provide the service intended. The TV was in good working order, but the antenna was mounted in the wrong direction for receiving available stations. Since the antenna was not moved during the mission, the TV was useless. The FM portion of the radio received music only about 10 days and it was used during that time. Then it ceased to function. The volume control on the tape recorder appeared to need adjustment. The music was either too low, or so loud it was annoying. Since these are convenience items and not mission critical, normal maintenance and repair between missions and proper setup procedure on-site would restore the service.

Electrical System

Before the mission began, there was considerable discussion concerning the disadvantages of using a center-Y ground to the habitat. It is considered safer to take the ground back through the umbilical and ground to support facilities to eliminate not only a potential mild-shock situation in the habitat, but also galvanic corrosion effects. It was not clear whether the grounding system was changed before the mission or not, but only the shock received from the seawater flow switch was reported and only very mild corrosion was noticed.

Many times when the generators were switched over, a momentary loss of power was experienced. On the 5th and 19th days habitat power failed because of a generator fuel-pump malfunction. All emergency systems worked well and emergency procedures were applied as planned. Power was switched back within 15 minutes and all systems resumed normal functioning.

It has been mentioned before that the reheater circuit breaker in the crew's quarters had a noisy and annoying action. This breaker could be replaced with a less noisy model in a different location.

In terms of habitability, the dryer, which worked well throughout the mission, could be replaced with a washer/dryer combination for convenience. Only a nominal amount of additional vertical space would be needed.

Habitat Interfaces and Connected Equipment

A number of interfaces and government-furnished equipment have already been considered in the section on Habitat Systems as they seem an integral part of the habitat though not specifically supplied with the habitat per se. These include the underwater TV cameras, the NASA mass spectrometer, and emergency air supply. Other items, to be considered in this section, include umbilicals, way stations, built-in-breathing (BIB) system, hookah system, aquasonics, and the dumbwaiter system.

Umbilicals

All umbilicals were layed and connected at either end with few problems. In connecting the communications umbilical, no strain relief could be found; this was corrected before the mission start. No chaffing gear was provided for the plastic water umbilical on the support barge, and the connection at the habitat slipped off twice, once before the mission and once during the mission. In each case, this was corrected quickly and the line was flushed. Prior to mission start, the casing of the high-pressure-air umbilical ruptured because of entrained gas, but it was repaired and provided uninterrupted service for the duration of the mission.

Way Stations and Navigation Markers

Five way stations were set in strategic positions on the ocean bottom. The stations were to be used to resupply breathing air, to communicate with the habitat and the control van, and as protection against dangerous sea animals if encountered. The only use of the stations was in transfer of air bottles, and this was done infrequently (see the appendix). As mentioned, the phones did not work consistently, were used little by the aquanauts, and could be improved for future missions. The fact that the stations were used during the mission and provided reassuring landmarks to the aquanauts indicates that they probably should be used in future programs. However, in areas where the bottom is precipitous, anchors or moors should be selected with care.

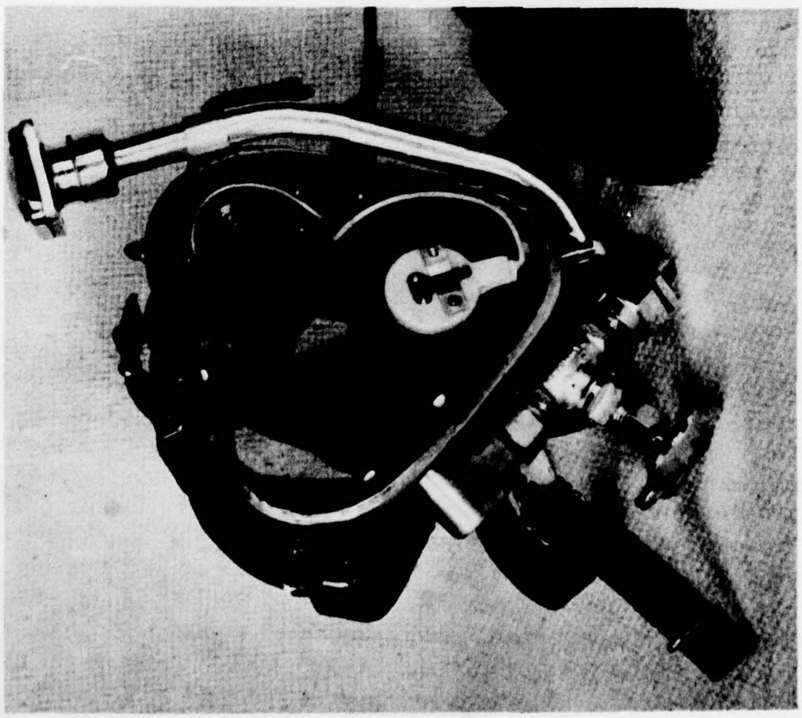
Conversely, the navigational grid system, which took days to fabricate and days to lay out properly, was not used. Obviously, considerable time and effort can be saved by eliminating this sytem.

Built-in-Breathing (BIB) System

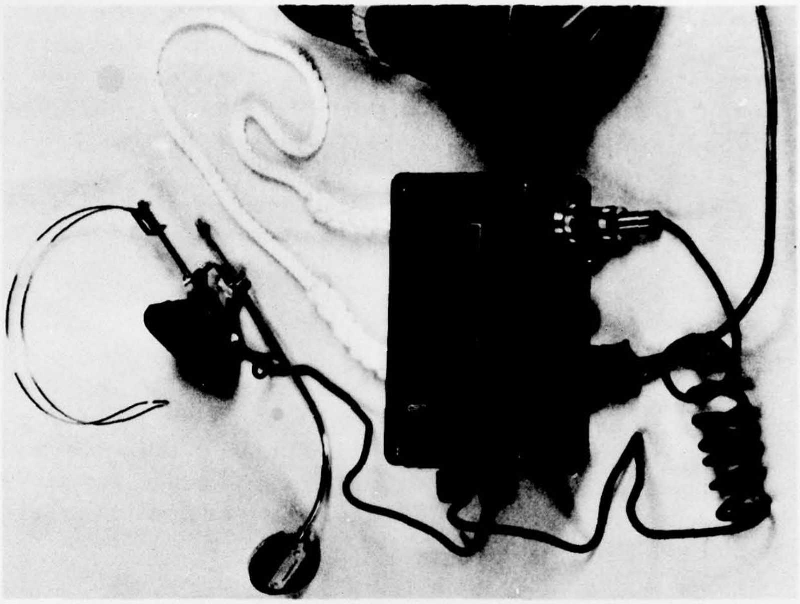
For some reason the BIB hoses and regulators in the bridge and engine room were supplied by GE, and the BIB's in the crew's quarters and wet room were furnished by NAVFAC. During the construction phase it was found that the NAVFAC BIB's were not of the water-immersible type. Since the main reason for installing an emergency BIB system was to provide life support in the event of flooding or contaminated atmosphere, last-minute procurement and replacement was necessary. Local procurement was not possible, so a Battelle representative returned to Columbus and was back on-site with eight BIB's 3 days later. This, and similar problems, may have been avoided by compiling a list of equipment to be supplied to each agency, which is disseminated for comment and returned to the central agency. In this manner, each person in each agency would know his equipment responsibilities, and discrepancies could be ironed out in the planning phase.

Hookah System

The hookah, supplied by Battelle, was a Jack Brown full-face mask with communications in each mask and a central tender control unit situated on the bridge of the habitat (Figure 4). The system was recently developed under contract with the U. S. Navy Experimental Diving Unit which provided it for use on the Tektite Project. It permitted tethered excursions up to 200 feet from the habitat.



Mask



Communication Unit

FIGURE 4. JACK BROWN FULL-FACE MASK WITH COMMUNICATIONS

The mask and communications worked well throughout the duration of the program, but the hookah system could be made more convenient to use. In Tektite I, the hookah hose was attached to the low-pressure-air source in the habitat, routed through the 10-inch truck from the wet room, and coiled on makeshift chocks outside the shark cage; then the mask was brought back into the wet room through a crack in the shark cage door and hung on a bracket for the aquanaut's use. The hose leading through the shark cage and wet-room trunk was fastened to the screening by short pieces of coated wire to keep it out of the way of swimmer traffic. For follow-on missions, the hookah could either be coiled and stored inside the wet room or be wound on a reel outside the shark cage with cleats to hold the hose to the side wall. Either of these methods would make the hookah more convenient to use.

The hookah was used for 41 man-hours of diving, about one-tenth of the total man-hours in the water (453:26).

Aquasonics

Two sets of aquasonic gear were supplied to the project. These included three diver units and two tender units. These underwater-communication units were used infrequently because of lack of reliability. More reliable, longer range swimmer communications would be useful in the next mission. If better units are not commercially available, they could be developed.

Dumbwaiter System

The large transfer pot, a heavy steel can, was overdesigned for use at 50-foot depths. It was too heavy for convenient handling, and had a tendency to rust. Considerable bottom time and energy was expended in simply transferring materials. Constant maintenance was necessary with each of the steel pots, not only to reduce external rust, but also to clean up sealing surfaces to effect proper seals. Furthermore, many items arrived in the habitat wet or crushed.

It is suggested that new noncorrosive transfer pots be bought or fabricted which are negatively buoyant when loaded. Small lead weights can be used to adjust the buoyancy for light loads. Then, a simple closed-loop dumbwaitering system, such as the one shown in Figure 5, could be used. A wave and tide canceller, nothing more than a counteracting weight sliding in a tube, could be attached to the platform sheave to keep system lines taut. The parallel lines to the habitat serve as guy lines for the pot in transit to and from the habitat. The pot is guided through a self-centering trap door in the top of the shark cage, and is then conveyed, via idlers, into the trunk. Slack is taken out of the lines by the electric winch which also acts as the driving force for pulling in the transfer pot. Idler sheeves could be placed so they are out of the way of entering and exiting divers when the system is not in use. The removable idler is placed in a socket in the trunk to provide clearance between the trunk and the pot when transfers are being made. When the system is not being used, the idler is removed, allowing guy lines to lie out of the way against the trunk walls in cleats.

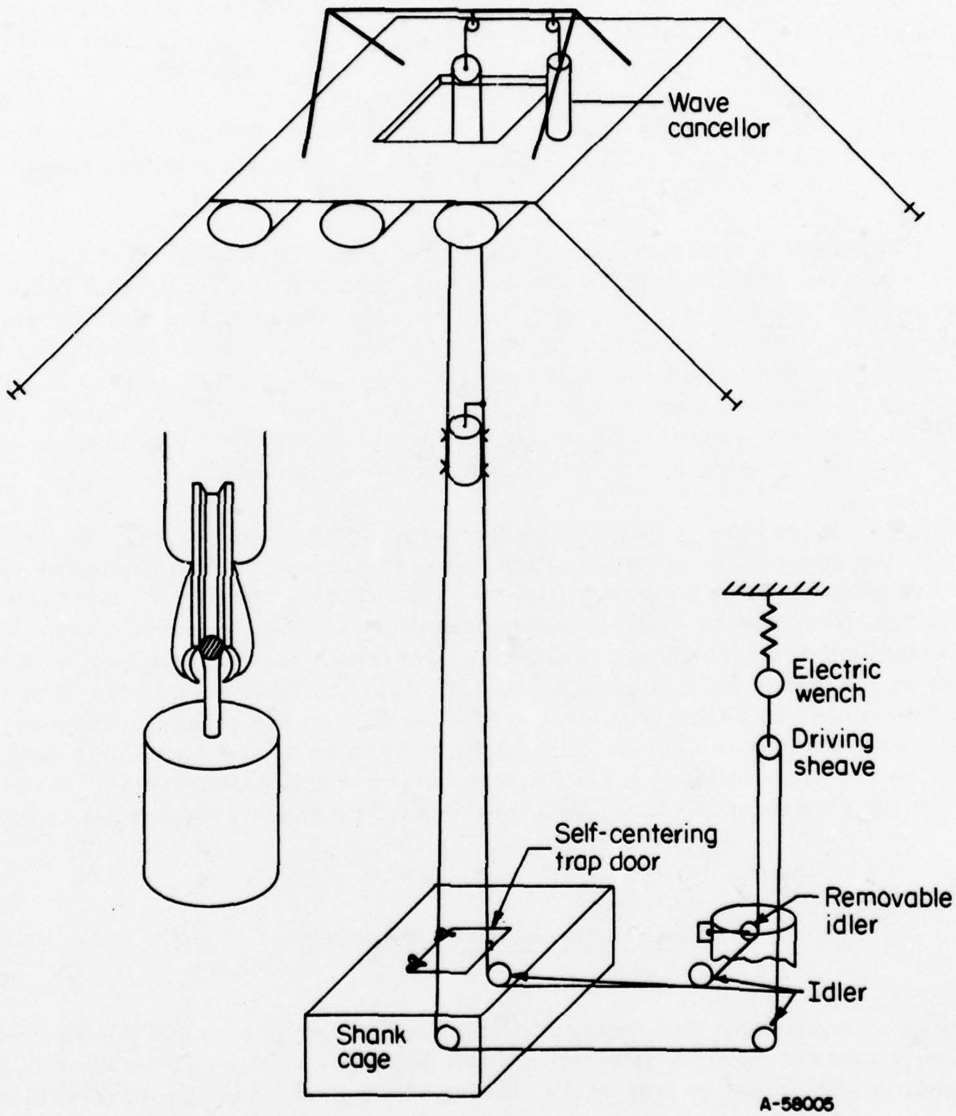


FIGURE 5. DUMBWAITER-SYSTEM CONCEPT

Habitat Support Equipment

The variety of equipment on both the control barge and crane barge (Figure 6) to supply power, gas, water, and monitoring support to the aquanauts functioned very well and allowed few interruptions in service.

The water-blister bag and the redundant electric generators both presented minor servicing problems. It took considerable time to replenish water to the bag and fuel to the deisel generators. During the time the supply boat was moored to the control barge, wave and wind action would knock the boat into the barge, jarring sensitive instrumentation. On future missions, regardless of whether or not AMMI barges are used, higher capacity pumps will be needed for tansfers. In addition, as mentioned before, the electric fuel pump on the generator failed twice during the mission, causing power outages in the habitat.

The decompression complex, supplied through the office of U. S. Navy Supervisor of Salvage, functioned well throughout the mission, and the Seabee divers and equipment operators are to be commended on their proficiency gained over the short period of time. However, problems occurred with the lift crane. Two times during the project the crane was inoperable for considerable periods of time owing to failure of parts, that required much time to procure. First the hydraulic accumulator failed, then, midway through the mission, a hydraulic valve failed. Fortunately the crane was not needed during these periods for emergency withdrawal of the aquanauts.

The support barge was raised out of the water away from wave action by winching it onto piles in the corner hawse pipes (Figure 6). Since the bottom along the east shore was rocky, the piles were to be held upright by guy wires attached to rock bolts in the bottom. Fourteen holes were drilled underwater in the igneous volcanic rock by the Battelle electric tool for installing rock bolts. Unfortunately the winches used to pull the barge out of the water did not have a capacity equal to the heavy load. The barge was barely out of the water in calm weather and was cocked on the pilings. In heavy weather, the barge was shaken by wave action. In future programs at the Lameshur Bay site, thought could be given to building a stable pier before the mission begins. At other sites, not readily accessible to land, a larger vessel could be used for all support functions.

Aquanaut Support Equipment

A variety of equipment was brought or shipped to the site to aid the aquanauts in conducting their marine science program. Included were lobster detection and tagging devices, plankton standpipe, coring tools, diving equipment, and the Aerojet General Mini Sub.

Lobster Detection and Tagging Devices

Two means were available for tagging the lobster population in Lameshur Bay and surrounding bays: sonic pingers and barbed spaghetti tags (Sphyrion) of different color combinations. The colored tags did a fine job of marking individual lobsters in the population, but to find a particular lobster over and over again to study migration, range,

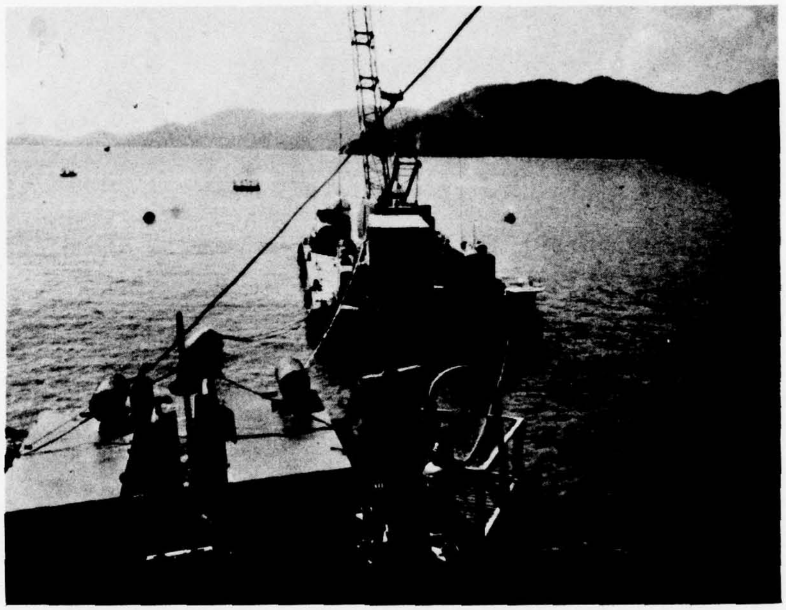


FIGURE 6. SUPPORT BARGE AND CRANE BARGE WITH DECOMPRESSION COMPLEX

feeding cycles, etc., a sonic tag was used (Figure 7). The sonic tags had an effective range of only 50 to 100 feet. Part of this problem may have been the extreme directionality of the receiver, but most of the problem was the low-intensity output of the pinger. For future programs, longer range pinger/receiver sets would be more effective. This is an item for development. The signal can be made stronger or the receiver made more sensitive.

Other equipment can be developed to study lobster habits. A small underwater photocell/light source, when placed near the lobster burrow, can indicate entry and exit of the animal. Perhaps phosphorescent grease or paint applied to the animal would permit simple detection of the lobster at night by means of an underwater black light.

Plankton Standpipe

Near the start of the mission it was found that the plastic water pump for the standpipe had been run dry and was useless. It was necessary to acquire another from the mainland. On the 18th day of the mission the plankton standpipe was carried away from its moor by the current. It was recovered, cleaned, and placed in position once again. Halfway through the mission the pump arrived and was installed, making the system operational. The first plankton experiment was started with 15 days left in the mission. Owing to the late date, the plankton experiment was cut short to allow more time for research in a more productive area.

Development of the plankton sampling equipment should continue. The equipment could be adequately designed for its environment during the lull between missions, and an inventory of spare parts could be provided to eliminate replacement difficulty.

Coring Tools

Two types of coring tools were supplied to the aquanauts by Battelle's Columbus Laboratories (Figure 8). The first was an electric underwater drill developed by Battelle under contract to the U. S. Navy Supervisor of Salvage. Two 14-inch diamond-tipped core barrels, 3/4 inch in diameter, were supplied with the tool. The electric tool was to be used primarily for taking geological core samples in hard rock and coral. It worked well during training, and halfway through the mission it was used to take rock core samples. During this experiment the diamond tip on the barrel broke off. The spare barrel was located, but the coring tool was not used again. If the tool is to be used on future missions, added protection could be gained by storing it inside the habitat rather than leaving it outside continuously, and to insure continuous good service, it should be thoroughly flushed with fresh water after each use to prevent salt buildup on the rotor.

The second coring tool supplied was a pneumatic impacting tool designed to operate with air from a SCUBA bottle. One-inch-diameter plastic core barrels of varying length were supplied with a core catcher. The air tool was to be used for coring in sand and mud. This was the same tool that was used in Sealab II with much success. The geological research did not require the use of this tool during the mission, and it was not used except in training. If future missions require the soft-strata coring tool, it can be supplied.

a. Sonic Receiver Device

b. Fixing Pinger on Lobster

FIGURE 7. LOBSTER DETECTING AND TAGGING DEVICE

a. Underwater Electric Coring Drill

b. Pneumatic Coring Tool

FIGURE 8. CORING TOOLS

Diving Equipment

The diving equipment available to the aquanauts consisted of open-circuit SCUBA and the Jack Brown hookah. The hookah has been discussed previously. The SCUBA equipment functioned very well; however, considerable time and energy was expended charging tanks. Furthermore, double-tank SCUBA breathing equipment is limited to a little over an hours' duration at a depth of 50 feet. As a result, working dives were short and excursions were limited. The bubbles from the regulators frightened the animals being studied.

In the future, marine research could be enhanced by procurement of dependable semiclosed breathing apparatus allowing dive times of up to 4 hours' duration. Three brands of equipment that may be satisfactory are the U. S. Navy Mark VI, the Drager, the Stark Electrolung, and the GE backpack. Both the Mark VI and the Drager units are dependable devices in use at this time; the Stark Electrolung is now on the market and may be good; the GE backpack is developmental equipment, but once it has been in service, and has been evaluated, it may prove to be the best for the job. In each case the duration of the dive is limited by CO_2 removal. It may be valuable to perform research to develop a long-duration, semiclosed breathing system using N_2O_2 breathing mix. Tektite has proved the worth of shallow-water saturation work for scientific purposes, but without the use of dependable, inexpensive, long-duration breathing apparatus designed specifically for that purpose, progress could be hindered.

Mini Sub

Since diving time was limited by the available breathing equipment, a swimmer delivery vehicle was procured from the Office of Naval Research to allow longer excursions from the habitat. The sub was an Aerojet General design (Mark VII, Model P, 1955 vintage), free flooding, and propelled either by electric power or by foot pedalling (Figure 9).

The sub had not been overhauled or evaluated before it arrived on-site. As a result, it was found to be defective in many areas. The original batteries were useless, the old-fashioned floating switch gear for selecting motor speeds was corroded and interconnecting wires were missing, steering linkages were disconnected and the wings were out of adjustment, the variable water ballast tank had a hole in it, the dogs on the stainless steel clutch in the electric motor were broken off, and insufficient Styrofoam buoyancy material was included. The sub had to be completely overhauled from stem to stern before it would be of any use, a difficult task without the proper tools and replacement parts. Batteries were replaced with semisealed lead/acid marine batteries, dogs were welded on the clutch, and the switch gear was rebuilt and rewired so the electric mechanism was in working order. Linkages were repaired and greased, the wings were aligned, and the ballast tank was silver soldered. However, during the first trial run, acid leaked from the batteries, ruining much internal wiring. No replacement batteries suitable for the job could be found in the area, so electric power was not used. Packing Styrofoam was assembled in the sub to provide neutral buoyancy; however, at a depth of 50 feet, this Styrofoam compressed, decreasing buoyancy. An attempt was made to replace the Styrofoam with inflatable life jackets, but none were available.

Because of the poor condition of the sub and the unavailability of replacement parts, the mini sub was not used by the aquanauts for excursions. However, other swimmer delivery vehicles are available in many of the Navy facilities that could be very useful

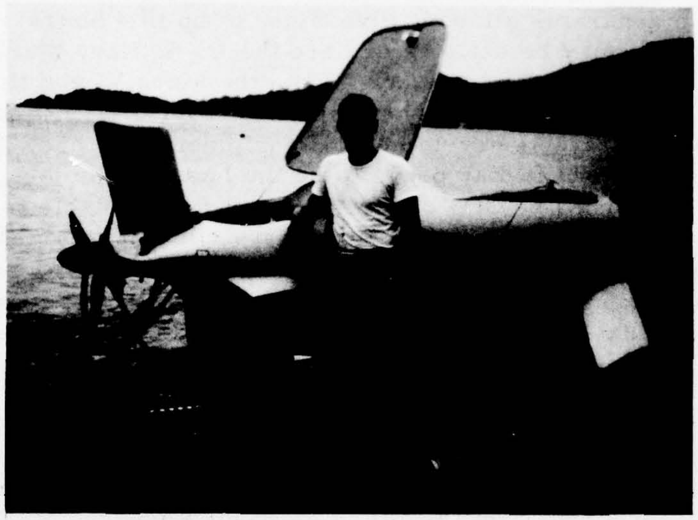


FIGURE 9. MINI SUB

for future programs. These could be readily adapted for use in the marine sciences mission. The vehicles should be capable of maintaining 3 to 5 knots for at least 4 hours. Recharging of the batteries should be easy to perform and facilites could be provided from the habitat for this purpose. Apparatus could be designed into each vehicle to hold aquanauts' research tools in a convenient manner to expedite their work, i.e., tools such as a clipboard and pencil, sonic tags, sonic receiver, geological equipment, etc. Swimmer delivery vehicles of the type briefly described here could provide a valuable service in the performance of the shallow-water saturation work.

PROCEDURES EVALUATION

This section includes a review of procedures used for deployment of the habitat, for aquanaut training, and for providing living facilities and logistics for support personnel. Procedures used in each of these areas were successful, but since hindsight is sometimes the best foresight, review may lead toward even more efficient and more cost-effective performance in Tektite II and future shallow-water missions.

Habitat Deployment

The Tektite habitat rigidly fastened to an AMMI barge, was transported to Greater Lameshur Bay, St. Johns, Virgin Islands, in an LSD. The barge was off-loaded, towed to the predetermined launch site, and moored.

Buoyancy and Stability

The primary means of counteracting the volume buoyancy of the habitat cylinders, crossover tunnel, cupola, and air bottles was to load open tanks in the habitat base with about 143,000 pounds of scrap steel punchings. In this mode, the habitat, dry on the AMMI barge, would have about 27,400 pounds positive buoyancy when lowered into the water.

Launch-Site Procedure

The habitat, moored at the launch site, was being thoroughly checked and final housekeeping was being completed prior to lowering (Figure 10). At the same time, the Seabees were placing and adjusting a nonrigid template on the ocean bottom to act as a guide alignment for the piles. Considerable effort was expended aligning the template dimensions; extreme accuracy was needed to allow the barge to slide down the pilings for 30 feet when clearance between the piles and the hawse pipes was only 2 inches.

When finally the piles had been driven into the bottom, lowering away was held up to complete habitat systems' checks. All the while the seas were working the barge against the piling supports. After only a few days the piles fractured at a stress riser (hole) drilled in each pile to allow the water to fill the inside of each pipe. The piles were withdrawn, cut, rewelded, and reinstalled at a slightly different launch location.

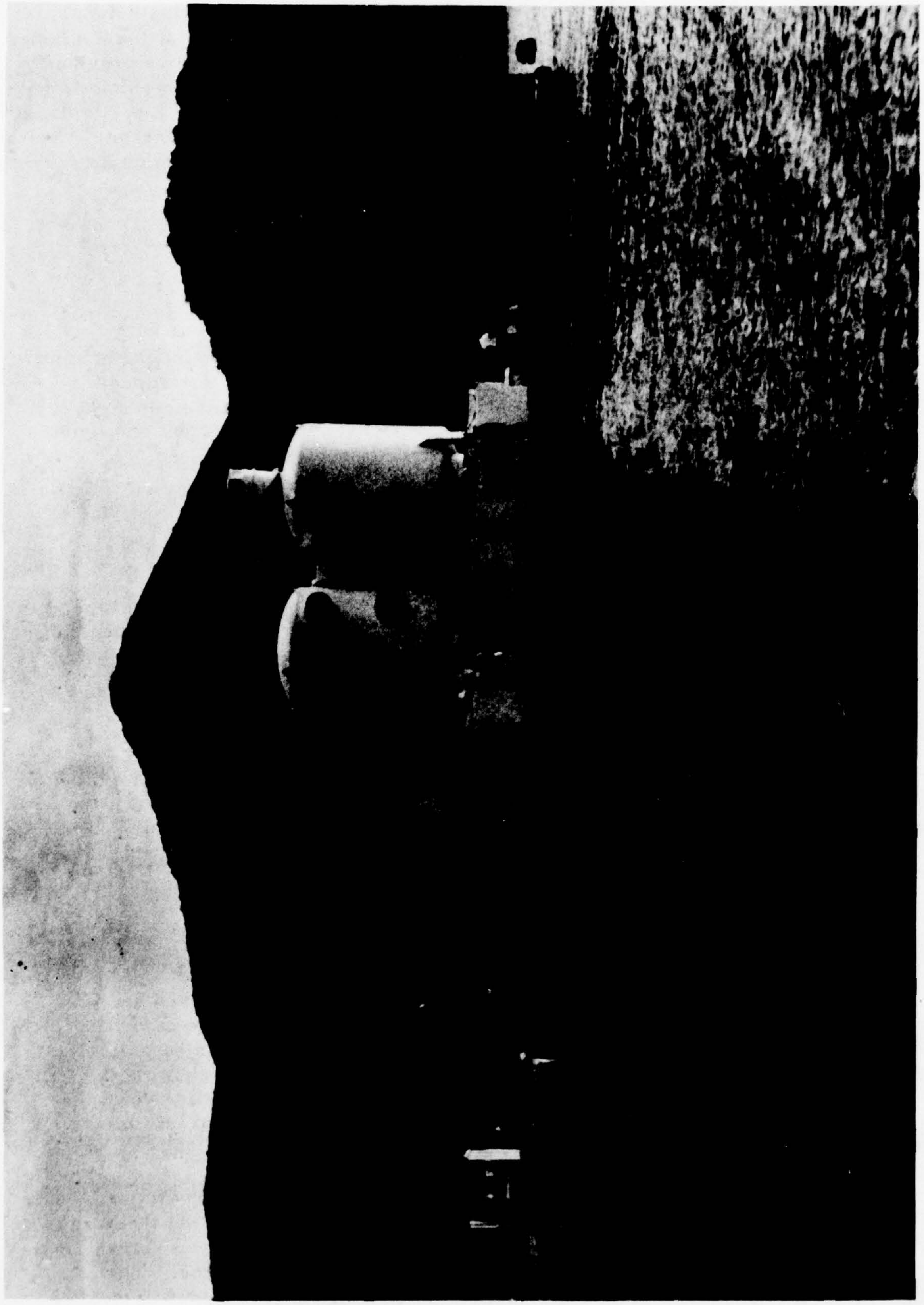


FIGURE 10. HABITAT AT LAUNCH SITE

Similar problems with the template had to be overcome before the new pilings were driven.

Three attempts were made to sink the AMMI barge to the bottom. The procedure used was to station Seabees in crows' nests on top each pile controlling 5-kip winches to stabilize each corner of the barge independently as it lowered (Figure 11). Tensiometers in series with the winch cables indicated forces at each corner. Steel tapes, read simultaneously, precisely measured the barge horizontal attitude. The first lowering attempt was aborted because of darkness. On the second attempt, a corner pile pulled loose from the bottom a distance of 3 feet and had to be redriven. The barge was raised overnight because of time-consuming technical problems. The third attempt to launch the habitat went smoothly, with a minimum of operational difficulties; however it required a full day to complete. The floating habitat just after launch can be seen in Figure 12.

Emplacement Site Procedure

The following day 10,000 pounds of pig iron ballast was placed in trays on the habitat base by Seabee divers; this reduced buoyancy to about 17,400 pounds. Towing lines were attached to chocks provided, and the habitat was towed about one-quarter mile to the emplacement site where it was placed in a two-point moor. Final ballasting was begun to adjust buoyancy to 5000 pounds before haul-down could begin. The original method of ballasting with pig iron from pallets was slow and inefficient. A trammie pipe was rigged so pigs could slide through the pipe from the surface into the trays on the base and this greatly speeded up the ballasting operation (Figure 13).

When the habitat was 5000 pounds positively buoyant, manual come-alongs were fixed between the base and steel-plate deadmen on the bottom, and haul-down commenced. The habitat went down smoothly and was secured to the deadmen within an hour. A 10,000-pound water ballast tank in the habitat was flooded and additional pig ballast was added to bring the total bottom weight of the habitat to about 30,000 pounds, sufficient to withstand seasonal weather and sea conditions.

The emplacement site had been prepared by the Seabees for the habitat weeks prior to actual emplacement. A frame had been constructed on the ocean bottom and sand had been sifted to provide a level bottom between the coral reefs.

Deployment-Procedure Evaluation

The single, most important criterion in analyzing the deployment procedure is transportation to and from the operations site. The limiting factor is the maximum depth the water can attain in the well deck of a Landing Ship Dock (LSD). It is obvious that the most efficient design of a habitat, slanted toward the emplacement process, is one that can be floated out of the well deck of an LSD as a unit without the use of an AMMI barge, moored at the emplacement site for engineering systems checks, then buttoned up and sunk to the bottom using water ballast tanks and supporting guide wires. However, the limiting factor is the 8-foot maximum water depth attained in the well deck of the LSD transport ship. The habitat, as designed, uses steel punching ballast, and with a total weight of 155 tons, the draft is about 22 feet. Even by removing the ballast and designing buoyancy tanks into the base, as intended in initial habitat designs, the less-than-8-foot draft and associated vertical center of gravity combined with the exposed sail area would make transportation and stable mooring a doubtful venture. Therefore,

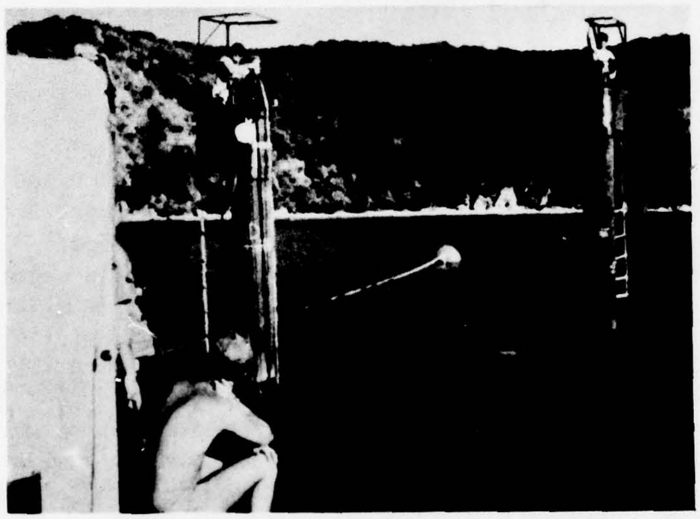


FIGURE 11. PILE TENDERS IN CROW'S NEST

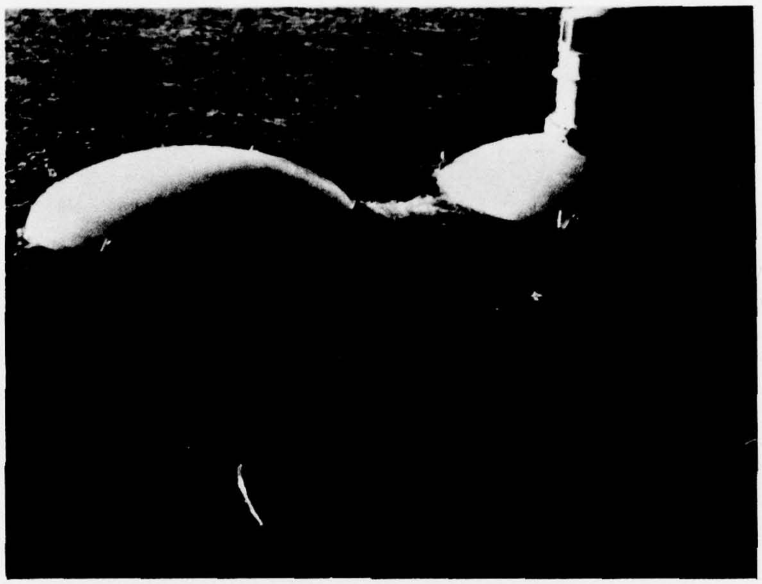


FIGURE 12. FLOATING HABITAT

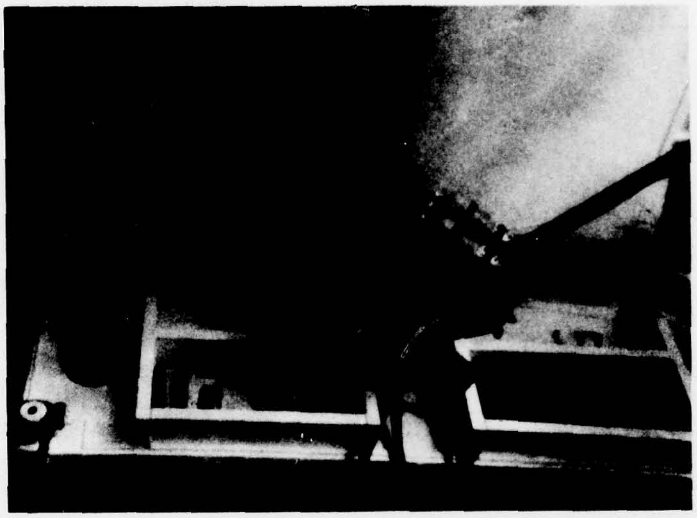


FIGURE 13. BALLASTING HABITAT USING TRAMMIE PIPE

the use of an AMMI barge becomes the most feasible method of habitat deployment. However, a more efficient method of habitat emplacement and ballasting could be incorporated. The use of electric downhaul winches would help with emplacement and a larger trammie pipe without joints would speed up ballasting.

Aquanaut Training

Habitat systems' training was completed in Philadelphia while support-equipment training and habitat refamiliarization were conducted on-site in the Virgin Islands.

Aquanaut training on habitat systems, 1 week in duration, was conducted by General Electric engineers in the Philadelphia Naval Shipyard where final assembly was being completed. Classroom lectures discussing system and sybsystem schematics were followed by familiarization with the actual hardware in the habitat. With the pressure of many visitors and work still being completed on habitat assembly, training suffered somewhat, but, in general, the acquainting of the aquanauts, standby aquanauts, and support divers with hardware intricacies was successful. However, a longer, more intensive training period, with fewer distractions, possibly could have reduced some of the maintenance problems encountered at the start of the 60-day mission.

Figure 14 shows the training schedule prepared for use on-site. The schedule was not clesely adhered to, but the major items were covered. Marine-science-equipment preparation and study as well as aquanaut physical training was carried on at the discretion of the individual aquanauts.

Habitat schematics were reviewed generally by the aquanaut responsible for respective habitat subsystems; however, the most useful experience was gained through two short (no decompression) habitat live-ins. During the first practice session, the aquanauts stowed gear, established contact with topside, filled out sample logs, changed Baralyme, charged SCUBAS, used the hookah and checked communications, took CO_2 readings with colorimatic tubes, had lunch, conducted a simulated contaminated-atmosphere drill, then came back to the surface. The second live-in occurred the day before mission start and included the following general items: start up the environmental control system and practice emergency procedures including habitat flooding, fire, and power loss. After each session, two of the aquanauts were picked up from the ocean bottom near the crane barge in the Personnel Transfer Capsule (PTC) and were locked into the Deck Decompression Chamber (DDC) as a training drill.

Biomedical refamiliarization was accomplished on a casual basis between individual aquanauts and the medical personnel on-site. This effort could have been more structured. Each Wednesday (biomedical day) during the mission, completion of the biomedical tests became more efficient, but for the first 2 or 3 weeks, excessive time was expended completing these tests.

Dumbwaiter-operation training was completed on schedule; however it was determined to be a difficult, time-consuming job when using the large transfer pot. Intermediate size pots were procured and used much of the time during the mission. A concept for a closed-loop dumbwaiter system has been described in the above text and is shown in Figure 5. A system of this type could reduce dumbwaiter training and resupply time.

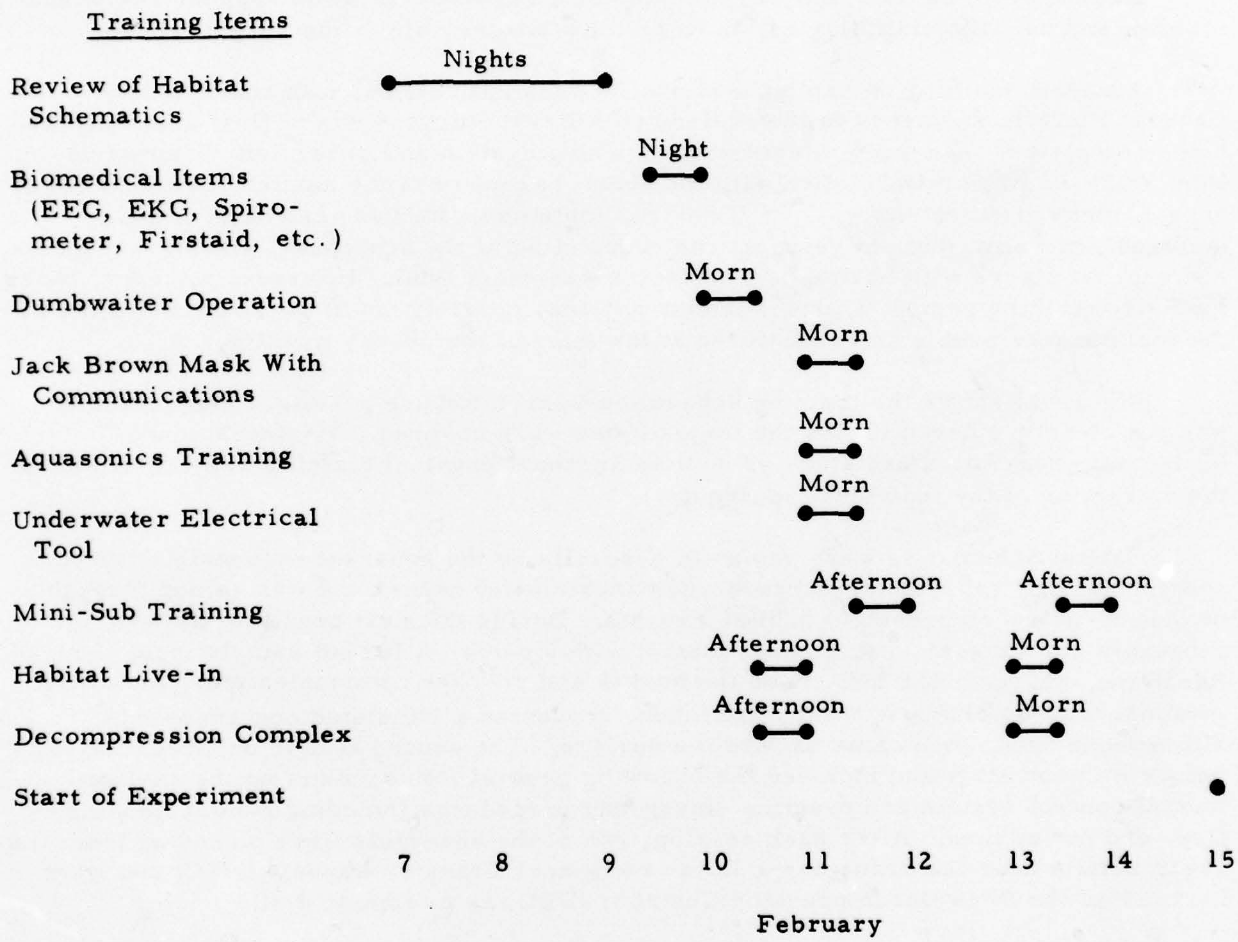


FIGURE 14. TRAINING SCHEDULE

Experience was gained with the hookah during the habitat live-ins rather than at the scheduled time. Most useful experience was obtained during the mission when the aquanauts used the hookah for 41 total diving hours, one tenth of the total dive time. Much of this on-the-job training with different items ironed out gray areas in the total training programs at some expense to the efficient use of saturated dive times.

Training with aquasonics units and with the miniature two-man submersible was completed by only one aquanaut. At the time, lack of training with certain equipment prior to mission start seemed unfortunate, but in retrospect, valuable time was saved. Neither of these items were used to advantage during the mission. The aquasonics were unreliable and the mini sub could not be restored to a useful condition.

The electric coring tool also was used only by the lead aquanaut before the mission started. It is important that the safety procedure is observed when the tool is used and that the current leakage detector is on-line. Operating procedures for the electric tool were reviewed before it was used during the mission.

A structured training program, however disagreeable, inconvenient, or distasteful, could be planned and executed with care in future missions. In Tektite II there is a possibility that a number of marine scientists may cycle through the habitat. When a group of people have different levels of underwater experience, training can be adjusted to satisfy the needs of the least experienced member at the unfortunate expense of the more experienced. No training program can satisfy each participant, but valuable know-how may be absorbed, seeming unimportant at the time, that, during the mission, may help to evolve a more meaningful and more efficient program. Training is an effort where, by organization, doubtful and potentially dangerous situations can be avoided.

Logistics and Facilities for Support Personnel

The site for the Tektite experiment was in Greater Lameshur Bay, St. Johns, Virgin Islands, where the base camp was carved out of the forest in the Virgin Islands National Park, and the habitat support site consisted of two barges moored off shore with no access except by boat. Logistics became a time-consuming problem, not only because most of the food and supplies were ferried over from St. Thomas, but also because personnel were transported to and from the support site only on regularly scheduled boat runs. When boats began to break down, the project suffered from lack of transportation.

If the same site is to be used for future Tektite programs, it is suggested that the road along the ridge leading to Cabritte Horn Point be extended to the tip, thus providing overland access to the support site. A short pier could be constructed off the point for habitat support equipment. If the site is judiciously selected, the pier would end in 30 feet of water, and a decompression complex could be placed at that point. If a number of jeeps are not available, three or four bicycles could provide adequate transportation to and from the support facilities. Two support-diver boats and two supply boats for trips to St. Thomas could supply the necessary supplies and logistic support.

It is assumed that for subsequent missions in Lameshur Bay the original base camp would be available for use. To impove "creature comforts", a method of supplying warm water could be installed; this would consist of anything from three 55-gallon drums exposed to the sun, to a large capacity, self-contained low-pressure gas water heater. In addition, improved latrine facilities could be constructed. Aside from nominal rehabilitation of the camp, these are the only desirable changes.

SUMMARY

This report has dealt mainly with problems and possible improvements in the area of system hardware and program procedure. As the report is read, however, it is realized that many of the problems were minor, but if each one could be eliminated in follow-on missions, much saturated dive time and program expense could be saved.

However, to summarize the program, aside from the problems herein described, one must realize that Tektite I was one of the most successful pioneering underwater projects conducted to date. The marine scientists discovered a new realm of detailed research subjects to study and the 60 days added significantly to man's knowledge of the sea. The behavioral study produced over 400,000 bits of computer data to become one of the most thorough and useful studies of its kind. The behavioral scientists believe this data has provided a highly successful and relatively low-cost analogy between saturated diving missions and long-duration manned space flight. The complete biomedical program that was conducted revealed no physiological effects from the long saturation dive on nitrogen-oxygen mix. Aside from the correctable problems mentioned in this report, the habitat and a majority of its associated systems functioned well, providing the very comfortable habitation so necessary to such a long-duration dive. At no time during the dive was the safety of the aquanauts impaired. Safety procedure was complete and understood by all.

From an overall viewpoint, Tektite I was an unqualified success.

APPENDIX

ENGINEERING DEBRIEFING

APPENDIX

ENGINEERING DEBRIEFING

Thompson: In conducting the engineering debriefing, let's start in the crews quarters of the Habitat. What can you remember in general about the problems associated with the use of the things. How were the bunks? Or, specifically, let's start with cooking equipment. Did you have any problems that developed in the mission with the use of the cooking equipment?

Clifton: If you hadn't supplied large utensils, and I hadn't taken quite a few little ones down in the beginning, we would have really been up a tree. There was no kind of casserole dish or anything, of this kind when we went in. There was, in fact, a cookie sheet that didn't fit in the oven, and there were three pans. I think the three pans and the cookie sheet that didn't fit the oven were the sum total of the cooking utensils in the Habitat. No coffee pot, nothing of this kind. Through the mission we requested and got a number of items that made the preparation of meals much easier, particularly that large casserole dish which was extremely useful. We could do sauteing in it, which is what we called the frying in order not to disturb the surface personnel. We could do baking in it; it was extremely versatile. It was a good thing to have. We later got down a small frying pan, Teflon lined, and that was very handy for small sauces and things of this kind being fixed up. Somewhere along the line I think Gary Davis' wife sent down a cake pan, didn't she?

Van der Walker: We were in bad shape for cake pans. Everytime I wanted to bake a cake I had to do it in the casserole pan.

Mahnken: By the way, John, I can attest to the quality of your baking at 2-1/2 atmospheres.

Clifton: So can we. The coffee pot which we christened Elmer, I don't know how many of you knew that the coffee pot's name was Elmer -- because it was Perkin.

General: Oh, no!

Clifton: Elmer went very well. That was a good thing to have. The blender was extremely useful not only in the late afternoon and early evening period, but also in the preparation of any of the powdered mixes, or any mixing. Also in the preparation of desserts, soups, and all kinds of things.

Batutis: Did you chop ice cubes?

Clifton: Yes, it chopped ice.

Mahnken: You turn it on high speed first, then drop the ice cubes in.

Thompson: The nature of the foods, as it developed, I guess you switched from the canned food to the fresh food. Specifically, in your opinion, was this a question of taste problem or was it just that you felt a need for variety? What would you say the motivation behind asking for fresh food was?

Clifton: Probably for more variety, in my case, than anything else. You can go so long on the prepared foods, and then they all start tasting the same. There is a lot you can do with prepared foods providing you have the right things down there: if you have sour cream mixes, gravy mixes, and things of this kind, cheese sauce mixes. We had a lot of good cheese down there. There's an awful lot you can do with the prepared foods to make them taste real good but you get to the point where you just want to try some different things.

Thompson: What about taste? Did you feel there was any depletion in taste at all?

Van der Walker: I'd like to comment on this food business and the type of food that was down there. I think that preparation of food at mealtimes was our biggest recreation. We really didn't have anything else in the way of recreation in the Habitat as far as radio and TV is concerned, and so I think we had a lot of enjoyment out of the meals. I think that throwing TV dinners in was all right when we were really beat, but preparing the food was not a task that we objected to.

Thompson: Who did most of the food preparation?

Mahnken: We put up a chart down there to count the number of times we prepared meals and did dishes, and as it turned out it was almost equal except in the case of Ed who cooked most of the meals, because Ed was the best cook. He prepared most of the meals.

Clifton: See, a little flattery goes a long way. They can con a person into doing most anything.

Batutis: Grilling or frying, did you really do any of that kind of thing?

Mahnken: Yes, from about the third week. We were broiling with an open oven, we were using formaldehyde in the wet room, we were using isopropal alcohol, John was using acetone, we were cleaning dead mollusks. The head gave a slight odor after we had good meals of a certain type, but as far as removing smells and odors from the atmosphere in the Habitat the system was very efficient.

Clifton: We think it would be very well to check the charcoal filters above the stove to find out what they have absorbed in the period of time and see whether or not they have reached their maximum absorption capacity or not. We didn't do excessive frying. We watched this pretty carefully, but we didn't hesitate. I fried chicken; maybe some of you have had some of the cold fried chicken we left down there. We just went all out and fried it -- combination of frying and baking -- and there was some other things. Occasionally if you take a can of hash, and you put it in the oven as happened on one occasion, and you let it set there in the oven long enough that stuff will sit there and boil, and it would be hard put to throw more oil in the atmosphere than with something like that. Certainly there would be more oil coming in the atmosphere, more organics coming there, than there would be from very lightly sauteing eggs in the morning where you just have the butter warm and not bubbling.

Batutis: Did you ever try running a carbon monoxide sample while you were doing this type of frying?

Mahnken: Yes, several times.

Van der Walker: Every time we did something that was out of the realm of the law, we ran all over with tubes of everything taking samples.

Mahnken: I took a formaldehyde test in the wet room when I was actually using formaldehyde in there and I got no reading on the MSA tube for formaldehyde. We took carbon monoxide several times.

Van der Walker: When we used these things, you know, we didn't slap it all over. We We just used what we absolutely had to use.

Lorenz: How about the equipment itself with respect to the stove and refrigerator?

Clifton: There were problems. As Bren knows the oven door falls off.

Mahnken: But it's not a General Electric product.

Clifton: That's right. That oven had several problems. One burner doesn't work unless the other burners are on, and the oven; one of the wires burned out in the back. We repaired it, but in the repairing we somehow damaged the door. The door had a propensity to fall off especially when something had been in there at about 400 F. Then there was a lot of dancing about trying to get out of the way.

Unknown: Excuse me, is it because the oven door fell off that you burned one of your chairs?

Clifton: No, what happened to the chair was a cookie sheet was taken out, and we didn't really think it was that hot and set on the chair. It was hotter than I thought it was. That's what happened to the chair.

Thompson: As far as the noise level down in the crew quarters itself is concerned, the only comment I heard at one time was that you were having problems, I guess, with the circuits; the relays were clicking on and off. How about the general ambient noise level and so on? Did you adjust to that? Any conscious problems sleeping?

Clifton: The only problems I noticed were with that relay.

Mahnken: In fact you can go on and say something here about the light level too. I think the light level was fine with the exception of my bunk which got light from the bridge. Especially the lights from the bench just at the top of the ladder, and I had to use those curtains all the time. The curtains weren't long enough.

Thompson: When you put the curtains around did you find you had enough circulation and body comfort?

Mahnken: Yes, I think we all slept with our curtains partially closed anyway.

Koblick: I sent you down some blankets. Did you use them?

Mahnken: Yes. The colors weren't exactly what we had hoped for.

Unknown: Let me ask you this, did you close the curtains to shut out light, attenuate sound, or for privacy?

Mahnken: All of those reasons.

Clifton: Mainly the light I think, in my case.

Van der Walker: I didn't sleep with them closed, because I had the feeling it got very stuffy if I closed the curtains all the way. I just drew them far enough to cut out the light that came down off the bridge. I tried to keep the one at the bottom of the bunk completely opened, and I couldn't sleep with that fan running. I slept with it running one night, and I woke up with a very sore throat.

Mahnken: I kept getting headaches, so I turned it off when I went to sleep.

Clifton: I did much the same. Started off using the fan nearly every night, and after about two weeks stopped.

Withey: How often did you adjust the temperature thermostat?

Clifton: As we adjusted the thermostate . . . No, we did it once. We did adjust the thermostats down there once.

Withey: Higher or lower?

Clifton: As I recall we dropped them just a bit, I believe, in the crews quarters. One of the problems, Dave, was when we developed those leaks we completely fouled up your well-balanced damper system, and threw it out of adjustment. There was some fiddling around with that trying to get balanced circulation and temperature back between the bridge and the crews quarters. We ended up shifting the temperature, as I recall, very slightly in the crews quarters.

Goldstein: Did you ever solve the leak entirely?

Clifton: Not completely. We stopped it, and it resolved itself, and I think we had about 4 weeks it was completely dry up in that cabinet. Towards the end it seemed like we got a lot more condensation, about the last two or three weeks, and we started getting a drip there. It became a small problem again but not like it was at first.

Tenney: For the record, why don't you say here that that wasn't a leak?

Clifton: Oh, right. This was condensation being blown up the air ducts and was running out through vents or through holes in the air ducts.

Goldstein: The panel above the refrigerator, when was that removed?

Clifton: About the second day.

Goldstein: Were there smears that were supposed to be taken from that specific location?

Clifton: Yes, I think they were taken from another location in the Habitat.

Van der Walker: There were extra spaces for smears. I took all the smears.

Goldstein: You left it off, why?

Clifton: Storage space for one thing. Secondly, it took us a long time to get that leak stopped up there. Until we had that completely under control, we had to keep it off to keep all the cups and pans in there to catch all the water. We were getting something on the order of three gallons a day coming down there.

Mahnken: It was also coming through the ceiling soaking up in the acoustic tile and was creeping ominously toward my bunk. Just in time Ed stopped the leak.

Clifton: You would sit there and all of a sudden you would hear "slurp", and you would look and here it would just be pouring out of a new place in the acoustical tile. You would shift the pans all around and wait a while, and you would think everything was in equilibrium, and all of a sudden you would hear "RIP" and there it would come off another place, and everybody shoved pans around.

Goldstein: Is that the reason you said there wasn't enough kitchen utensils on board?

Unknown: Did you also say there was condensate in the cross over tunnel or the engine room? What was wrong?

Clifton: Similar problem.

Mahnken: You notice there was also a small dyke up there we used to divert the water around the rug. It drained back in the toilet then. We made it out of "perma seal" up there, you know. Ed read the gages. We always had condensate above the head.

Clifton: Yes, but not a great deal. Maybe we can get to that when we get up to the engine room.

Mahnken: One of the things in the crews quarters, as Brooks pointed out to me when I first came into the Habitat, was the trouble I had with the drainage in the sink. Well, Rick and John got down there, one night, in the bilge with the plumbers' aid, and they pumped, pumped, and pumped and it opened up. We never had any trouble with drainage in that sink after that. You'll notice now it drains very nicely.

Clifton: Yes, however I would suggest in the future a small disposal be built in. This would be extremely useful, because I don't know how much longer the drain would remain open, because when water stopped flowing down the drain, and knowing that that system had been plugged at one time, very likely it would become plugged again. I think if you had a little disposal there that you could run and also work as a pump, this would help a great deal.

Thompson: Let's get around to the bunks for a bit. As far as the bunks were concerned you were the largest guy (Mahnken). Did you have any trouble?

Mahnken: It was not long enough for me.

Thompson: How tall are you?

Mahnken: About 6 ft 1 in., but I couldn't stretch my toes out, and keep my head in the bunk. I had to sleep like this always (fetal). I couldn't stick my toes out, the bunk was too short. But I was never uncomfortable.

Thompson: You two (Van der Walker and Clifton), I guess, had the (EEG) curlers. That didn't impede your sleep in any way, did it?

Van der Walker: They sure did.

Clifton: It did to some extent. I think the location of those boxes could have been vastly improved had they been at the end of the bed rather than at the side, because there was a great tendency on both of our parts to get our arms tangled up. It is just great fun to get your arm all fouled up in those electrodes and then straighten them out in the middle of the night.

Van der Walker: And roll over.

Thompson: (To Waller) The EEG cap, I guess, gave you some problems. Did they ever get resolved? I didn't catch the second phase when they were going to send you another cap.

Waller: You said it gave you some problems?

Thompson: No. It gave you some problems.

Waller: Oh. Yeah, it gave me some problems.

Thompson: Did they make changes and give you another one?

Waller: Yes.

Thompson: OK, how about the stowage lockers by your bunks?

Van der Walker: The channels that the plastic went back and forth in and slides, ended in a very sharp point right by my head. So, when I went to bed at night, I put sweat pants over that portion so when I roll over I didn't take the chance of hitting it, because I did hit it once. I think that was a bad thing, and it should have been changed. You notice that I took my doors off. I thought they were just in the way.

Clifton: Another thing you probably noticed was that those little steps down there (for the bunks) were gone. They lasted, I suppose, about two hours after we got into the Habitat. Two hours and three barked shins, and then those little steps came down. They are really sharp.

Goldstein: Did you have any difficulty getting in and out of the top bunks as a result of the steps not being there?

Mahnken: No, I didn't because I had the strap in my bunk, but John didn't have a strap in his bunk. I had a strap that came up and over, but it was missing from John's bunk.

Thompson: That storage space right by the bunk, the curved portion, was there utility to it? Did you use those things as a matter of course? Did you find you had enough storage for your personal, occupational needs?

Mahnken: I would have preferred one shelf on the top and one shelf below, so I could have rolled over with my knees. I don't know, maybe if you put an oval mattress in there or something or maybe just a pad back in there so you could roll over. Give you a little more lateral space. I didn't use all the shelving. I never used the shelving at my feet past the center of it.

Goldstein: The swing-out door you mean?

Van der Walker: No, the sliding door.

Thompson: Very early in the program there was some talk about putting portholes -- equivalent of flat portholes -- at each bunk. If this was done, in retrospect, do you feel there would have been any utility to it?

Van der Walker: I would have loved to have had a porthole.

Waller: Why?

Van der Walker: I think it would have been great to look out through the window there while you are laying in the bunk.

Waller: How many times did you lay around in the bunk?

Van der Walker: Well, I spent a lot of time in the bunk, Rick.

Mahnken: Through the day, Rick? (laughter)

Unknown: How about the commercial TV and radio? Were you well satisfied or happy with the way that entertainment provided for you?

Thompson: Do you want to separate the problem, or together: TV versus the radio, or TV and the radio. Did you use them much?

Clifton: We used the radio with Bob's help and John got the FM so it worked for a while, and we used it when it worked -- we used the radio. That only lasted about 10 days as I recall and then something happened, and we didn't get any more FM at all. This was fairly close to the end of the mission and there was no reason to pursue it. Personally I didn't really miss the television. I don't know, we seemed to be so awfully busy down there I don't know when we would have had time to watch it, but it might have been nice to have the option.

Thompson: At great expense as you can appreciate that furniture was custom designed by a leading architect for use in the crews quarters. I'm just curious as to how you felt in regards to that furniture? See, we may have achieved a breakthrough in the sense that now Sears & Roebuck can now get on the list of approvals for suppliers of space hardware, who knows.

Waller: Excuse me, but are you going through that habitability list?

Thompson: No, I'm not. No, I'm looking at occasional items from cabin to cabin. I want to make sure we cover all the land.

Waller: Has anyone touched on the circuit breaker down in the crews quarters? Nobody has discussed that specifically as yet.

Thompson: Well we mentioned it in relation to the noise level.

Clifton: That's really disconcerting, because it would wake me up probably once a night because those things go off with a bang, and on that particular side right behind your head, you're always a little bit alert of the noises in the Habitat anyway. I woke up, I suspect, an average of once a night. Just came to a sensible level for a second, as a result of that circuit breaker.

Thompson: Well, let's get back to the furniture problem. Did you necessarily see any big problems?

Waller: Yes, we did. You need a heavier table down there.

Mahnken: One of the legs of the table would bend out, and the table would become quite unstable. We were all kind of clumsy at times and would bump the table when we got up and spill coffee quite a lot, or soup, . . .

Goldstein: Were the table and chairs constantly set up or did you stow them at the end of meals?

Many: They were set up.

Clifton: There was plenty of room in the crew quarters with the table and chairs out in the center as long as you didn't have 4 people down there occupying it. But when you put 4 people in there and the table and chairs, it got crowded.

Goldstein: You had utility of the refrigerator and the stove even with them set up?

Clifton: Nope, no. Not with people sitting there. We had utility as long as we weren't at the table. But as soon as we settled at the table, and it became a real chore to move the table and chairs about, then the utility dropped way down. For example, if you needed to get something out of the vegetable compartment of the refrigerator, where you have to open the door up all the way in order to slide the compartment out -- and this happened with butter on numerous occasions -- then we would have to move the whole table, everybody would have to move their chairs, we would have to open the refrigerator door up, open the compartment, and get the butter out. I suppose we might have thought of moving the butter. But, at any rate, if all 4 of us were sitting there, and you were on the inside, it was extremely difficult to get out, and get around the other people. If you were on the outside and had to get to the sink, it was kind of impossible. But, I don't think the table could have been any smaller.

Goldstein: What utilization were you able to make of the bottom drawers in the bunk areas with the table and chairs set up?

Clifton: Again, as long as there was no one sitting at the table there was really no problem, because the table and the chairs could be moved.

Mahnken: We really didn't use those drawers very often. We kept towels and linens in there just as you had them. We didn't put very many of our personal things in there.

Goldstein: Stow much of anything in the bunks themselves?

Mahnken: Yes, quite a bit of stuff.

Waller: One of the things that surprised me very much was how absolutely clear the port was in the crew quarters.

Thompson: You used it as a monitoring station for outside egress, did you? What was your general impression on your ability to see outside looking through those windows?

Waller: Very good. The one in the crew quarters wasn't used for monitoring the people in and out, because this is just a carry-over from Sealab. Ever since that fellow had a problem in Sealab I where he kind of got lost outside, everybody's been a little bit concerned about entrance problems. I think it's a big waste of time. As long as two people go out at the same time and come back in at the same time that's all the monitoring you need. I was never in the crews quarters to watch anyone exit or enter the Habitat. What it was used for was an outside port from the crews quarters to look outside and see what's going on. To look at the fish and things like that. It was little inconvenient. It was aligned directly under the port on the bridge, and if it could have been shifted around a little bit more toward the fuse box it would have been better. It was a tight squeeze because of the panel that was located there. A shift of about 8 to 10 inches.

Mahnken: Every time I went back to that port I banged my head on the TV camera.

Thompson: In terms of what you could see when you looked through the port was it a sensible picture in your terms. Could you use it directly, could you use it for anything other than just casual observation? I mean was there any real information involved. Was it great to see and recognize fish for example?

Waller: Any casual observation involved there was data.

Mahnken: I set up fish identification stations and I established that as Station No. 1 and I went around the Habitat and monitored each of these stations for a set period. I didn't continue this throughout the operation, because I got into doing other things. But it could be set up as a fish monitoring station. The one on the bridge was more useful for this because you had a greater viewing vista.

Unknown: It was also hard to keep the ports clean for any period of time.

Clifton: To keep it clean enough to see I think we would have to do it at least once a week, to get out there and just run your hand over it; it didn't require a full cleaning. If you let it go for any period of time then it did require a thorough cleaning. It seemed like every few days somebody was out there and just happened to swim up to the port to look in and see somebody, or to say the big pot was ready to go up or something like that, and while they were there they would just rub their hands over the thing and clean the slime off.

Waller: I think we paid particular attention to the ports, and just a hand wipe would clean them. From three to four weeks on or about half through the mission we started getting small encrusting, bryozoans and stuff. When this pavement was laid down then they became progressively harder to clean. Then you had to use a nylon brush and then a nylon brush wouldn't clean them.

Thompson: Well we've got limited time, so I guess we better keep pushing on.

Clifton: Bren, another comment on the crews quarters. Those doors to the cabinets are awful. They have to be closed just right and held, or they swing back open. We all banged our heads on them, because you close the upper one and you reach down into the garbage can, then you straighten back up and catch the thing as it swung back out. That was a real nuisance. They could sure have better magnetic catches.

Tenney: Which door was it?

Clifton: The one above the sink and the one above the stove. You had to push the door shut and hold it. It had to be a very positive action.

Goldstein: It was just a matter of adjustment, that's all.

Clifton: Is that right?

Mahnken: When I would be working at the sink, or at the counter next to the sink, to get to the back I would have to stoop down and look underneath, because my head was above the cabinet. There is not enough clearance. For instance, there is not enough clearance in the above portion of the counter to get the blender back there.

Goldstein: Did you think the sink was too high for good utility, and working in it, and washing the utensils?

Mahnken: No, but the spacing in the cupboards was bad. They were all just too small, and there were not any high or deep storage spaces.

Clifton: Also, I think it would be real good to have some kind of dish strainer or drainer. A thing where you could stack the dishes in, and a drainer that would run the water back into the sink. Otherwise, you either have to dry the dishes, which is an additional chore, or you have to leave them, and they don't dry.

Tenney: What did you think of the ladder in the crews quarters?

Clifton: Rick answer that?

Waller: I think a little evaluation needs to be done on ladders. Whether in the same amount of space you could turn one sideways common to the wall and go up at an angle instead of going straight up with one hand or something else.

Mahnken: Of course the next step from that is to build the Habitat all on one level where you don't loose any floor space to ladders.

Waller: Well the Navy's got some of those. I don't think they are very desirable.

Mahnken: What, one level habitats?

Waller: Yes.

Thompson: All right, let's go upstairs if we can to the bridge. Of course, the key event around the bridge is the MS system, you know, the gas analyzer which misbehaved. Along those lines, what intrigued me most was that you elected to start scrubbing with your vacuum cleaner round about 5 mm of mercury or so. Do you have any conscious reason other than the fact that that seemed the number to settle out at, or was it because around that value, or higher, you could begin to detect sensibly certain qualities in the atmosphere, and might have wanted to take action on it?

Waller: I don't ever recall using the limit of 5 mm throughout the mission. Are you talking about just when we used the vacuum cleaner as a scrubber?

Thompson: Yes.

Waller: I wasn't aware that we used that limit. I thought that we used somewhere between 6 and 7 mm. Of course, that depends on the accuracy.

Clifton: That was sort of a variable figure that changed, I think. When we went down there, I believe that alarm was set at 6 on the CO_2 meter. This was the maximum level before the alarm would go off. I think when we started off our main goal was to keep it below 6. Then, we slowly learned that there was nothing magical about the number 6, and that we could tolerate 7, 8, and so on up the scale without any real problems. Still there was some desire to keep it down in these lower levels, so I think maybe we did have it on around 5 there for a while. Then, I think, it slipped up.

Waller: I don't recollect it, because, you know, we got into the Habitat on Saturday, and by Sunday morning the CO_2 was up to 8, and by Sunday afternoon late it was up to 10. It went straight up right away, so we didn't have all those options going up. On Sunday the meter level was at 11. I think that is where we started using the vacuum cleaner.

Clifton: Did we start using the vacuum cleaner before or after the Perkin Elmer went out?

Waller: Before.

Thompson: You see it just happened that I seemed to have a lot of watches at that particular time when all this gobble-de-goop was happening. It was an observation of mine, that was uniquely mine, because I knew when you guys were scrubbing with the vacuum cleaner both by (a) hearing and (b) seeing the drop-off, and I knew that you seemed to initiate it at 5. In fact, I remember talking to the watch director at the time saying, "Watch, you know. It's coming up now. In a very few minutes we are going to see that thing going." And sure enough it would happen. This led me to believe that you set yourselves 5 as a number, and what I'm struggling for is whether this is anything other than a number that you had gotten out of a book somewhere, or talked to someone about, or whether it was something sensibly that you were experiencing that caused you to settle round about this number. It's like setting a thermostat at 75 degrees, because that sensibly is what you would like to have. OK, who thought up the vacuum cleaner?

Waller: I did.

Thompson: What exactly did you do?

Waller: We used our spare ECS scrubber canister, and John blocked up the hole with a piece of plastic, and we moved the vacuum cleaner hose to the blow orifice, and blew the air through the canister. We figured this would get us a lot more air movement than the suction side, which it did. It was pretty efficient.

Thompson: Did you file a patent on it yet?

Waller: Oh, yes.

Van der Walker: That canister got pretty warm. I don't know whether that was the reaction going on or whether that was just the vacuum cleaner getting hot.

Waller: It was both.

Goldstein: I noticed that you took the orifice plate off.

Waller: Yes, that was in order to use it as a scrubber.

Thompson: I guess I don't know if the company will necessarily get any great publicity about the use of the vacuum cleaner as a scrubber, but we are working on it. As far as the bridge is concerned itself, functionally did you use that for your dry-lab work and report writing, and so on, your study? What essentially did you use it for? Did it work out the way that it was intended? That is, did you have enough storage space?

Mahnken: As far as I was concerned there was not enough bench space to work at.

Thompson: OK, what specifically did you work at in there? Microscope?

Mahnken: The most popular space was the low bench next to the ECS panel and beneath it, and over by the port.

Unknown: Did you find that you used the desk for its intended purpose?

Mahnken: You could not put a chair in front of the desk and have people going up and down that ladder.

Van der Walker: Could I ask a question here just to give us a frame of reference? Are we talking about improving Tektite I in the site that its in, or are we talking about what we would like to have in another one?

Thompson: We are really talking about both. We are leading, first of all, to a negative reaction that implies that you essentially have a suggestion. If it's a larger element, fine, or if it's just something that could be removed. So it's a bit of both.

Van der Walker: Well, I agree with Connie. That bench, between the tunnel and the stairs was really a waste of space. You couldn't work at it; it was just a storage and that was about it. Things just got piled up there.

Waller: That was where the amplifier system for the EEG stuff was.

Mahnken: It was pretty useless really. We used it to pile our bio-medical equipment on when we were doing our medical studies.

Clifton: Then there was a limit, as I recall, as to the depth of this particular useful bench. It was underneath the communications panel for something like 1/3 or 1/2 of its length. As you went toward the port you had a depth that was approximately one tablet thick. Then you had a working space that went clear back to the wall, but it wasn't quite enough for two people to get in there and spread anything out. I think this problem of counter space, I sure agree with Connie. This was a real problem. Any of the mapping work I was doing using the light-table, and we all used the light-table, anytime we were using this and had things spread out, we covered up nearly that whole area. It would be very difficult for anyone to get in there. This really meant that only one person could work well on the bridge at a time. If you've got all your stuff spread out and you are in the middle of a map of compilation, you have your graphing equipment out -- it's a pain-in-the-neck to close everything down when you go out in the water so the next guy can go up and use that space.

Unknown: Could you have used a bridge table in the center of the bridge?

Clifton: Not with that ladder.

Waller: Not with that great big access trunk right over the space.

Mahnken: We had a little space where the spirometer was stored.

Waller: Well, yeah, but you could have also made that opening smaller. I know you had to have it large to get things up there, but if you could have built some false floor to cover up part of it . . . I don't know about Connie, but I cleared that by about a couple of feet coming up and down the ladder.

Mahnken: I cleared it by quite a bit too.

Waller: The bio-medical cabinet where all the medicine and stuff was stored, if that had been moved out, you know completely, I don't think we would have lost any room. That's all it was used for mostly, just a little storage space and for medical stores. A nice big built-in light-table over there would sure have gotten somebody out of the way of the general traffic on the bridge.

Mahnken: In fact, if the whole ladder system had been built right next to the Habitat as you came in it would have given you more space. It was a pretty useless work area right there between the hatch and the crawl-way.

Unknown: I don't know how we could have rotated that particular ladder and still had a safety trunk access to the bridge because that's the way that hatch opens.

Waller: I just wonder if the ladder could be turned so you could go up the wall with the bulkhead near your shoulder, and have the ladder hook in to two or three points down the line so that if you do want to get to the hatch you can simply push it out of those pins or toggles or something.

Koblick: If you were to berth a fifth person in the Habitat, Rick, do you think they could comfortably be put up in the bridge maybe where the amplifiers for the EEG were or something, a bed. Do you think there is any room up there for another person?

Waller: Yes, I think in consideration of the money and other things, there would be a need for at least one more person. In fact, maybe in that Habitat, only one more person. A person could sleep on the bridge all right.

Thompson: The problem with the master communcations switch -- I guess everyone in the room does know at this stage -- in general the utility of the communications from the bridge, and perhaps I can touch on communications in the other areas also, what would you recommend in terms of changes if any? Did you have difficulty at all? Could you speak to each other? Was it even necessary to have an intercom between any two rooms?

Waller: Oh, yes, but I think it would have been nice to have had a private intercom between the four rooms in addition to the intercom to topside in the four compartments. I think there needed to be a Bogen on the bridge as well as a Bogen in the crew quarters as well as a sound powered phone on the bridge. The sound powered phone was no good as an auxiliary communications system. It was only an emergency system. I think two Bogens were needed.

Thompson: You say two Bogens, what would you use the second one for specifically?

Waller: So two people could talk instead of having to stand in line and wait for the Bogen. You would need another Bogen on the barge also.

Thompson: You are saying more lines to the topside.

Waller: Yes, just that one extra line.

Clifton: One other thing concerning communications. There was a tendency I think for the watch officers to consider that anyone who was sitting and working at the bridge be free and available for all sorts of errands. This got to be real annoying when you were in the middle of something and they call down to the bridge and want to check on this and that. They call down sometimes just to tell you divers were turning around and returning to the Habitat or something of this kind. In every case when they called down you had to get up, put down what you were doing, go clear over, depress the button, and say "yes". Then they give the message, and then you turn around and go back and sit down. This was a real source of interruption, I felt.

Thompson: When you slept at night did you find, you know, when you were on night watch, that the voice over the intercom did wake you up?

Van der Walker: We turned the intercom off down in the crew's quarters, and we turned it down in the bridge, at least when I was on watch.

Clifton: Yes, we kept the volume pretty well down so that people in the crew's quarters could sleep.

Waller: Now that would have been another excellent time to use the Bogen. There was some attempt to use the sound powered phone just to hold down the intercom noise, but on the sound powered phone you made more noise screaming through that than you did on the intercom, so I think the Bogen would have been handy here.

Thompson: OK, you didn't have any problem in taking your engineering measurements and doing the things we requested of you, I presume, in the bridge? OK, let's pass on through unless anyone has any other questions.

Unknown: One of the things you said you missed on the bridge facility was additional work space or desk space. Is there any other facility now, not equipment but facility, that you would have liked to have had in that bridge that you didn't have, like a bigger light-table or two light-tables?

Clifton: I would have liked to have had a drafting table.

Unknown: Why in the bridge? Why not in the wet room or in the crew's quarters? I am specifically concerned with things that we should consider in the future to stick in the bridge.

Clifton: Well, I don't know where you could stick a drafting table unless you had additional room for it. Certainly you couldn't have it in the wet room, because that was just too wet and sloppy down there. You couldn't do any kind of work down there; in fact, when we get to the wet room we'll agree that there was really pretty limited space for laboratory work in the wet room. I think for a scientific mission you really need laboratory space, as such, in addition to the bridge and the communications center.

Van der Walker: I really agree with that. If I had my choice I wouldn't put the bridge and the study area together at all.

Mahnken: Additional laboratory space should also include additional desk space.

Thompson: You are making a plea then for considerably more work space. Let me ask you this then. Is it because you're a planktonologist (Mahnken), or you're a geologist (Clifton), and, I don't know if this is something that John addresses or Rick, but the point is that they are fundamentally different. You don't tend to use the same instruments, do you, and the same . . . You (Clifton) use light-tables for maps and so on, and you (Mahnken) probably use the microscop for . . .

Mahnken: No, we all use the light-table -- all four of us. We use the light-table at various times down there.

Clifton: And we all used the microscope at various times too.

Mahnken: It's just like Ed said. If we are sitting using the microscope or the light-table and are called on the bridge to do something when we are trying to concentrate on something that we had to do at the light-table.

Van der Walker: And we all use paper, pencils, and books, and we don't like to have to put it all away so someone else can sit down for perhaps an hour. Then when we come back to it we have to get it all back out. We spend a lot of time putting things away.

Mahnken: This is the same problem that Ed mentioned that we'll get into in the wet room. You would set up a piece of equipment down there, but when the divers came in, they required more space than they had to lay down face masks and depth gages and places to put their tanks. By that time the noise and confusion and the space available to the divers almost precluded the area as a laboratory space.

Clifton: What with our schedule and the maintenance, etc., that went on, it was seldom that you could work more than an hour at any one thing before you would be called off for one reason or another, and if you were right in the middle and you have all your shelves stacked up, you really don't want to put them all away -- you have them all sorted out as to to size but you haven't counted them yet and you haven't got them completely sorted out - the most convenient thing to do is to leave them on the counter.

Mahnken: Just as long as the space is used exclusively for laboratory space not also as a wet room, not also as a communications room.

Unknown: Now you've been commenting about the fact that you had to remove your equipment so someone could use the same site and my question is do you just want more facilities or would you like to have a personal area for you to leave your stuff out between dives.

Clifton: That would be great -- that would be the best goal.

Thompson: Did you bring enough books, reference books, textbooks for your own needs? Did you have enough storage for them?

Mahnken: Yes, the bookcase was the shelving above the desk in the bridge. We use that as a bookcase which I assume it was designed for.

Goldstein: We also noticed that it was used as the music room, Ed, and we wondered how you progressed with your guitar playing.

Clifton: I'm not about to give a recital. On this business of music in there though, I don't know whether it was the tape recorder or the acoustics or the tapes, but there was a great difficulty in adjusting the sound level between having it so loud it just sort of knocked you out of your seat and barely being able to hear it -- I don't know whether it was because the ambient sound was sufficient on the bridge that you really had to turn up the music where you could hear it and, at that point it became too loud, or whether it was in the atmosphere, or the density, or if it was the tape recorder or what it was. This was a real problem. It was very hard to adjust.

Thompson: What is trying is that we use it all the time. It could have something to do with the ambient noise. How was the ambient noise, incidentally, in the bridge itself? Did you find it was too much so that you could not do your study?

Mahnken: The curtains helped in the ECS room (across the tunnel) -- it would have helped more had they been a little longer. Double curtains would have been better.

Clifton: It's hard though because they restrict your air circulation across there. Your CO_2 scrubbing took place only on the bridge, and there was no way of circulating air through except what just circulated through the tunnel. So you couldn't afford to close that off. When we made phone calls home we took some foam rubber or styrofoam or whatever the packing material was, and when we covered that other end up with the packing material. That just cut the noise level way down and that worked fine. But then the CO_2 started to go up.

Mahnken: Are we to the tunnel now?

Thompson: Yes.

Mahnken: Well, I think that Rick and Ed and John could duck-walk pretty effectively through the tunnel, but I couldn't. I tried it -- I tried it a number of times, and it was pretty painful. So I almost always crawled through it. It was pretty annoying at times to have to crawl through that tunnel. Would it have been possible to have made a larger tunnel?

Thompson: *We're going to have to put one of these things these automobile guys use,* you know, you get on your gut and roll on over, but we decided that would run into more problems. OK, but the tunnel was restricting to you?

Clifton: I would go along with this; it was almost as uncomfortable to crawl as it was to duck-walk.

Mahnken: You had to put the load down and scoot it to the end of the tunnel, then go to the end of the tunnel -- I did -- and get past the load and pull it out.

Clifton: We rolled the tomato juice cans across. It was tough getting across John, too.

Van der Walker: Well, if you would have put a port in there it would have been different.

Waller: I know -- you used to spend an awful lot of time in that tunnel.

Thompson: OK. The engine room, what did you think of the head?

Clifton: I still think there is something wrong with that toilet -- it works two different ways, it either drains all the water out or else the water comes up in it -- I'm not sure which is the proper way a head like that should function. Secondly, there was the continual problem of having fluid through that sanitary system so that you could flush it, which meant that we had a can sitting there that we had to keep filled with water. It took a lot of water.

Tenney: How long did you hold a flush?

Waller: Long enough to macerate whatever material was in the toilet and clean it.

Tenney: About how long? Would you say you held it 15 seconds?

Mahnken: No, I think we held it longer than that sometimes, because what I usually had to do was flush it, so that it would macerate the material in there and then take my finger off of it and then the level would rise, then I would push it down again and hold it for maybe 15 seconds.

Tenney: One of the problems with putting a conventional toilet in is that normally in a shipboard installation you are pumping through the hull and out, and here of course, you have a much longer pump to make it clear, and this causes your additive to be loose. Now, one thing you could have done, and I know we've talked about this, but it must have slipped your mind, is that that tube that controls the additive could have been pinched off with a clothespin. In other words, it won't work as long as that's drawing, so you either have to pinch it off completely or keep it going.

Mahnken: Well, Brooks, as I understood it, you either have to have water in the chamber or some of the additive in the chamber.

Tenney: You either have to have water or water-additive mix; you don't necessarily have to put the additive in there. You either have to have something in there or it has to be pinched off.

Mahnken: I don't remember anything about a clothespin.

Clifton: I don't either.

Mahnken: That would have been the solution then.

Clifton: There was a problem on occasion with gas backup -- you would flush it and there were a couple of times where I got some real big bubbles coming back up, and it was real good sewer gas.

Batutis: Well, that explains some of the methane that we've seen in the air.

Clifton: There was some methane detected and that's a very good source.

Cole: How frequently does this happen? Because it has to happen fairly frequently to get -- for example, methane.

Clifton: You always got some bubbles.

Mahnken: It happened every time I flushed it, because I would flush it for a while until the level went below the bend in the toilet, and then I would take my finger off, and I found that I could flush it more rapidly that way if I let it come back up again and then flush it again. Every time I did this something bubbled back up.

Adkins: This is a case-in-point for a gooseneck to trap the gas, and also perhaps the attachment of an air fitting outside so that you could take a scuba tank out every once in a while and blow your line out. We mentioned this at the beginning of the mission.

Waller: Well, how much methane did you measure? Where was this measured -- topside?

Batutis: We took a whole air sample.

Cole: The samples that we took back showed, for the middle and the end of the mission, traces of methane.

Batutis: Yeah, a couple parts per million. You see the charcoal won't pull it out. No, it's not really bad.

Cole: It wasn't really bad but it was noticeable.

Waller: Well, this had got a lot of use, and I am sure there was a lot of methane in that 1000 foot line. If there had been much more bulk backed up in there I am sure we would have gotten more methane than we actually got.

Batutis: Well, those MSA canisters that you had on a lot of your vent pipes would have taken care of any methane, and it would have sucked the methane out of the line so that this might have held it down a little.

Waller: The MSA what?

Batutis: The gas mask canisters, you know, the red canisters sitting on the top of the cabinet. That was their job.

Waller: There was a lot of problems with those -- those things didn't work, Ed. They were wet most of the time from condensate.

Batutis: Yeah, but they would work even though they were wet.

Thompson: OK -- did you use the toilet for anything other than your own human waste disposal, if I may be so indelicate? Did you use it for a garbage disposal or anything like that?

Van der Walker: No.

Thompson: You'll probably find that the engine room was probably the noisiest place in the Habitat.

Unknown: Before we leave the John can I find out if it was ever cleaned.

Answer: No.

Unknown: What about the rug in the John?

Van der Walker: No, not the John, the bathroom -- I would prefer that. (laughter)

Unkonwn: Sorry about that.

Van der Walker: Well, there's not many of us that have things named after them!

Mahnken: The counter there where the basin was sitting, you would get a little puddle behind it because the counter sloped in the same direction that the counter sloped in the wet room and the same direction that the cupboards opened in the crew's quarters. I wondered several times if the Habitat was level or whether this was in the construction of the Habitat.

Clifton: Yeah, there was a drainage problem there.

Thompson: How about the noise level itself? Was it loud? We can measure DB's and all this business but could you communicate with each other satisfactorily?

Waller: If you shouted.

Thompson: I guess you didn't have any occasion to stay in the engine room too long for any period of time.

Mahnken: The intercom was very ineffective in the ECS room, unless you used the earphones. Then there seemed to be a lot of interference on the intercom from the bridge. You got a lot of whining and screaming on the intercom.

Thompson: Well, changing the Baralyme was a very popular occupation of yours because you seemed to like to do it so often.

Waller: Well, we needed the exercise.

Thompson: By now there are only about 3 or 4 bolts as I get the report from the technical people. Was this a progressive thing? Or did it happen fairly soon? You know, the bolts started to drop off.

Waller: The bolts, we never got the washers down there, we were eating fairly steadily into the aluminum face plate on the scrubber, and the frequency of changes -- what were there, Dave? 8 bolts on there?

Withey: There was 12, I think.

Waller: I decided that was just too many, and I tried to get a seal one day with 4 bolts at the corners and got just as good a seal. I think we would have gotten a seal with 3 bolts -- maybe 2. But we stopped with 4 and that provided the seal.

Mahnken: The canisters didn't hold together, the lids wouldn't stay on the canisters, and I think Mr. Withey already found out that the lids wouldn't stay on the canister

Withey: Somebody boobytrapped that.

Waller: Today? (laughter)

Thompson: How about the cupola? Anyone got nice things to say about the cupola? Did you use it a lot?

Waller: No, we didn't use it very much at all.

Clifton: If the water had been as clear as it had been when we had been down here previously, or as it was on Easter day, we probably would have used the cupola extensively.

Waller: There was limited visibility -- 3 days is all we had, and I imagine we could have mapped, not distances but at least sketched in, a fairly effective chart extending out a radius of 75 feet.

Mahnken: I spent more time probably in the cupola during those 3 or 4 days than I did any other 4 days in the Habitat. It was really beautiful, and if somebody had been down there working specifically on fish behavior that cupola would have been a God-send.

Waller: If we had had a straza, we would have used it a lot more.

Goldstein: What's a straza?

Waller: A sonar, I'm sorry.

Thompson: How did you know specifically when the days were clear? Did you as a matter of course every day visit the cupola? Or was it just casual?

Waller: No, we looked out the ports every morning.

Van der Walker: You wake up every morning and look out the window just like you do at home -- to see if the dog is still in the yard.

Goldstein: What about the ports in the engine room? What utility did they serve for you? The one particularly behind the freezer?

Waller: Well, that was difficult to get to and that became the closest for the auxiliary scrubbers -- both the EDU and the Duke scrubber. It was difficult to spend much time in the engine room with the EDU scrubber. It whined. But even without the scrubbers that was kind of a tough port to get to. I think that port would have been a lot better in the bathroom.

Clifton: Well, actually it was the only port in the Habitat that you could see out that end, and there were a couple occasions when we had divers out and specifically wanted to watch what they were doing or check on them, and that was the only port you could actually see what was going on in the backside.

Waller: I think, though, when you would look out that other port, you couldn't see around the corner out to the gully, but it could be the fact that we didn't use the port, even though it was the only one you could see out back. With one the bathroom maybe you could look around the corner as far down that way as possible it would have been more effective. It could have been placed just behind the toilet.

Koblick: Do you think the cupola could be redesigned with the addition of something like a Pitot tube for sending up spent baralyme, and things like that to the surface instead of having it as a viewing port and trying to haul that stuff out every day?

Waller: No, I think if we just had a little visibility and a sonar we would have used it a lot more. Oh, one other thing, the ports should probably have been slanted slightly down. To look directly down in the front yard you had to put your nose against the port.

Mahnken: The ports in the upper compartments were too low for me. In the lower compartments they were just fine.

Tenney: They aren't all the same height -- the ones on the bridge are lower.

Mahnken: Right -- and I had to get on my knees almost to see out of them, particularly if I was going to do any lengthy viewing out of them.

Clifton: You bang your head pretty easily on that one port trying to get out by that cabinet where the medical supplies were.

Tenney: The criterion was the height of a seated man.

Aside: Some general comments while the tape was being changed concerned the proximity of the freezer door to the ladder and the angularity of the ladder itself. Discussion eventually turned to the barrier that was supplied to protect against objects falling down the ladder into the wet room.

Mahnken: The guard around the ladder? I don't think we used it but one or two nights, did we?

Goldstein: Oh, the barrier, you mean?

Thompson: OK -- do you want to go to the wet room now?

Van der Walker: Oh, by the way, about that cover. It would have been real handy to have had a solid thing there or a net, because we put things behind the ladder, Baralyme in particular, and it could have gone off that backside and click -- really got someone below. So I would suggest putting a solid backing in there so that nothing could be kicked off the floor and down onto someone in the wet room.

Clifton: Another point along these same lines -- the emergency air bottles are sitting right there, and those things -- when we went into the Habitat, the one right above the opening was unfastened; it was just in there loose. I kicked it and caught it as it went out and started to go over the side. Those things do come loose, and it's conceivable that somebody could have gotten banged pretty badly.

Van der Walker: A rubber strap or something to hold them in would be better than tieing it in -- something that could be disconnected quickly -- not those metal clips because they're just not positive enough.

Thompson: Do you want to try the wet room? You say you have some specific observations about its storage space, and so on -- do you want to amplify what you said earlier?

Clifton: In terms of space, there was really room for two people to suit-up and get out, or come in and get their gear down, but as long as there were two people in there getting their gear together it was impossible to do any suit-up although we could do it -- this could be done. But if you were trying to work in there, as I was on numerous occasions, you could work only until somebody came in and then you just had to clear out.

Mahnken: I agree 100 percent. When I had to set up that plankton stand-pipe, there were so many coils of wire below that one port that by the time I got the standpipe set up, it was nearly impossible to get to the port for two reasons -- because of the standpipe and because those wires were stacked back in there.

Waller: The panel, the air-changing scuba-charging panel, could probably be shifted -- it was a bit of a problem blocking the trunk when you were charging tanks. If it could have been shifted somewhere -- I don't know where -- .

Clifton: We ended up not charging the tanks in the water, so there was no real requirement for that thing to be over the trunk.

Waller: It would have been nice to have had a 3000-pound system on the emergency air or else have a much larger 3000-pound bank on the barge for scuba air. But three bottles simply wasn't enough. I think the refill time was, by the time you got up the ladder and got back out and took off again, on the order of about 45 minutes to fill if the bank was relatively high. If it wasn't high and you had to pump, you could lose a lot more time.

Mahnken: It would have been nice to have the switching panel for the emergency air and the scuba air in, etc., nearer to the scuba charge apparatus also, I think. Because every time we wanted to top off the emergency air we had to go all the way across the room and change the valving and then come back.

Clifton: It seemed like about the most effective way of filling the bottles was to put all the air that we could from the three bottles on the surface and then top off and cascade it in with the emergency air, and then when that dropped a little bit low, we just opened up the system and had them charge it back up over night or something like this.

Van der Walker: I don't know how much room there is between the two floors, but I think we always charged our tanks up on the bench usually. That was the most convenient. I think it would have been real nice to have had the dials right on the ceiling, the valves right over the railing that went down into the tube, and have the hoses on a reel, so you just pull them down and hook them up to the tank and charge. When you're done reel them right back up.

Goldstein: How about the railing? That railing and the diameter of the trunk cuts down the useful space within that compartment to some degree. Any comments along those lines?

Waller: There is nothing wrong with the diameter of the trunk. It couldn't have been any smaller. You really didn't need a fin ladder as it turned out -- we didn't know at the time. The fin ladder was wasted -- we always took our fins off in the trunk. With those double tanks it would have been better to have had the standard ladder all the way down. The rails on that ladder needed to be divided or separated maybe 8 inches.

Mahnken: It also would have been nice to have the emergency air tanks elsewhere -- like over under the crew's quarters rather than under the wet room because that was an area we used as storage space. In addition to that, it was a great spot for Moray eels. They lived behind the tanks, and they got quite nasty at times.

Goldstein: How much difficulty did you find, just digressing back to the crew quarters, in lifting the floor plate when and if you got in there.

Clifton: It was inconvenient.

Mahnken: It was a real finger-snapper. Rick, I think, caught his fingers once anyway on that. You mean to get into the bilge? The sump? It wasn't that bad.

Waller: You could have made the cover out of aluminum to make it a little lighter. It was awfully heavy and it was hard to get a purchase anywhere because the bunks were in your way and you normally had to straddle the thing, and it also applies with that grate in the wet room. We had to open that fairly often and that was a tight fit because the post stuck out of the one corner and it was heavy. Now, if that could have been made out of some lighter material and still maintain enough strength to support a man with two tanks on, it would have been better.

Mahnken: That bilge was a real pain-in-the-neck.

Waller: Also, it continued to rain rust down there, some fairly large flakes at times which, I am sure, was no good for that bilge pump. If that could have been galvanized or some other material rather than raw steel . . .

Unknown: Why would that rain rust?

Waller: It was raw steel.

Unknown: Was it primered?

Waller: No, it was raw.

Van der Walker: There was rust and paint going down there that was clogging up the pump.

Clifton: The big pieces of paint were really the things that gave us the problems -- the flakes from the deck -- and those big flakes would get down in the bilge and then they would plug up the pump.

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Waller: We scraped a lot of transfer pots and a lot of tanks over that deck. If there had been a better primer, some primer that would stick a lot better . . .

Unknown: How about fiberglass or indoor-outdoor carpeting?

Unknown No. 2: No, that would have collected too much water.

Unknown No. 1: I think it's great.

Waller: You might consider it.

Clifton: We had enough stuff drop through that grate into the bilge as it was. I think if we had an entire wooden grate in there we would have lost all kinds of stuff.

Waller: Well, you have to put a grate in in sections and if you had to move a 3 x 4 wooden grate it wouldn't be very difficult.

Unknown: How about floor tile, Rick, or some solid flooring like for kitchens, and what would you recommend would be the characteristics of the new flooring: resiliency, non-skid?

Adkins: Well actually you seem not to be satisfied with painted steel floorings.

Batutis: It was a good non-skid aircraft carrier deck paint. It's supposed to take a tremendous beating. Somewhere along the line the primer got fouled before we got the deck paint down, so we lost a good bond between the steel and the paint. And I think that the paint itself, from my experience with it, was a good non-skid paint.

Mahnken: But Ed, it did peel between the primer and the metal not between the primer and the paint. It's the primer that came up.

Batutis: It was very thin primer, it's hard to say. It was a chromate primer which is probably only 1/10 inch thick. We just didn't get a good bond.

Thompson: OK, that's fine, let's move on to a couple of other points now. How about the shower? I ask this particularly because I suspect of all the places where you had been most conscious of the fact that you had the big eye on you, the shower would have been the one. As a shower functionally, I presume it was average and normal, but it leads to a bigger question. Were you conscious, you were originally when you went down, but at any time did you get rid of the consciousness of the cameras on you?

Mahnken: I answered that for the behavioralists, and I think that's their question.

Waller: If that had bothered me I would have moved the camera over to the other side.

Mahnken: I always pulled the curtain when I took a shower.

Van der Walker: There are two things that bothered me; one was that the hangers that were supposed to go in there, or where there was supposed to be an area to hang up your wet suits, isn't wide enough for the wet suits, and it was a real pain-in-the-neck.

Waller: In the locker you mean, John?

Van der Walker: Yes, it just didn't hold a hanger.

Mahnken: That had to do with the hangers that we got down later in the game. They were just too wide for it.

Waller: Those cabinets down there in the wet room were still probably over half full of the same food that went down. You could probably put in another cabinet as large as the wet suit cabinet up off the deck and maybe even stored some tanks in there. Downstream from the one, and just remove one or two of those food cabinets.

Goldstein: You mean with a shelf at hip or belly level for storage of the tanks?

Waller: Something like that. In one big pot transfer you could bring in enough canned goods to last you for maybe four weeks and have a little more variety than was in all those cabinets. Well, you might want to very carefully consider your ballast before you remove that Raveoli, because the Habitat may come straight up. (laughter)

Mahnken: We were really hurting for shelving space down there at times, and the spacing of the shelves themselves, again, was very poor. There were no large shelves. I personally felt that the height of the one formica counter top was too low.

Clifton: Absolutely, without any question. That was too low, because the working that could be done in the wet room was not of the type that you would be sitting down. The only way that you could sit down was to pull that bench over and work off the end of the bench and that's uncomfortable at best. It was usually wet. Most of the work would have to be done standing up, and that was table-top level so you were all hunched working.

Goldstein: Now there again the height was sized on a sit down kind of basis.

Mahnken: Yes, but you couldn't sit down and get up to it, because there was no where you could get your knees in there.

Clifton: But this was only part of the problem. Secondly, there were no chairs in the wet room.

Mahnken: Third, you could never set desk material down there anyway because of the diver traffic.

Thompson: What was most of the work you did in the wet room? What was the nature of it? Did you, I don't know, did you cut fish or what?

Clifton: I was continually pulling shells and sand and stuff like that in and making cores from the sand and getting sand all over the place. Bring shells in and sorting them as to size -- these were always somewhat dirty and had sand with them, so I was bringing in an awful lot of sand. There was just absolutely no place where you really want to sit down and really write anything, to keep a notebook or something like this was about the best you could do.

Thompson: How about John? Were you using the wet room for anything in relation to your lobster work?

Van der Walker: Well, I found the wet room to be an awful crowded place, and I just got tired of trying to shuffle around between everybody.

Waller: You tagged a little bit John, remember?

Van der Walker: I was going to say that the only thing that I did was bring in my lobsters and tag them. Then I had to disrupt everything else that was going on, so I think you should just use that room as a wet laboratory and have another area for suiting. I would move everything out of there that had to do with going into the water.

Thompson: OK, now you are talking about a wet laboratory and just now you were talking about a dry lab as well.

Van der Walker: If I were going to build another Tektite I'd make three cans. One can would have a wet lab and a study area in it and everything else would be the way it is now.

Adkins: It might be a good idea to have a garage to park and service your submersible and to provide space in the laboratory for use of your toxic materials.

Unknown: You could also use that for storage.

Waller: I think you are going to have to go with a more expensive, slightly more complicated habitat with three cans, or if you don't have the money you are going to have to make the best you can with the two cans.

Mahnken: But that still doesn't solve the problem of storage of Baralyme and food.

Waller: No, but are we talking about 60 days or 6 days? It all depends on what you want to do and how much money you have.

Thompson: You are talking less about a storage problem than you are talking about a work space problem.

Mahnken: I agree. I think there could be a space beneath say the crew's quarters that wouldn't necessarily have to be connected to the crew's quarters. I mean you could have a storage space beneath it. A dry storage space for food with a pressure lock somewhere in the crew's quarters beneath the floor board that you could climb into and get food and Baralyme out of periodically. If you are going to go on an extended mission, say like 60 days, but like Rick says it's not necessary if you are going to have a short mission.

Clifton: Well, even with a long mission, I think Tektite kind of suffered from isolationist syndrome from the very outset when it was decided that we would go down with everything intact, and we would never receive anything from the surface. We didn't need all that Baralyme down there at the beginning. We transferred Baralyme -- it was kind of a pain-in-the-neck -- but we transferred Baralyme throughout the mission. Likewise we had far more food than we needed down there. We didn't need a full 60 days supply.

Thompson: If you hadn't taken the Baralyme down and if you had the storage space available, would it have affected the comments you made regarding the lab space?

Waller: We want to make that thing, self-contained because originally, GE, as soon as we finished the 60 days out here were going to be into orbit. (laughter)

Thompson: If you guys didn't get out quick enough you were going to go up with it.

Goldstein: Let me ask how much functional use you made out of the stainless top (bench).

Mahnken: I used it an awful lot.

Waller: Yes, that was a good item.

Mahnken: Except that it sloped the wrong way and you would get puddles of water in one end of it.

Clifton: Yes, that was an excellent place to work on sand samples, because you could get that sand out of there.

Goldstein: But you did use it quite extensively, you say?

Mahnken: I set aquaria up on it and I had some problem with an aquarium set-up because the heat from the dryer raised the heat in the aquarium so high that the animals died, but I moved the aquarium over to the other side then later anyway and it was all right.

Tenney: What about the fresh water hose? How useful was that?

Mahnken: Oh, that was indispensible.

Tenney: What was the frequency of the use? Right whenever you came in did you wash everything off?

Mahnken: We washed our diving gear off sometimes, and I hosed my suits off with that.

Waller: I didn't use it every time I came in. I used it mostly for hosing the decks.

Clifton: You used it at the end of the day your last dive for washing your gear down.

Tenney: When you were hosing your suits did you try to aim it so most of the water ran back into the trunk or did you just let it run into the bottoms and pump it out?

Waller: It wouldn't run into the trunk. There was a lip on the trunk.

Clifton: You would have to hold the suit over the trunk.

Mahnken: This was difficult to do sometimes because we would be charging tanks, and the charging lines would come over across the rail, and you didn't have access to the trunk very easily.

Tenney: So you would just let it run into the bottom and then pump it out.

Mahnken: Well, sometimes I hosed mine off in the shower. Then I got to using the shower to hose off my suits.

Waller: We usually try to have a lot of turnover down in the bilge; and then we lost the bilge pump for a spell. After we recovered it, it wasn't anything very difficult just a nut came off, Ed went down and cleaned it out and there was apparently some hydrogen sulfide down there or something very similar to it.. So then I made a real conscious effort to, and I think everybody did, to put a lot later down there and do a lot of pumping. Even more than we had to do.

Clifton: The bilge pump itself is located so that the orifice is at the side rather than at the very center. This means that you can never get all the water out. And if you get enough sediment down there then you're going to have problems. It got to the point where the only way effectively pump the bilge was to direct a jet of water down and wash the sediment away while the bilge pump was on.

Thompson: How did the General Electric dryer work?

Mahnken: Why wasn't that a washer-dryer combination?

Thompson: The unit we put in? I cannot think of a good reason at the moment, but I am sure I will.

Unknown: You talked about it at first, but I don't recall a reason for changing it.

Thompson: I think it was just having all that water around plus the degree to which you would want fresh, clean laundry as opposed to just dry towels.

Waller: Do washer-dryer combinations work as good as one or the other?

Mahnken: Sure. They take up the same space.

Van der Walker: I got tired of washing my clothes in the bottom of the shower and stopping up the drain, and stomping them to get them clean.

Waller: A washer that really washed for once! (laughter)

Clifton: Yes, he filled the shower.

Mahnken: He had 60 tee-shirts.

Goldstein: In retrospect would you say that if you were to do this again there was sufficient time allocated to crew training before mission startup?

Waller: I am not as concerned about . . . I was never concerned about crew training as you know. I think the Habitat should have set there with the ECS and everything turned on and going, and a watch set up on the van monitoring to see that it did not flood or anything.

Goldstein: You mean unmanned?

Waller: No, manned during the daytime, and 100 minute dives throughout the day just to see if things were all right. Cook several meals and things like that. Give it a week or two to settle in. I think a lot of our minor problems that come up in the first two weeks would have been solved if we had just had another two weeks which we didn't have unfortunately.

Thompson: OK.

Mahnken: One more comment before we leave the wet room. I think you need a better storage area for tools. Those drawers down there were very, very poor for storing tools because the tools were too heavy and the drawers began to bind. But by-and-large those swing out doors were very good I thought.

Clifton: We needed some more hangers -- metal, cuff-hook type hangers or something of this kind, particularly in the scuba storage cabinets. All there was when we went in there was just a rail. There's not a heck of a lot that you can make use of with a single rail with all that sort of gear. We finally sort of juggled things down, and we sort of jerry-rigged little hooks that would hang down that we could hang a lot of the assorted equipment on. It all worked out OK but it would have been a lot more helpful it those things had been there.

Thompson: OK. We'll get outside now into the trunk and the exit passage ways.

Unknown: Could I interrupt for a minute: We tried to design the Tektite interior as a place to live adequately and a place to work adequately. OK, can you rate us from 0 to 10 with 10 being an A as to the whole Tektite taken as a whole device. Whether it was a good place to live and a good place to work in?

Waller: I'd rate it at 8 or 9. I've stayed in a lot of things a lot smaller than that and I think 18 x 12-1/2 feet was very luxurious. I think the thing was well put together generally and, aside from a few bugs, it was a fine little Habitat.

Clifton: If you want to split livability and workability apart I would rate it up pretty high like Rick, 8, 9, 9-1/2 somewhere up in there in livability. It was a very livable Habitat. There were times like in the last couple days that I wished I were back down there. In terms of workability I would rate it down a little lower. Maybe put it on something like 6. This is primarily due to lack of work space.

Mahnken: I'd have to go along exactly with what Ed said.

Van der Walker: I think Ed summed it up very nicely. I would even rate it as 10 as far as livability.

Thompson: We are now in the entry trunk and outside is there anything specifically that you want to mention in regard to access: you bumped your head enough times or anything?

Clifton: We raised welts on that shark cage door. It dropped down just far enough that we very commonly banged our tanks on that.

Mahnken: The whole front should have opened up.

Waller: Well, maybe from the top too. You could have very easily had the whole top section -- you know if the whole top came out and down a ways, you could have had hinges here just to pull this up if it was difficult to make the whole front a door. You might even have considered hinging it back here so the whole top opened up.

Adkins: You could have articulated it so that when you opened one door the top would go up and when you closed it the reverse would happen.

Waller: What I was thinking about was that if you hinged the top so that it came all the way up, and there wasn't any particular danger to a port there, if you had a real dependable taut-wire system and an underwater pump, you might rig up a real good transfer system right down to inside the shark cage. That was always a big barrier and you might even, if you are a real fine engineer, be able to design some little thing that will run up to the cage and pop the thing up, I don't know.

Mahnken: One of the problems that we had with time was as they lowered the pot, the pot itself began to hollow out a hole in front of the shark cage, and it became more and more difficult to get the pot in because the distance between the lip of the shark cage and the bottom increased as we worked in front of the shark cage. After a while I think there must have been about a foot drop off the end of the shark cage to the bottom.

Clifton: I don't know if the shark cage is really necessary but it's awfully comforting.

Thompson: Comforting in what respect?

Clifton: Just knowing that when you stepped out the back door something wouldn't take your leg off that you couldn't see.

Thompson: That Moray eel that you guys fought valiently with and dispatched; I understand that you are getting a Congressional Medal of Honor for the daring deed. Where was that specifically located and how big was it really? It ranged all the way from two feet to ten feet and it depended on who you were talking to.

Clifton: It was three, maybe three and one half feet. It was a lot bigger alive than dead. It shrunk afterwards.

Waller: It wasn't it, there were several in there. They lived there behind the tanks, and it was very disconcerting to come down that ladder and see them in there. There were some large holes about that big (4 or 5 inches in diameter) in the top of the base so the shark cage was of absolutely no use for the eels. They just go in and out of there. All the fishes would go down in those holes and feed on the minnows under the hatch. I'm sure that's how the eels got in.

Van der Walker: I saw them going in and out.

Mahnken: I bet there were more eels back there than we ever suspected.

Clifton: It will be interesting when you guys take the bottles out.

General: Oh, yes. (laughter)

Unknown: Could those holes be grated in some fashion?

Mahnken: Take the bottles up out of there. That would be a big help.

Waller: Oh, one thing that I forgot; you better watch your sea water pump system. You've got an intake right around the side of the wet room and then you've got an exhaust right there too. Lots of times when we had the lights on, it would just suck these minnows in through the flat grille, and they would apparently go all the way through the sea water system and they kept trying to block up the exhaust, the sea water exhaust. You could see them just packed up in there, but fortunately there was enough passage not to burn the pump out. It occured to me that just a piece of plastic floating around out there far enough in front of there or if you had a globe grid or a globe screen or something other than a flat surface, it may solve the problem.

Mahnken: The same can be said for fish getting caught in the screen around the base of the entry trunk. We found a number of yellow tails and trumpet fish that would kill themselves in there.

Van der Walker: That's a hard thing to avoid though.

Mahnken: Well, I think the mesh could have been a little larger, and then we would have caught groupers; maybe a little smaller and then we would have caught jankinzia.

Thompson: How about the way stations? Did you use them?

Clifton: The use of the way stations was in bottle transfers. They provided really the only means where we could, other than having bottles with regulators dropped on; they provided the most convenient means of getting and exchanging bottles.

Mahnken: They were always a reinsuring landmark though.

Thompson: How did you find these lines the Seabees laid down? (the navigation markers). Did you navigate on those?

Waller: No, we didn't do any navigation on them.

Clifton: By the time those were put in we had the reef mapped to the extent that almost anyplace on that reef you could locate yourself within 5 feet.

Waller: Well, they would never be used for navigation. You know, when you go camping you don't really depend on trail markers to move out from a tent site. You depend on trees and things, then you gradually range out farther and farther. When you are properly oriented you don't have any problem. Well, we had the entire reef area running north and south. We had a depth barrier. There was no problem, we didn't need them.

Aside: While the tape was being changed the conversation turned to communications.

Clifton: Some people were pretty good about it (communications) but other people made themselves evident about every 10 minutes. You can't fault the communications for that.

Thompson: It's not so much the physical operation of the equipment that I am talking about. You know, the utility as far as the system is concerned. As far as retaining the strict requirement to set up an isolation routine we tended to use only the barest minimum in the way of communications. Sometime I guess you never really were conscious of this, but we were deliberately, in our own conversations, trying to shorten up as quickly as possible. This bespeaks of a certain economy in terms of operations but at the same time did you ever feel the need to want to elaborate more or feel that you were necessarily being cut off or something of this sort? In other words is there a more efficient way of doing this communication policy?

Waller: Yes, try not to restrict it. Make people available. It's very annoying asking a question and taking 5 days to get an answer when there's a particular engineering system involved.

Clifton: A phoneline in the base camp would have solved a lot of the problems.

Waller: I hear there's a unique technology in the United States, it's called telephone cables.

Thompson: Has anyone got anything else they would like to bring out in order that we may free these good gentlemen?

Unknown: Yes, I would like to find out if the external lighting was adequate? No problems?

All: No problems.

Clifton: It's very reassuring to come back from a night dive and be able to see that glow.

Unknown: Could you give me a judgment as to the average visibility at night? Was it about 50 feet?

Van der Walker: No, much further away than that if I look at the surface, because the light goes up and apparently travels along the surface some way and is reflected back down.

Clifton: It's like a city in a fog.

Unknown: You're the first reporter of that phenomena. I would really like to know about it.

Van der Walker: Well, you know as much about it as I do now.

Goldstein: Could you get directionality by looking up at the surface?

Van der Walker: No, it's not a sharp thing. It's like, well, you know its that way and not that way.

Unknown: Is it like a glow from one vector, and you see it upward but you don't see it downwards?

Collectively: Yes.

Unknown: May I ask you, is the water clarity near the surface better than it is at the bottom?

Clifton: We never got up that for. We couldn't go above 21 feet.

Thompson: OK, anybody else? OK, in the absence of any questions, gentlemen, we are going to essentially terminate this interview, and I thank all three of you, and I even thank Rick believe it or not, for gracing us with your presence. Thank you very much for all the information and data you have given us. We are all very proud of you.