Technical Memorandum WHOI 3-76: *Alvin* Users Manual

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TECHNICAL MEMORANDUM WHOI 3-76

Woods Hole Oceanographic Institution

WOODS HOLE OCEANOGRAPHIC INSTITUTION

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TECHNICAL MEMORANDUM NO. 3-76

ALVIN USERS MANUAL

E. L. Bland
J. D. Donnelly
L. A. Shumaker

November 1976

WOODS HOLE, MASSACHUSETTS 02543

WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts 02543

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prepared by

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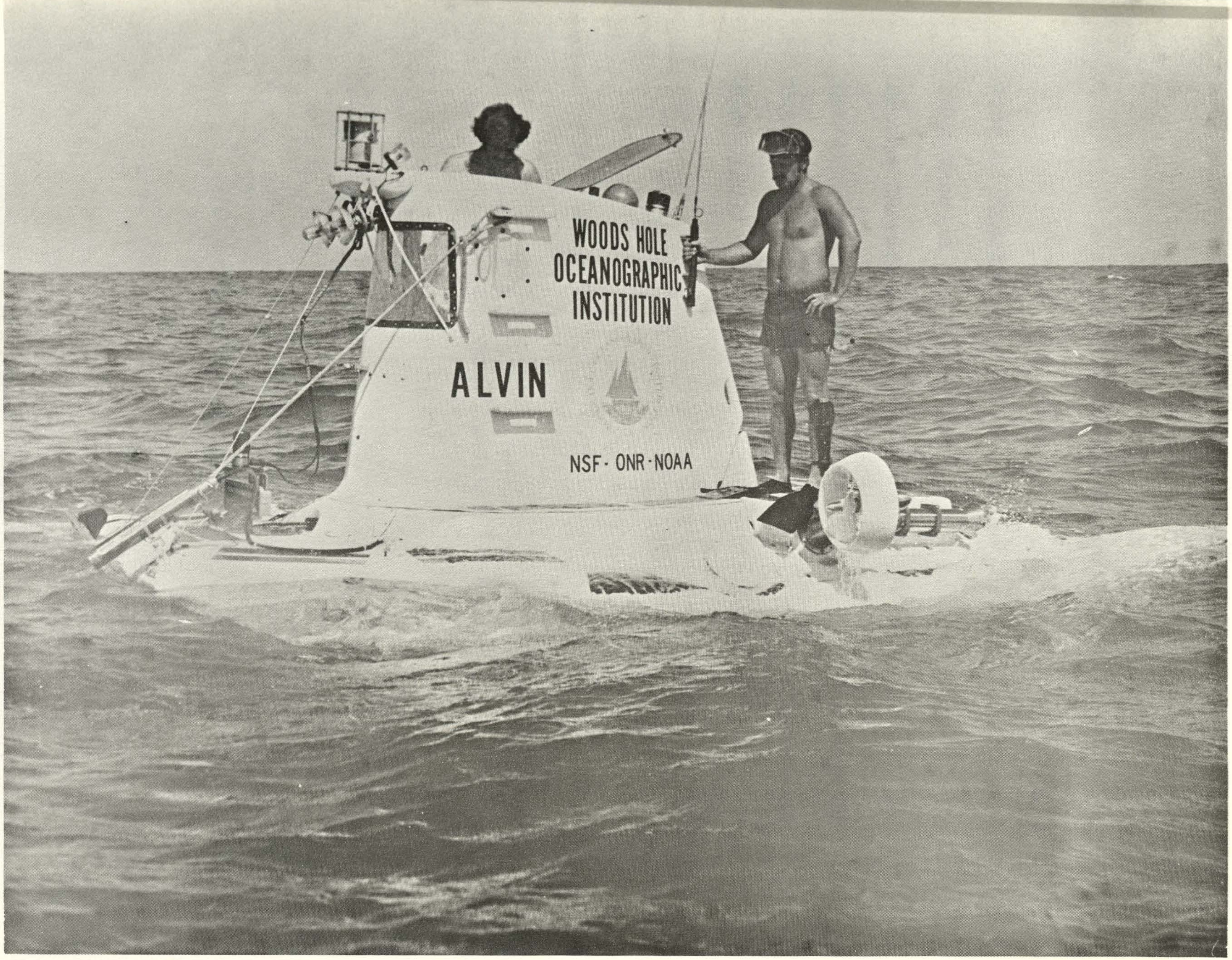
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INSTITUTION
ALVIN
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INTRODUCTION

Planning

In order to plan a successful cruise utilizing the ALVIN/ LULU system it is important for the user to understand the capabilities and limitations of the system. The Deep Submergence Engineering and Operations Section provides this manual as a means for the user to become familiar not only with the deep submersible ALVIN and its mother ship LULU, but also with the constraints put on the system by the environment, both above and below the ocean surface, and by geographic considerations.

We strongly urge that, after reading this manual, potential ALVIN users contact us to discuss their plans and objectives. Such detailed discussions with experienced members of our group often lead to improved methods for accomplishing scientific objectives. Contact at Woods Hole may be made with:

Larry Shumaker, Program Manager

or

Skip Marquet, Assistant Program Manager

Phone Number (617) 548-1400 Ext 407, 408

ALVIN Mission

In general, ALVIN's capabilities are as follows:

1. Operate at any depth from the surface to 3658 meters at speeds of 0-3.5 km/h.

2. Carry one or two observers and various internal and/or external instrumentation and tools.

3. Perform scientific or engineering tasks.

4. Maneuver within one foot of slopes or other bottom topography.

5. Rest on the bottom to perform tasks.

6. Hover at neutral buoyancy.

7. Remain submerged for periods up to approximately ten hours.

Each of these "missions" and the compromises and constraints that go with them will be discussed in this manual. Before requesting the use of ALVIN however, a user should understand that this is a sophisticated and expensive oceanographic tool. It is therefore important to consider the proposed tasks in the light of two questions. First, has all of the groundwork been done which leads up to ALVIN's utilization. This should include, where applicable, thorough bathymetry of the area and enough data from cable lowered or free fall instruments (cameras, cores, dredges, CTD's, current meters, etc.) to validate the need for the manned submersible. Secondly, have all other reasonable methods of accomplishing the task (including manned submersibles of lesser capabilities) been thoroughly reviewed to insure that when economical, technological and scientific trade offs are considered, the manned submersible is clearly the best method. The ALVIN/LULU manned submersible system should be used to accomplish only those tasks which cannot properly or economically be accomplished with any other available oceanographic tool.

ALVIN has proven most effective when used in a well planned, coordinated program, where the ability to observe directly, photograph selectively and sample <u>in-situ</u>, all with specific relation to the immediate surroundings, is complementary to the total program.

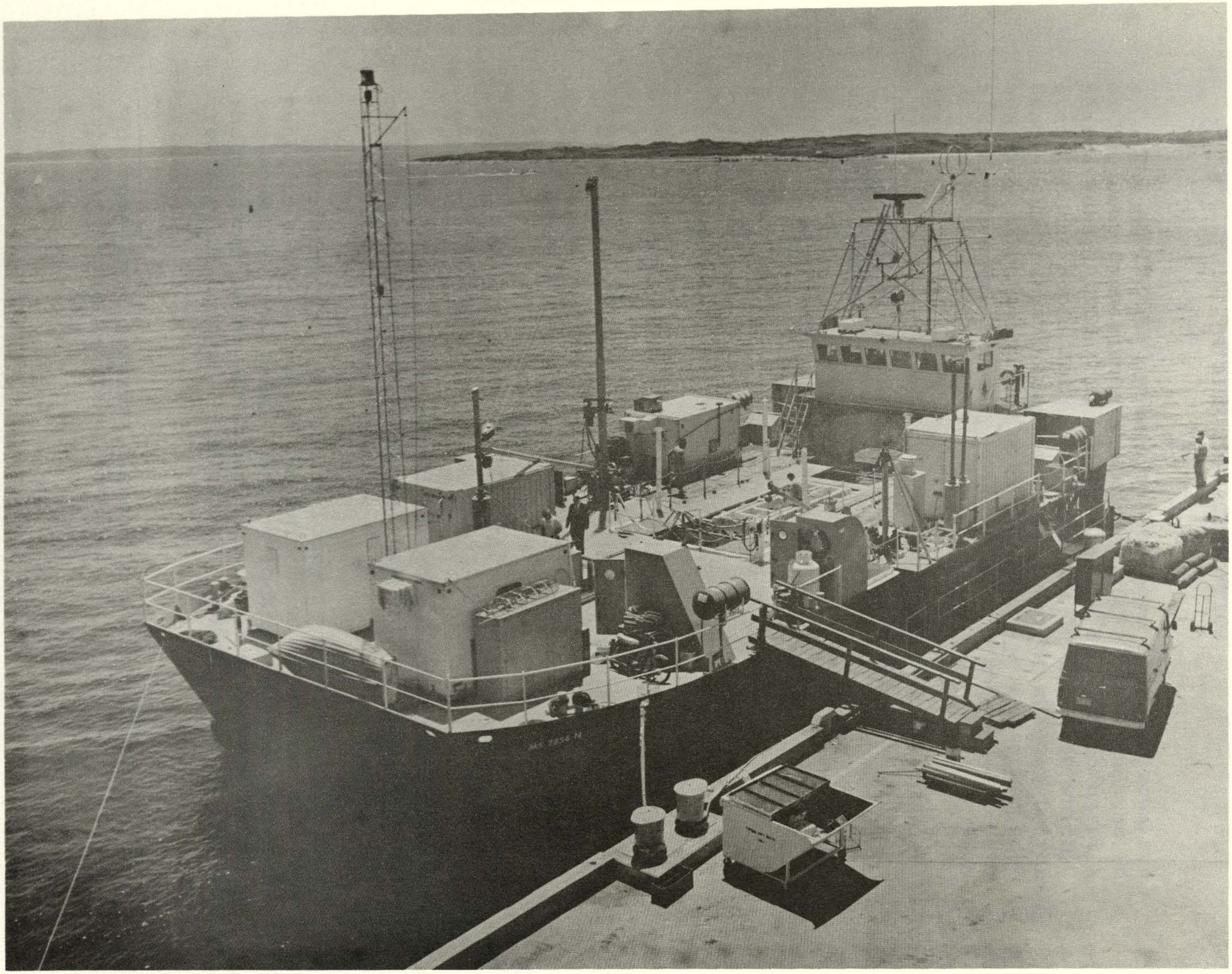


Figure 1   Research Vessel LULU

SYSTEM CHARACTERISTICS

The ALVIN/LULU system, as the name implies, consists of the Deep Submergence Research Vehicle ALVIN and the Research Vessel LULU. In addition there is a shore based staff at the Woods Hole Oceanographic Institution which handles logistics, clearances, engineering changes to the vehicle, maintenance and overhaul planning and other administrative routine.

LULU

The general characteristics of the Research Vessel LULU are as follows:

Length overall	-	32 m (105 ft.)
Beam	-	14.6 m (48 ft.)
Draft	-	3.3 m (11 ft.)
Displacement	-	417 tonnes (460 tons)
Speed	-	6 knots (calm sea)*
Berthing (crew)	-	22 (including ALVIN crew)
(science)	-	8
Endurance	-	14 days

The LULU is a catamaran-hulled ship designed specifically to support the ALVIN, and has only minimal additional oceanographic capability.

Berthing for the science party is provided with four bunks in a living van on the main deck. This van also has two desks and four small hanging lockers as well as book shelf space. Four additional bunks are available in the crew's berthing area. Additional working space is available

*For open ocean transits a speed of 5 knots should be used for calculating length of transit.

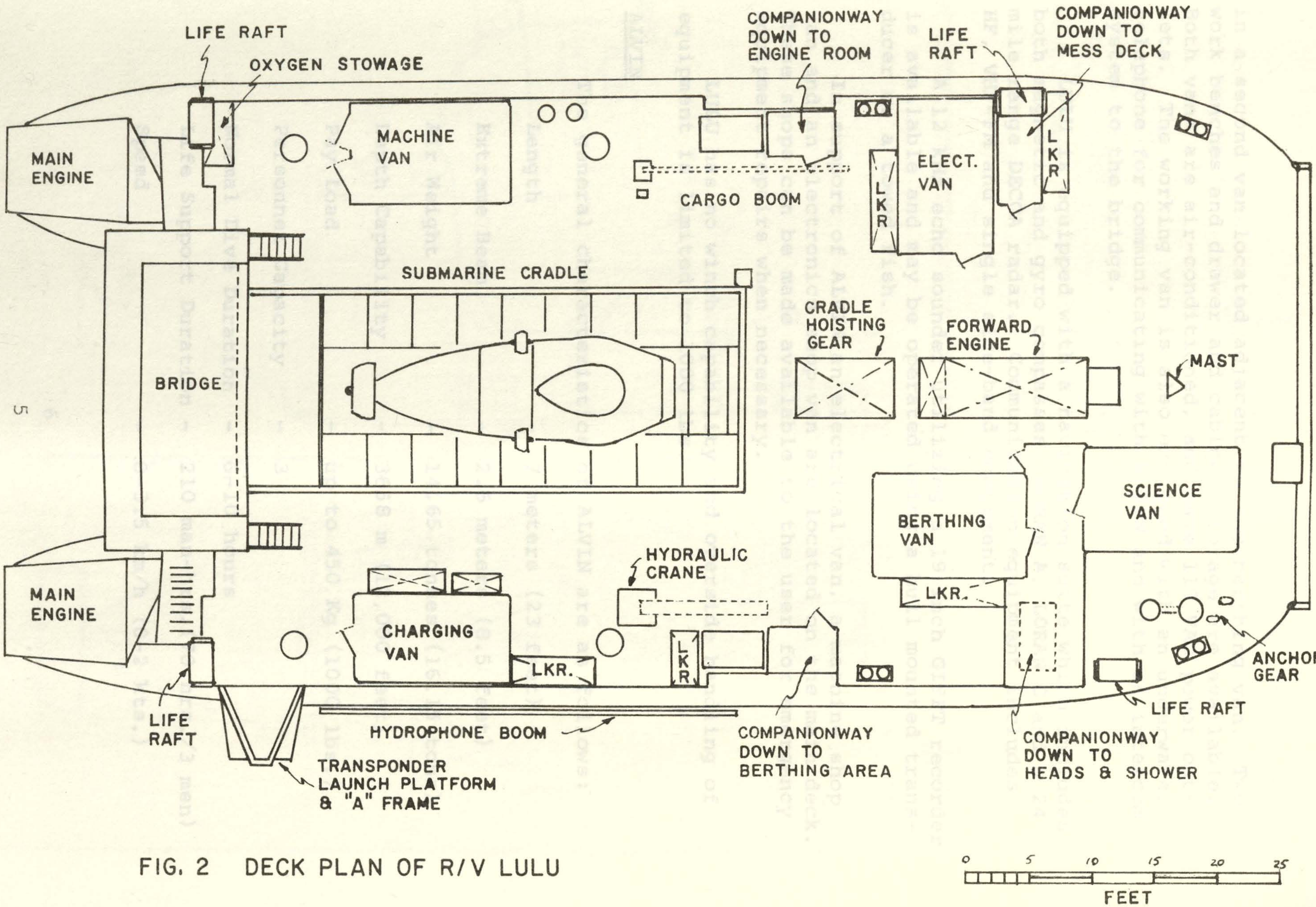


FIG. 2 DECK PLAN OF R/V LULU

in a second van located adjacent to the berthing van. Two work benches and drawer and cabinet storage are available. Both vans are air-conditioned, and have 110 VAC power outlets. The working van is also equipped with an underwater telephone for communicating with ALVIN and with an intercom system to the bridge.

LULU is equipped with a navigation suite which includes both magnetic and gyro compasses, LORAN A, LORAN C and a 24 mile range DECCA radar. Communication equipment includes HF, VHF-FM and single side-band equipment.

A 12 kHz echo sounder utilizing a 19 inch GIFFT recorder is available and may be operated using a hull mounted transducer or a towed fish.

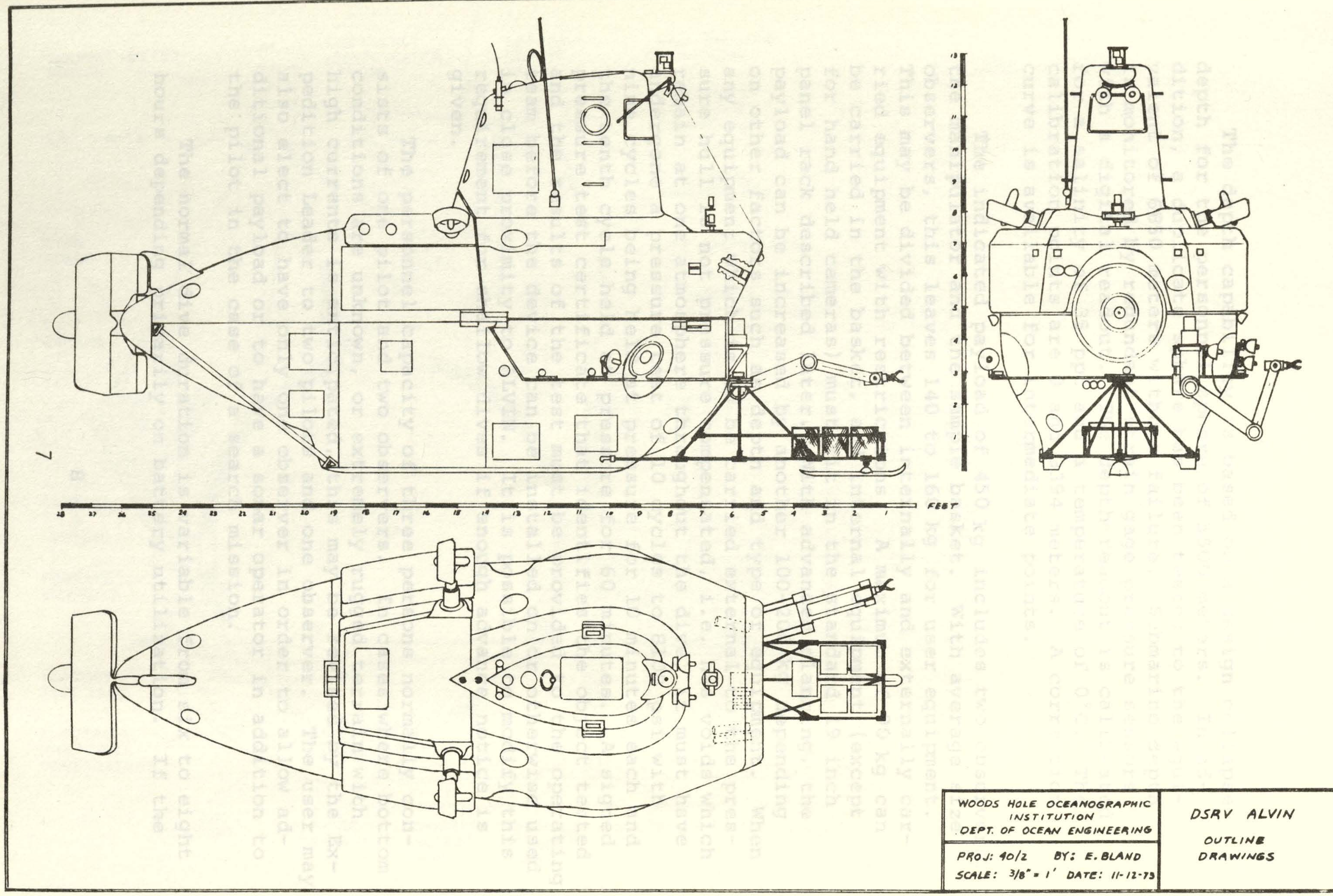
In support of ALVIN an electrical van, a machine shop van and an electronics shop van are located on the main deck. These shops can be made available to the user for emergency equipment repairs when necessary.

LULU has no winch capability and overside handling of equipment is limited to 1000 lbs.

ALVIN

The general characteristics of ALVIN are as follows:

Length	-	7 meters (23 feet)
Extreme Beam	-	2.6 meters (8.5 feet)
Air Weight	-	14.65 tonnes (16.15 tons)
Depth Capability	-	3658 m (12,000 feet)
Pay Load	-	up to 450 Kg (1000 lbs.)
Personnel Capacity	-	3
Normal Dive Duration	-	6-10 hours
Life Support Duration	-	210 man-hrs.(70 hrs./3 men)
Speed	-	0-3.5 km/h (0-2 kts.)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BY: E. BLAND
SCALE: 3/8" = 1'
DATE: 11-12-73
DSRV ALVIN
OUTLINE DRAWINGS

Figure 3

The depth capability is based on a design collapse depth for the personnel sphere of 5500 meters. In addition, a duplicate sphere has been tested to the equivalent of 6850 meters without failure. Submarine depth is monitored by redundant strain gage pressure sensors with a digital readout. The depth readout is calibrated for a salinity of 35 ppt and a temperature of 0°C. The calibration points are 0 and 3394 meters. A correction curve is available for intermediate points.

The indicated payload of 450 kg includes two observers, the manipulator and the sample basket. With average size observers, this leaves 140 to 160 kg for user equipment. This may be divided between internally and externally carried equipment with restrictions. A maximum of 90 kg can be carried in the basket, and internal equipment (except for hand held cameras) must fit in the standard 19 inch panel rack described later. With advanced planning, the payload can be increased by another 100-200 kg depending on other factors such as depth and type of equipment. When any equipment which is to be carried external to the pressure hull is not pressure compensated, i.e. has voids which remain at one atmosphere throughout the dive, it must have undergone a pressure test of 10 cycles to 8100 psi with nine cycles being held at pressure for 10 minutes each and the tenth cycle held at pressure for 60 minutes. A signed pressure test certificate that identifies the object tested and the results of the test must be provided to the operating team before the device can be installed on or otherwise used in close proximity to ALVIN. It is possible to modify this requirement for shallow dives if enough advance notice is given.

The personnel capacity of three persons normally consists of one pilot and two observers. In cases where bottom conditions are unknown, or extremely rugged terrain with high currents is anticipated, this may be revised by the Expedition Leader to two pilots and one observer. The user may also elect to have only one observer in order to allow additional payload or to have a sonar operator in addition to the pilot in the case of a search mission.

The normal dive duration is variable from six to eight hours depending primarily on battery utilization. If the

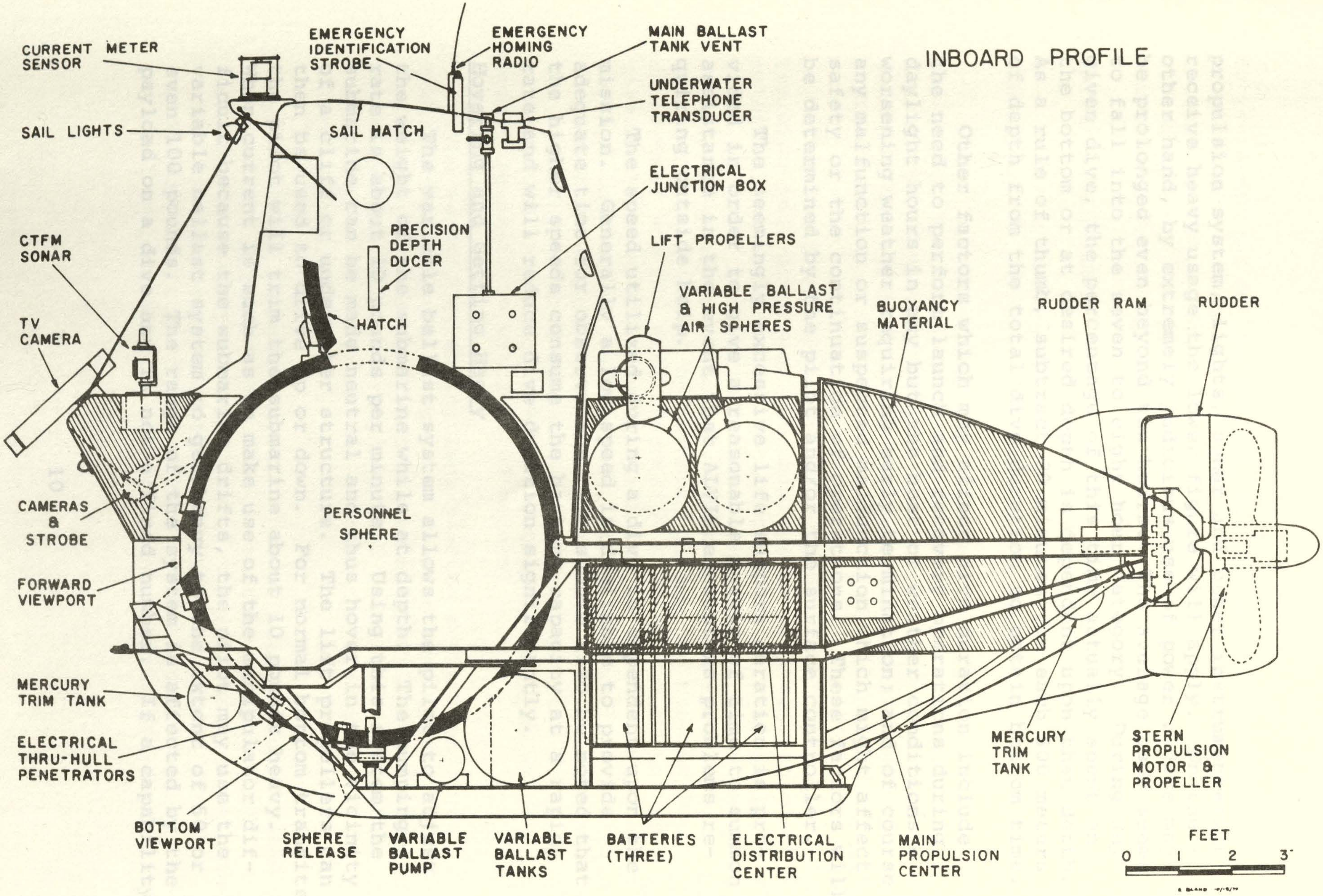

INBOARD PROFILE
CURRENT METER SENSOR
EMERGENCY IDENTIFICATION STROBE
EMERGENCY HOMING RADIO
MAIN BALLAST TANK VENT
UNDERWATER TELEPHONE TRANSDUCER
SAIL LIGHTS
SAIL HATCH
ELECTRICAL JUNCTION BOX
CTFM SONAR
PRECISION DEPTH DUCER
LIFT PROPELLERS
TV CAMERA
HATCH
VARIABLE BALLAST & HIGH PRESSURE AIR SPHERES
BUOYANCY MATERIAL
RUDDER RAM
RUDDER
CAMERAS & STROBE
PERSONNEL SPHERE
FORWARD VIEWPORT
MERCURY TRIM TANK
ELECTRICAL THRU-HULL PENETRATORS
MERCURY TRIM TANK
STERN PROPULSION MOTOR & PROPELLER
BOTTOM VIEWPORT
SPHERE RELEASE
VARIABLE BALLAST PUMP
VARIABLE BALLAST TANKS
BATTERIES (THREE)
ELECTRICAL DISTRIBUTION CENTER
MAIN PROPULSION CENTER
FEET
0
1
2
3

Figure 4

propulsion system, lights, sonar and other instrumentation receive heavy usage the lower figure will apply. On the other hand, by extremely judicious use of power a dive may be prolonged even beyond ten hours. The average user seems to fall into the seven to eight hour category. During any given dive, the percentage of this time actually spent on the bottom or at desired depth is dependent upon that depth. As a rule of thumb, subtract 30 minutes for each 500 meters of depth from the total dive duration to obtain bottom time.

Other factors which may affect dive duration include the need to perform launch and recovery operations during daylight hours in any but the best of weather conditions - worsening weather requiring early termination; and of course any malfunction or suspected malfunction which might affect safety or the continuation of operations. These factors will be determined by the pilot and/or the surface controller.

The seemingly excessive life support duration is provided in order to give a reasonable margin of time to summon assistance in the event that ALVIN encounters problems requiring outside help.

The speed utilized during a dive is dependent upon the mission. Generally a low speed is desirable to provide adequate time for observation. It should also be noted that the higher speeds consume the battery capacity at a rapid rate and will reduce dive duration significantly.

Hovering and Getting Heavy

The variable ballast system allows the pilot to adjust the weight of the submarine while at depth. The pumping rate is about 10 pounds per minute. Using this system the submarine can be made neutral and thus hover in the vicinity of a cliff or underwater structure. The lift propellers can then be used to drive up or down. For normal bottom transits the pilot will trim the submarine about 10 pounds heavy. When current is such as to make use of the manipulator difficult because the submarine drifts, the pilot may use the variable ballast system to get heavy to the extent of 50 or even 100 pounds. The range of the system is affected by the payload on a dive and is not a fixed number. If a capability to get heavy on the bottom is required and advance notice is given the ballast system can be configured to provide as much as 400 pounds of negative buoyancy. An additional 150 pounds can be applied by downward thrust of the lift propellers for short periods of time.

Navigation Systems

Normally installed equipment in ALVIN gives basic capabilities to navigate, observe, photograph and manipulate.

There are three primary methods of navigating the submersible. The first two are available under normal circumstances, whenever needed. The third requires advance planning and additional funding over the normal operating costs of ALVIN.

The first and simplest method consists of surface tracking and vectoring. In this system, a precision clock on ALVIN, synchronized prior to each dive with a similar clock on LULU, controls the emission of an acoustic pulse from ALVIN every two seconds. This pulse is received on LULU on a directional hydrophone, giving the bearing to the submarine, and the time of receipt is compared to the precision clock on LULU giving slant range. With knowledge of depth, slant range, and bearing, ALVIN's position relative to LULU can be determined and compared to LULU's position. The accuracy of this system is dependent upon the accuracy of the LULU navigation. With relation to LULU it is generally accurate to within ±100 meters.

The second system involves placing a transponder on the sea floor in the vicinity of desired operations. ALVIN can then operate around this transponder utilizing its sonar to obtain range and bearing out to a radius of 1500 meters. Resolution of this system relative to the transponder is shown in Table 1.

The third system, utilizing two or more bottom mounted transponders deployed from LULU or another surface ship, can provide precision navigation of the submersible, relative to the transponder net, with an accuracy of ±10-20 meters, and a repeatability of ±1-3 meters. This system requires additional technicians for its operation and therefore additional

Table 1

Range Scale (Meters)	Range Resolution (Meters)	Lateral Resolution (Meters)
3-15	.3	.1-.5
10-50	1	.33-1.7
30-150	3	1-5
100-500	10	3.3-17
300-1500	30	10-50

funding. On a ten-day cruise, added cost would be approximately $12,000 plus travel from Woods Hole to port of embarkation and return for the technicians and equipment. In addition, as much as one full day of diving may be lost due to the need for deploying, surveying, and recovering the transponders. At the end of each dive, the

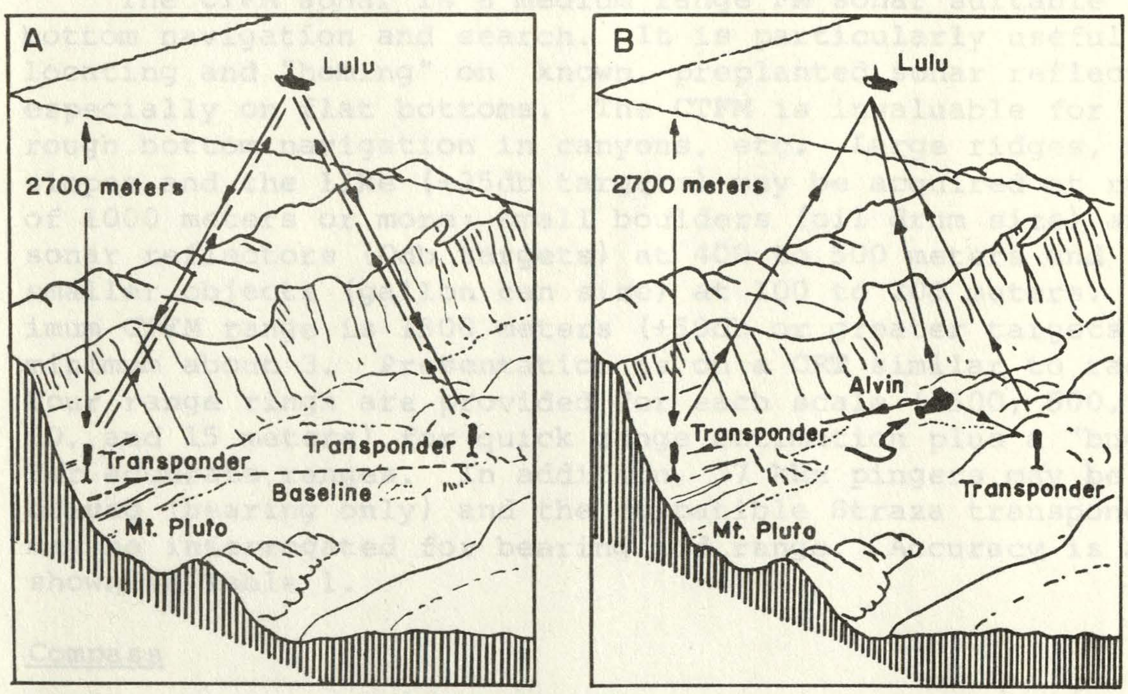


FIG. 5 A. LULU INTERROGATES TRANSPONDERS FOR OWN POSITION.
B. ALVIN INTERROGATES TRANSPONDERS, AND LULU RECEIVES FOR ALVIN POSITION. A COMPLETE CYCLE, RESULTING IN ONE LULU POSITION AND ONE ALVIN POSITION, REQUIRES 30 SECONDS.

user will have a precise chart of ALVIN's track during the day's dive. In addition the system may be used to do precision navigated bathymetry from LULU during night hours while ALVIN is being replenished.

Depth Gauge

The depth measuring system on ALVIN consists of two redundant strain gauge pressure sensors feeding a digital display reading in meters with a least significant digit of one meter throughout the full range of 3700 meters. The same sensors also feed a panel meter which is marked in both feet and meters. An outside dial gauge in a pressure proof housing may be read through the front window by the pilot. The underwater telephone may also be used as an upward beamed echo sounder to measure depth acoustically. This system is activated by the pilot but must be used selectively as it interferes with normal communications and tracking.

CTFM Sonar

The CTFM sonar is a medium range FM sonar suitable for bottom navigation and search. It is particularly useful for locating and "homing" on known, preplanted sonar reflectors especially on flat bottoms. The CTFM is invaluable for rough bottom navigation in canyons, etc. Large ridges, steep slopes and the like (+25db targets) may be acquired at ranges of 1000 meters or more; small boulders (oil drum size) and sonar reflectors (0db targets) at 400 to 500 meters and smaller objects (gallon can size) at 100 to 200 meters. Maximum CTFM range is 1500 meters (+50db or greater targets) and minimum about 3. Presentation is on a CRT similar to radar. Four range rings are provided for each scale (1500, 500, 150, 50, and 15 meters) for quick range estimation plus a "bug" for accurate ranges. In addition, 37 kHz pingers may be received (bearing only) and the compatible Straza transponder may be interrogated for bearing and range. Accuracy is as shown in Table 1.

Compass

A gyro compass and remote repeater are provided to indicate true ship's heading. Digital readout of gyro heading is displayed in convenient locations for the observers. Back-

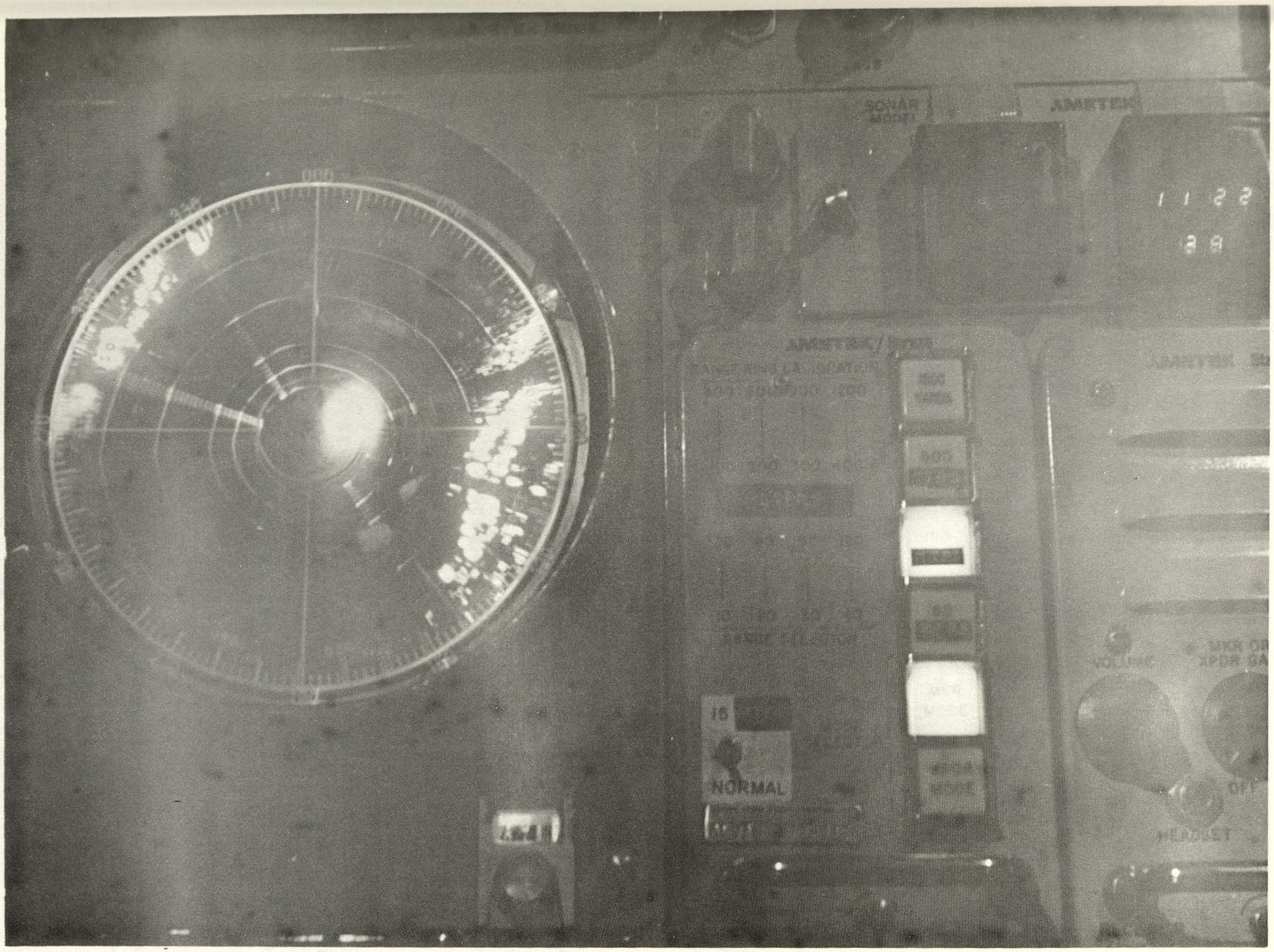


Figure 6 **CTFM Sonar Presentation.** Range scale in this picture is set for 150 meters. Presentation shows steep scarps 90 meters to starboard and 120 meters to port. Note digital time presentation in upper right hand corner for data correlation.

up systems include a magnesyn compass (with remote indicator) and a magnetic compass mounted outside the front window.

Tape Recorders

Portable cassette tape recorders, with spare cassettes, are carried on each dive for scientists' use. Tapes used during each dive are turned over to the user for his retention.

Underwater Telephone

ALVIN's underwater telephone is used for normal voice or CW communications with the surface support ship. It is compatible with Navy systems. In addition, it has built into it, echo sounder, pinger and transponder capabilities. LULU's identical unit can thus interrogate the submarine for ranges or ALVIN may interrogate LULU. Since ALVIN has both "up" and "down" transducers, the phone may be used to echo range to the bottom for altitude or to the surface for depth. Ranges read out digitally in meters.

Echo Sounder

ALVIN's 12 kHz echo sounder will usually acquire the bottom at an altitude of up to 1500 meters (depending on type of bottom). Accuracy at extreme ranges is not great but improves closer to bottom. Echo presentation is on a cathode ray tube.

Altimeter

For very accurate close-to-the-bottom soundings, a high frequency, high resolution fathometer is provided. Maximum range off the bottom is 100 feet and an accuracy of ± one foot may be expected. Digital readout is in feet and updated every second.

Current Meter

The current meter module, driven by a Savonius rotor located on top of the sail (see Fig. 4), reads water current, in knots, if the vehicle is stationary or vehicle speed if moving. Current direction must be determined visually. Scales are 0 to 1 knot and 0 to 4 knots; threshold 0.1 knot.

Clock

A precision clock is installed in the submarine. This clock is synchronized with a clock on the mother ship prior to each dive. In addition to controlling the signal output of the navigation pinger, the clock is used to provide digital display of time at each observer's window and on the front panel of the scanning sonar. It also provides time reference marks on the data logger when that equipment is installed, and to the external camera system.

External Cameras

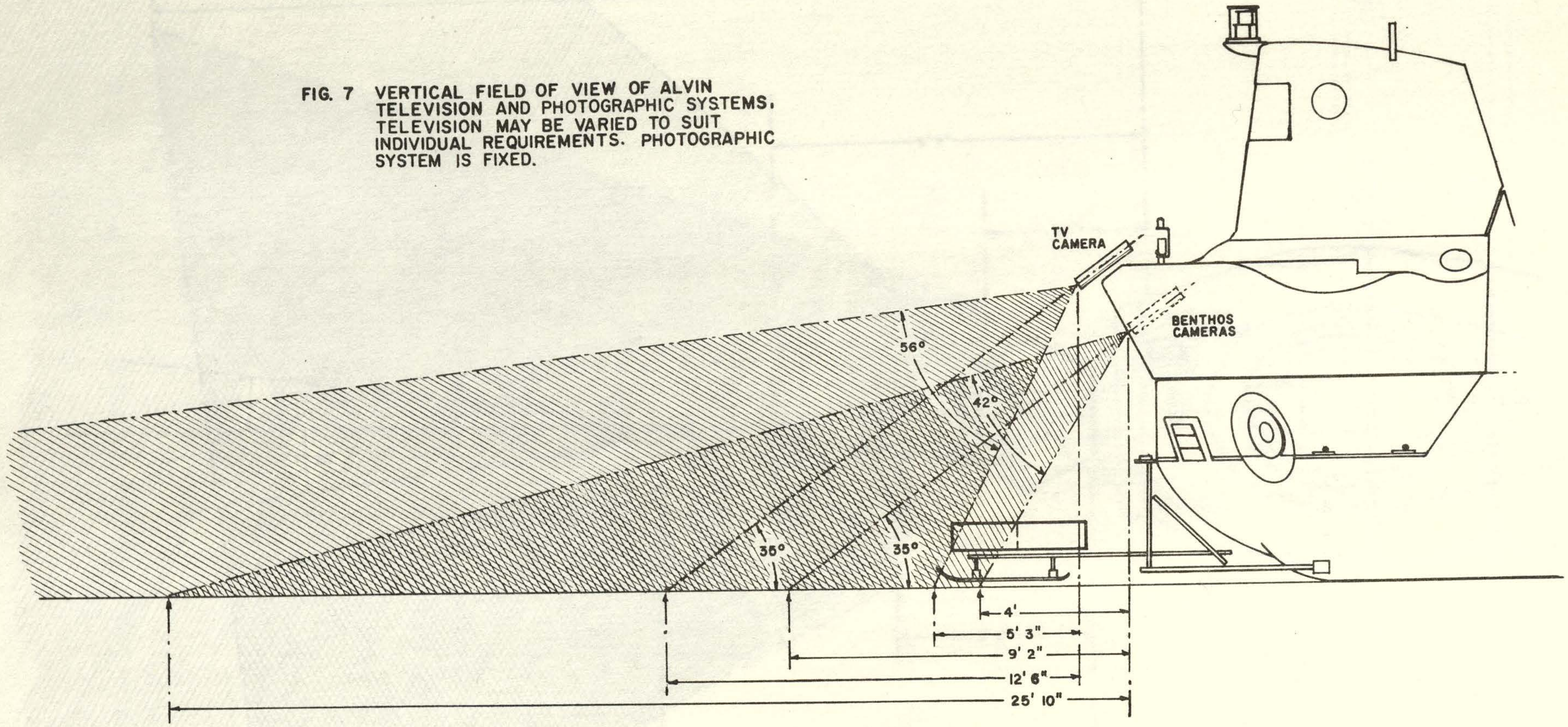
The external camera system consists of two Model 371 Benthos 35 mm cameras with 35 mm lenses, mounted above the forward viewport and aimed at a point about 12 feet in front of the submarine. Each camera may be triggered separately or they may be triggered together for stereo pairs. The cameras may be loaded with black and white (Plus-X) or color (High Speed Ektachrome) and each has a capacity of 750 frames. In addition to manual triggering a timer is incorporated in the internal controls allowing the cameras to be triggered at 4 to 14 second intervals. The orientation and field of view of these cameras is shown in figures 3a and 3b.

Each camera has a logging system which records a data frame on each picture taken. Figure 9 shows the format of this data. Data recorded includes time to the nearest second; last two digits of the ALVIN dive number which effectively gives the date; last three digits of depth in meters; submersible heading (direction) in degrees from true north and submersible altitude in feet.

Film

All exposed film becomes the property of the user; however it is requested that duplicates be provided to Woods Hole Oceanographic Institution for archiving.

FIG. 7 VERTICAL FIELD OF VIEW OF ALVIN TELEVISION AND PHOTOGRAPHIC SYSTEMS. TELEVISION MAY BE VARIED TO SUIT INDIVIDUAL REQUIREMENTS. PHOTOGRAPHIC SYSTEM IS FIXED.



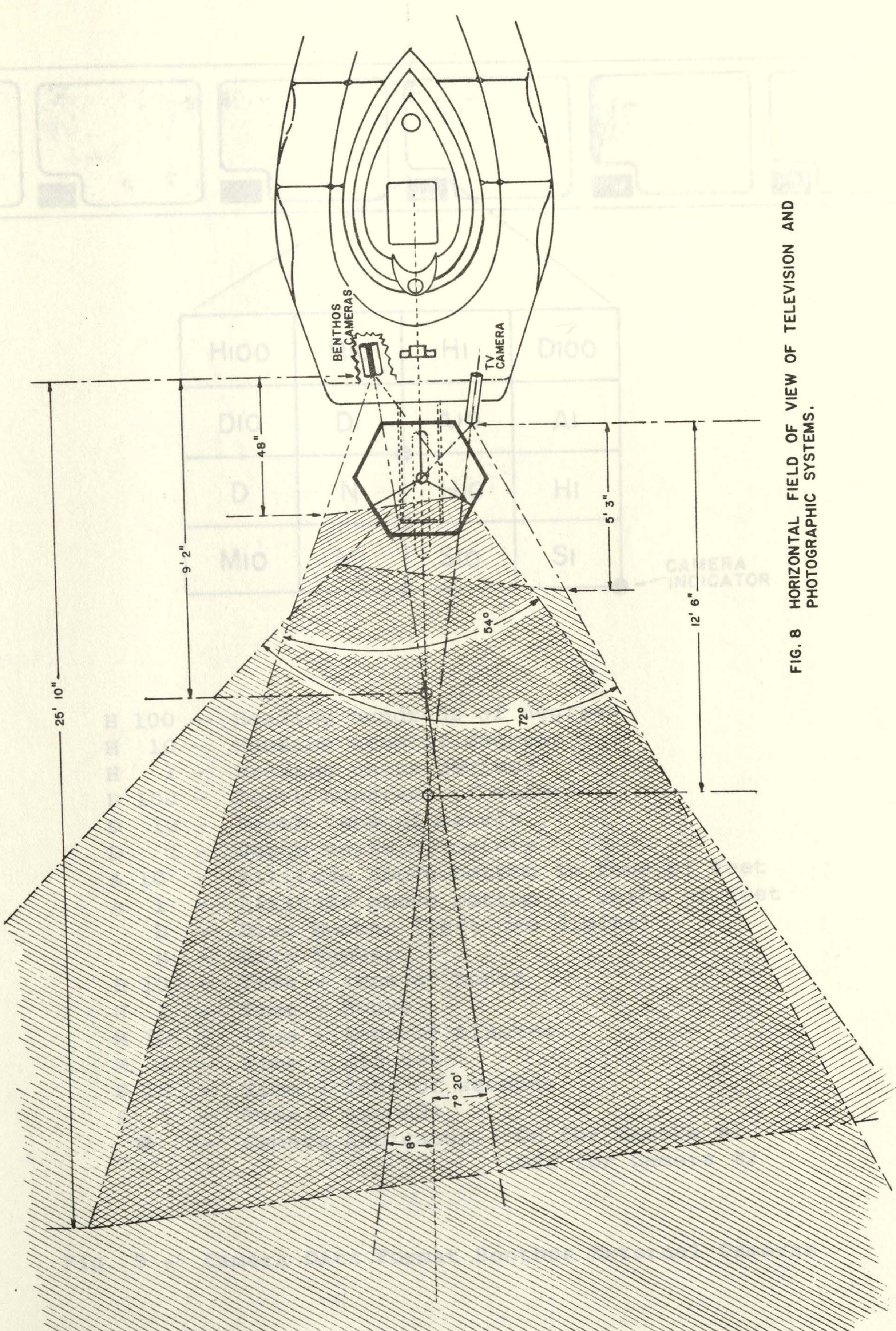
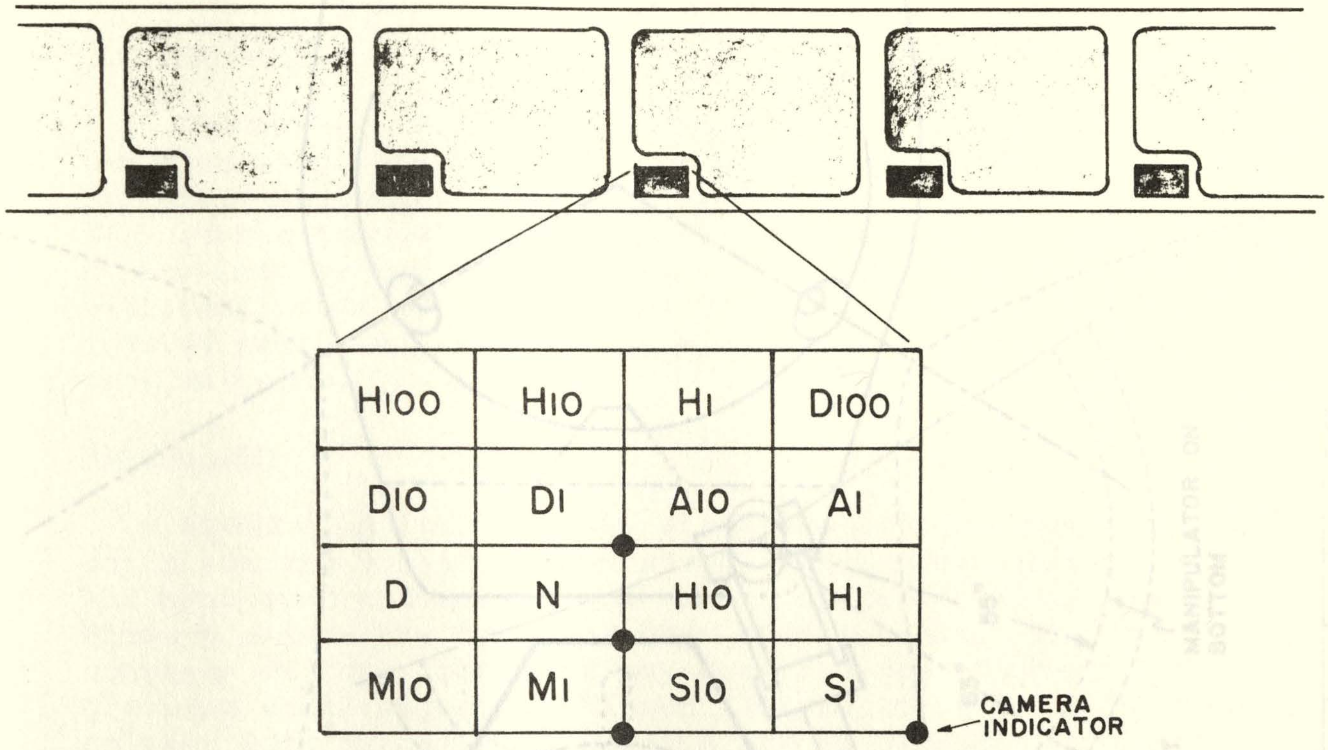


FIG. 8 HORIZONTAL FIELD OF VIEW OF TELEVISION AND PHOTOGRAPHIC SYSTEMS.



H 100 - Heading hundreds of degrees
H 10 - Heading tens of degrees
H 1 - Heading units degrees
D 100 - Depth hundreds of meters
D 10 - Depth tens of meters
D 1 - Depth units of meters
A 10 - Altitude above bottom in tens of feet
A 1 - Altitude above bottom in units of feet
D - Dive Number (last two digits)
N - Dive Number
H 10 - Time - tens of hours
H 1 - Time - hours
M 10 - Time - tens of minutes
M 1 - Time - minutes
S 10 - Time - tens of seconds
S 1 - Time - seconds
● - Camera Indicator. On for Camera #1
Off for Camera #2

Fig. 9 - Camera Data Format Benthos External Cameras

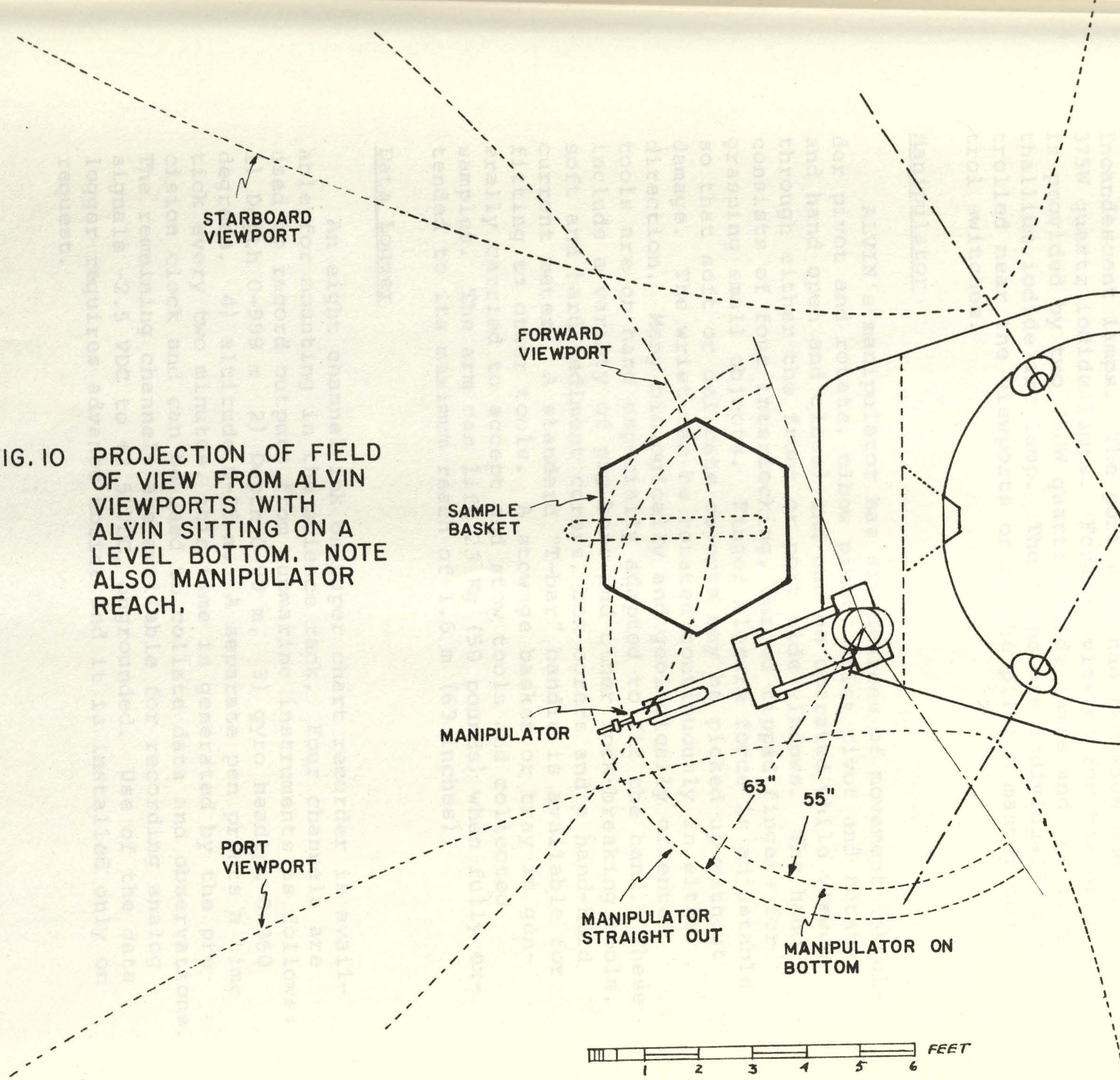


FIG. 10 PROJECTION OF FIELD OF VIEW FROM ALVIN VIEWPORTS WITH ALVIN SITTING ON A LEVEL BOTTOM. NOTE ALSO MANIPULATOR REACH.

Viewing Lights

Underwater lights are located outside the viewports. The starboard side has one 750W and one 375W quartz iodide incandescent lamps. The port side has two 750W and one 375W quartz iodide lamps. Forward viewing for the pilot is provided by two 750W quartz iodide lamps and one 150W thallium iodide arc lamp. The lamps are individually controlled near the viewports or by the pilot's master control switches.

Manipulator

ALVIN's manipulator has six degrees of movement (shoulder pivot and rotate, elbow pivot, wrist pivot and rotate, and hand open and close) and can be operated while viewed through either the front or port side windows. The hand consists of four interlocking, curved tipped fingers for grasping small objects. Finger closure force is adjustable so that soft or delicate objects may be picked up without damage. The wrist can be rotated continuously in either direction. Many biologically and geologically oriented tools are on hand especially adapted to fit the hand. These include a variety of pry bars and other rock-breaking tools, soft and hard sediment corers, box corers and a hand-held current meter. A standard "T-bar" handle is available for fitting to other tools. A stowage basket or tray is generally carried to accept and stow tools and collected samples. The arm can lift 23 Kg (50 pounds) when fully extended to its maximum reach of 1.6 m (63 inches).

Data Logger

An eight channel ink on paper chart recorder is available for mounting in the science rack. Four channels are used to record outputs from submarine instruments as follows: 1) Depth 0-999 m 2) Depth 0-99 m, 3) gyro heading 0-360 degrees, 4) altitude 0-25 m. A separate pen prints a time tick every two minutes, this time is generated by the precision clock and can be used to collate data and observations. The remaining channels are available for recording analog signals -2.5 VDC to +2.5 VDC, ungrounded. Use of the data logger requires advance notice and it is installed only on request.

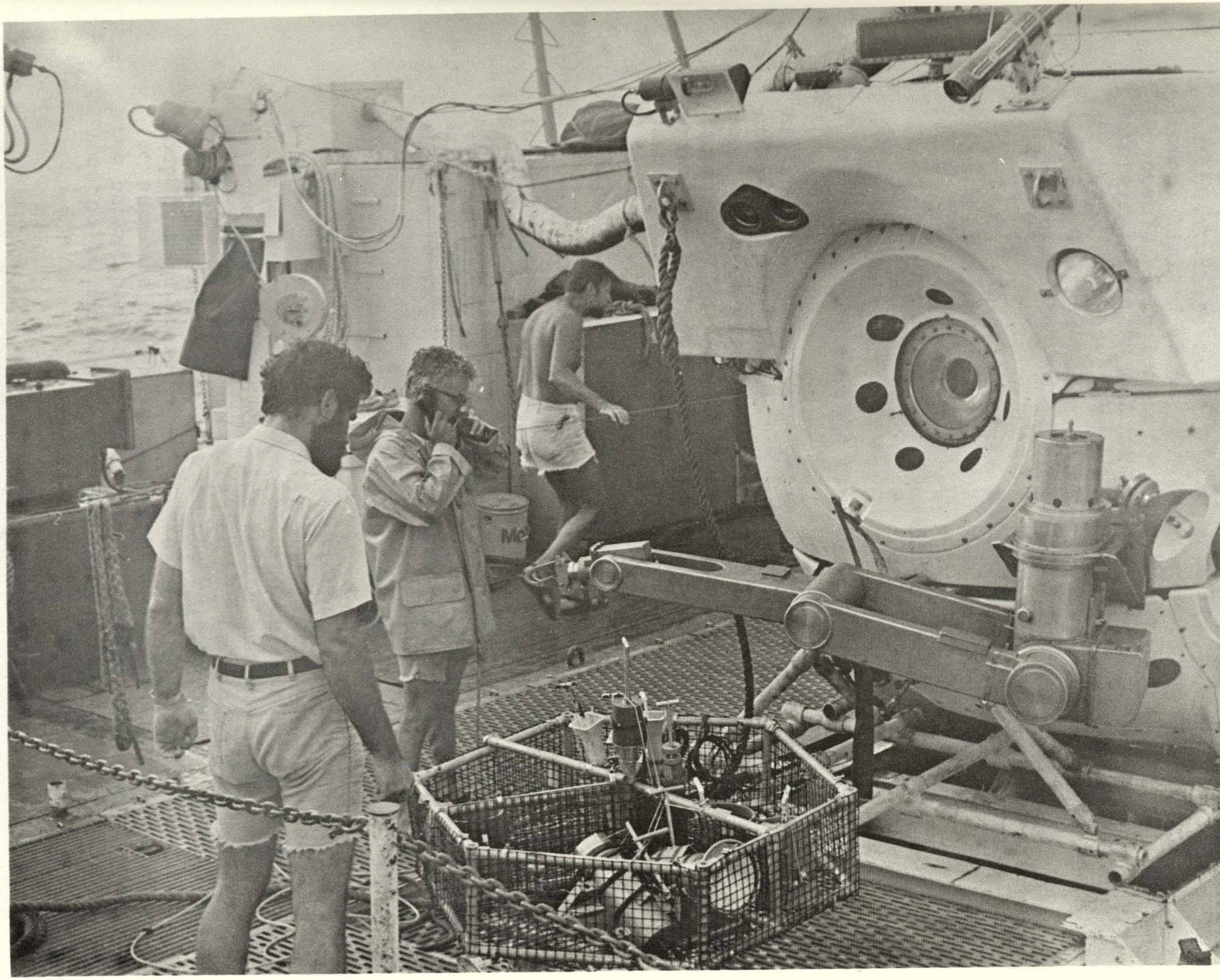


Figure 11   Mechanical Arm and Sample Basket

and the sixth is circuit breaker protected at 20 A. In addition, limited 60 Hz, 110 VAC power is available from a receptacle strip located behind the science rack. ALL ALVIN ELECTRICAL SYSTEMS ARE UNGROUNDED (FLOATING). Science instruments must have power input connections isolated from ground. A large number of spare wires are available for science usage to the outside of the submarine as follows:

1. To sail and forebody 12 singles, 1 shielded pair.

2. To afterbody foreward 24 singles, 2 shielded pairs.

3. To afterbody aft 33 singles, 9 shielded pairs.

Afterbody "aft" spares terminate outside in "J" boxes and other equipment boxes. Figure 13 shows the general arrangement of these wires. All single wires are #16 AWG and are rated at 10 A. Shielded pair wires are #18 AWG. Additional wires can be installed during an overhaul if sufficient advance notice is given.

Provisions For Exterior Equipment

Equipment and devices may be externally mounted on the forebody structure (sponson, sail) or inside of the sail, with location and mounting method at the discretion of the ALVIN group. The spare wires terminate in the oil filled sail "J" box. Wires from installed devices must be of sufficient length to reach and enter the junction box. All wires, since they terminate in the oil filled box, will hose oil unless dammed or otherwise blocked.

ALVIN is equipped to carry droppable pipe structures, in a variety of configurations, to mount and carry scientific equipment and samples. These baskets or trays are attached to the bow at three points and are jettisonable. Up to 110 Kg of instrumentation may be put in the basket depending upon location from the release device. The afterbody forward spare wires terminate in pull type disconnects (to separate basket wiring from submarine in the event that the basket has to be jettisoned). These disconnects are located on the skin under the front window and are oil filled.

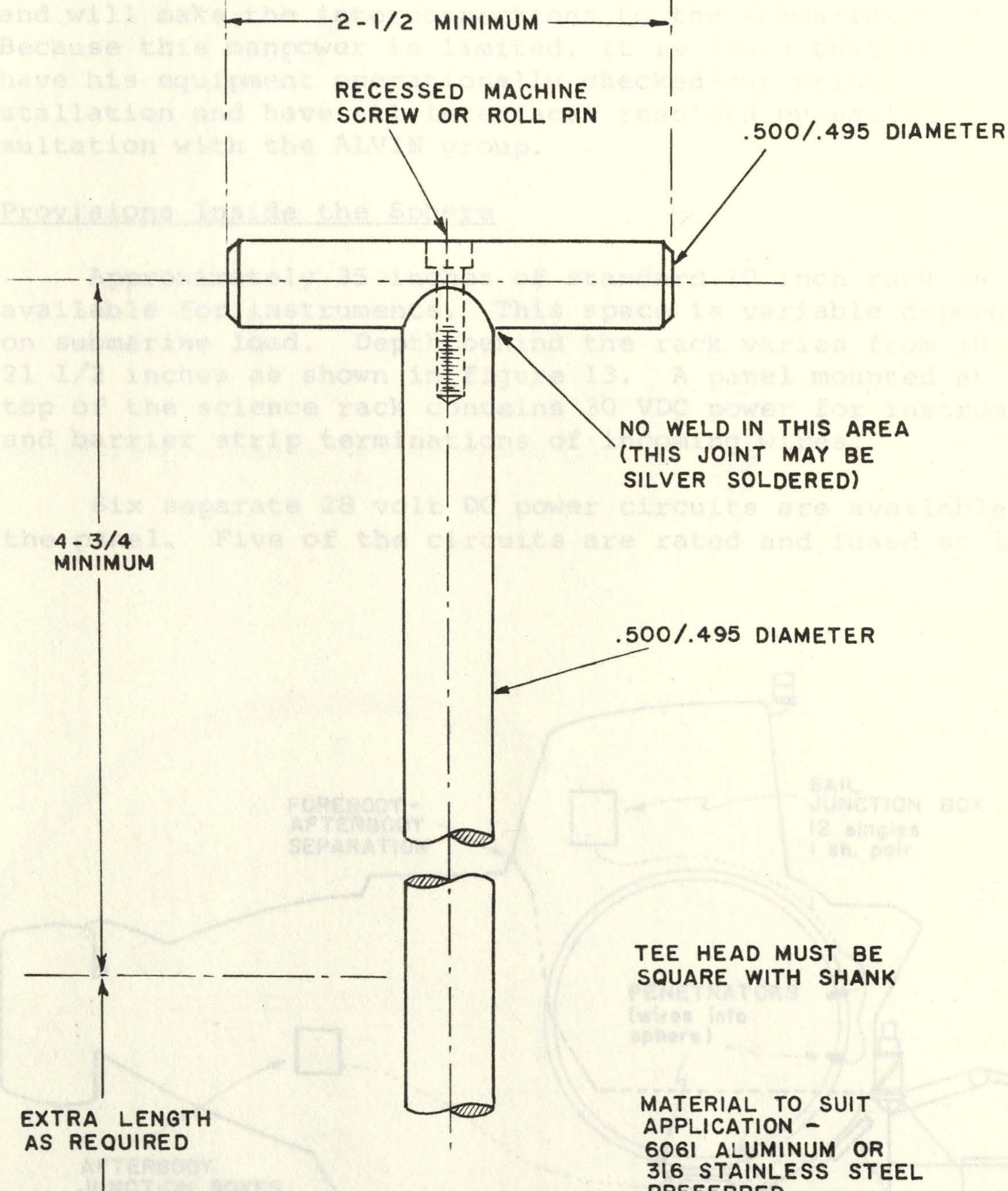

2-1/2 MINIMUM
RECESSED MACHINE SCREW OR ROLL PIN
.500/.495 DIAMETER
NO WELD IN THIS AREA (THIS JOINT MAY BE SILVER SOLDERED)
4-3/4 MINIMUM
.500/.495 DIAMETER
TEE HEAD MUST BE SQUARE WITH SHANK
EXTRA LENGTH AS REQUIRED
MATERIAL TO SUIT APPLICATION - 6061 ALUMINUM OR 316 STAINLESS STEEL PREFERRED

FIGURE 12

Interfacing Science Equipment to the Submarine

ALVIN personnel will mount or install science gear and will make the interconnections to the submarine systems. Because this manpower is limited, it is urged that the user have his equipment operationally checked-out prior to installation and have all interfaces resolved by early consultation with the ALVIN group.

Provisions Inside the Sphere

Approximately 35 inches of standard 19 inch rack is available for instruments. This space is variable depending on submarine load. Depth behind the rack varies from 10 to 21 1/2 inches as shown in figure 13. A panel mounted at the top of the science rack contains 30 VDC power for instruments, and barrier strip terminations of incoming wires.

Six separate 28 volt DC power circuits are available from the panel. Five of the circuits are rated and fused at 10 A

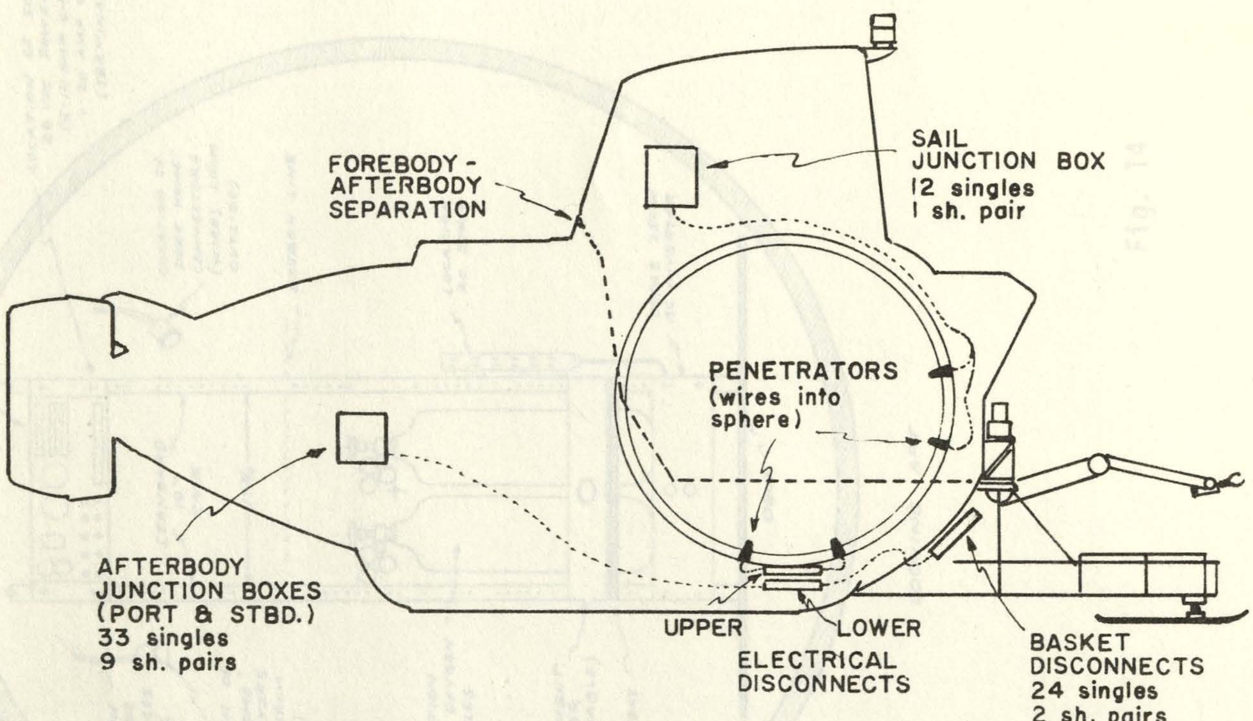


FIG. 13 LOCATION OF EXTERNAL SCIENCE WIRES.

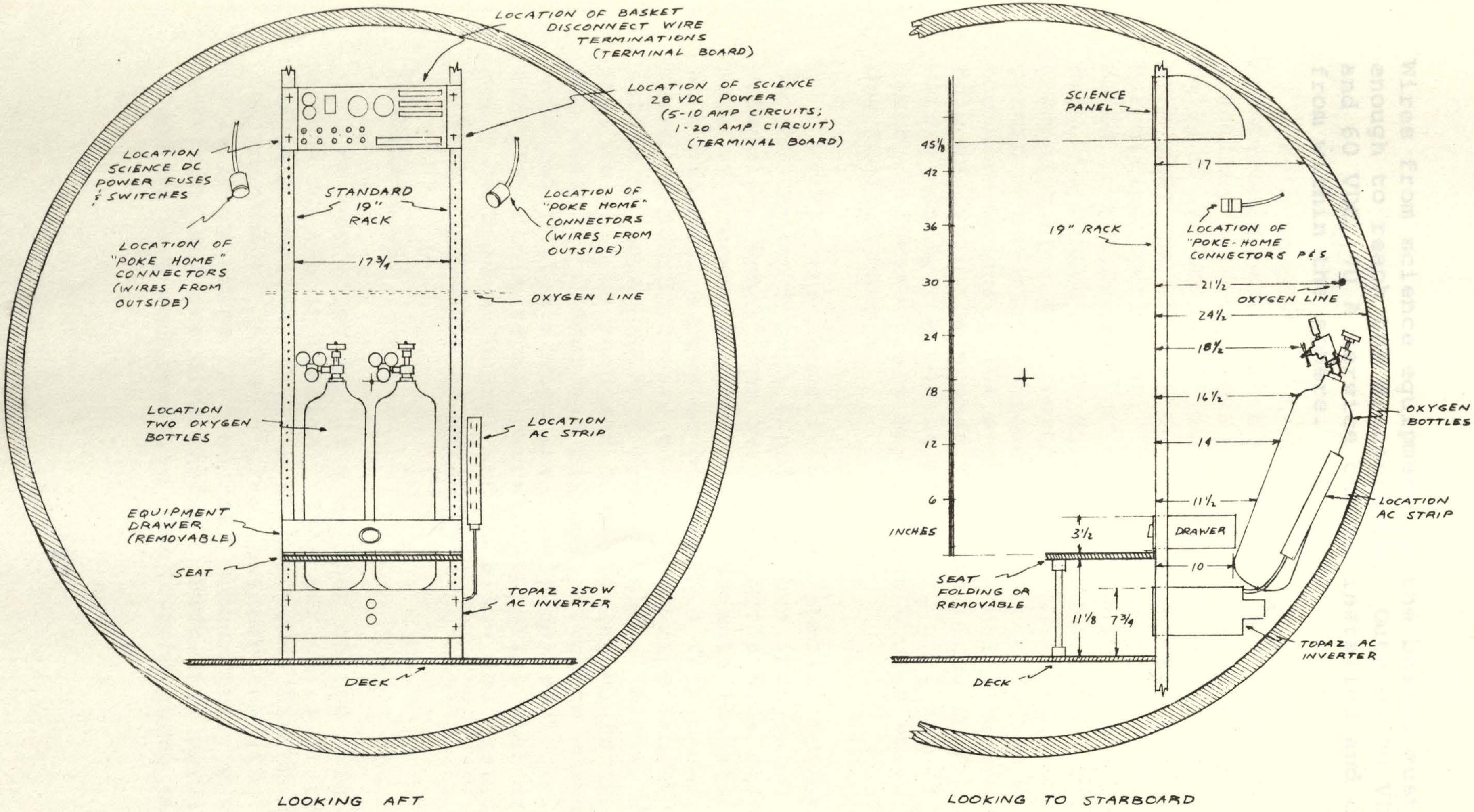


PLATE #2
UPDATED 5-15-74

WOODS HOLE OCEANOGRAPHIC INSTITUTION DEPT. OF OCEAN ENGINEERING	TITLE DSRV ALVIN SCIENCE RACK PHYSICAL & ELECTRICAL PROVISIONS
PROJ: 40/2 BY: E. BLAND SCALE: 1" = 1' DATE: 11-15-73	

Fig. 14

Wires from science equipment on the basket must be long enough to reach the disconnects. Outside 30 VDC, 40 A and 60 VDC, 70 A service can be installed and controlled from within the sphere.

OPERATIONS

Annual Schedule

As a complex machine, ALVIN requires one extensive maintenance period each year in order to assure the operability of subsystems and the safety of personnel. Normally this "overhaul" is conducted in the fall at Woods Hole when the weather in New England waters is unsuitable for diving operations. Typically, the system has been moved to the Bahamas or the Caribbean in December or January, to conduct test dives in the more favorable climate. Depending upon the length of overhaul required this may permit science operations for as much as six months in southern waters. The system is usually returned to Woods Hole early in the summer for operations in New England waters during the months of June, July, August and September. Future plans may include longer stays away from New England waters.

Within the above framework, special operations such as the Cayman Trough Expedition are integrated into the schedule. Operations away from Woods Hole require a good deal of preparation to insure adequate logistics support. As a minimum, a base or port with a fair harbor is required where on-board repairs to the submarine can be made with little or no assistance from outside. Diesel fuel and provisions will be required on a regular basis (about every two weeks). Commercial air and telephone communications with the United States are highly desirable in order to readily obtain repair parts or supplies that are not normally carried on board, and to allow the arrival and departure of scientific personnel.

Operating Day

An operating day is a 24 hour period (midnight to midnight) at sea on station. This period is divided into three distinct periods: predive preparation, diving and post dive replenishment. After a dive, battery charging takes from 8 to 12 hours which is conducted concurrently with post-dive servicing and pre-dive checks. Post-dive servicing takes about an hour and pre-dive checks take about two hours.

If the submarine is ready to dive but weather prevents launch, the day is still considered an operating day. Under certain circumstances when dive locations require long transits which reduce the number of diving days available during a given year, an arbitrary number of transit days will be considered operating days for fiscal purposes. This is necessary since the daily at-sea costs of the system are relatively constant whether diving or in transit and the yearly costs are based on a fixed ratio of transit vs. dive days.

Framework Within Which Dives Can Be Made

Under normal circumstances it is expected that all equipment on ALVIN and LULU will be operational. There are however many equipments on both vessels which have no impact on the operational safety of ALVIN. It is left to the discretion of the Expedition Leader and the Pilot-in-Command which and how many of these equipments may be out of commission and still allow ALVIN to make a useful dive. Certain other systems and equipments, particularly life support and safety items, are considered vital and must be operational at any time that ALVIN submerges. In some cases loss of the equipment during the dive will not constitute a reason for aborting the dive if adequate backup is available.

There must be a clearly defined need for the dive; i.e. scientific, engineering or task objective, training or public relations. Weather predictions for the next 24-hour period must be obtained. The depth of water in the area of the dive must not exceed 4026 m (13,200 feet). Agreement must be reached among the Chief Scientist, the Expedition Leader, the Surface Controller, the Pilot-in-Command and the Master of LULU, that there is reasonable probability of a successful launch, dive, and recovery. Any one of the five persons can veto the decision to dive. The probability of a successful launch and/or recovery is low when the wind is above 25 knots or the sea state is higher than 3 (6 to 8 foot waves). Night operations are not precluded but generally will introduce personnel hazards that make better weather necessary. If the particular science requirement calls for night dives, advance notice should be given to allow proper planning.

When dives are to be made in remote areas, i.e. areas in which a quick response by U.S. Coast Guard or U.S. Navy is not feasible an escort vessel may be required. Funding for the escort vessel will normally be provided by the user. The appendix gives the official Escort Policy, however if any such operations are anticipated, or if any doubt exists, the ALVIN Program Manager should be contacted as early as possible.

Predive Briefing

Every observer is given a briefing inside the submarine prior to making his first dive. This briefing, which takes about 30 minutes, details the location of observer controls, instruments, and operator's manual, and covers normal and emergency procedures including the donning of the Emergency Breathing Appliance Mask.

The ALVIN Operator's Manual should be read by each observer before his first dive. It contains descriptions of normal and emergency operating procedures, vehicle performance data, casualty procedures and information for observers.

Resume of Some Jobs Done

Project FAMOUS was a geological investigation of the mid-Atlantic rift valley in the vicinity of the Azores in 1974. This encompassed 16 dives to 2400 to 3000 meters where volcanic rock was sampled and slopes from horizontal to vertical were encountered.

The Cayman Trough expedition in 1976 was in the Caribbean, south of the Caymans where 15 dives were made to depths of 3660 m. Rock samples were collected and steep slopes were examined.

A special sample basket containing a plankton net or plankton recorder has been fitted to the submarine for deep tows at the bottom or in midwater.

Bottom stations have been established off New England and in the Tongue of the Ocean where laboratory-prepared samples have been placed by ALVIN, and then retrieved after months or years of exposure for subsequent laboratory analysis.

Engineering tasks have included the inspection, video recording, and photographing of cables, bottom arrays, and arrays suspended in mid-water. Other dives have been devoted to the search for and retrieval of lost objects of value to the Navy. A buoy mooring has been inspected from the surface to the bottom in 3600 meters of water.

One task that can be done only with difficulty is to manipulate in mid-water while attempting to hover or remain at neutral buoyancy.

SAFETY

Since ALVIN operations are somewhat unique, and the environment in which she operates is popularly thought to be extremely hostile, the question of the safety of the participants often arises. This section is presented to allay any fears on this score, that the first time user, his associates or the members of his family, may have.

Perhaps the most misunderstood effect is that of the extreme pressure at the maximum operating depth of 3658 meters (12,000 feet). It should be understood that at no time are the operator or the passengers exposed to other than normal, sea level pressure and temperature. The cabin of the submersible is built to withstand an external pressure equivalent to a 50 per cent overload thus insuring its integrity even in the unlikely event that the normal operating depth is exceeded. An exact duplicate of this cabin has in fact been tested to nearly twice the operational pressure without failure.

In order to insure that no water leaks into the cabin all openings for wires, viewports and the entrance hatch are designed in such a way that they actually provide a tighter seal the deeper the submarine dives, and these devices are thoroughly checked prior to each dive.

While the submarine weighs 16 tons in air, it is so configured that when submerged in salt water it is exactly neutral so that only a very slight force is required to move it up or down. It is therefore possible, even if all normal power is lost, to ascend to the surface by dropping a small amount of weight. In order to insure that this can always be done, three small emergency batteries are provided within the cabin, any one of which is capable of operating all of the weight releases. In normal operation, two 250 pound weights are mounted on quick releases. Releasing either of these will make the submersible buoyant enough to return to the surface with no further action. If for any reason additional buoyancy is needed, each of the three normal battery packs may be released. The batteries weighing over 500 pounds apiece, are each mounted on a separate release device, and may be powered by any one of the three emergency batteries. In the very unlikely event that the submersible still fails to ascend, it is possible to release the cabin from the rest of the submersible. The cabin will then float to the surface where the occupants may be safely picked up by the surface support ship which is always in the immediate vicinity and in continuous communication with the ALVIN.

A normal dive lasts for about eight hours; however sufficient oxygen is provided to allow the submersible to remain submerged for over three days, thus allowing a more than adequate safety factor.

Each year all of the safety equipment as well as the rest of the systems receive a thorough overhaul by the highly trained technicians and engineers of the ALVIN crew. Their work is reviewed and checked by the U.S. Navy and any discrepancies must be corrected before authorization to operate is granted. Prior to each dive all systems and components are checked, and operated by the crew and the pilot, before the ALVIN is launched. Any failure or malfunction found during these checks must be corrected and the equipment re-checked before a dive can begin.

Over a decade of operation, and 700 dives, attest to the efficiency of the rigorous program which has and will continue to assure the safety of ALVIN operations.

APPENDIX 1

INSTITUTION MEMORANDUM #8-76

Subject: R/V LULU Escort Policy
(This expansion of Institution Memorandum #2-71 replaces that Memorandum)

Escort requirements for at-sea operations involving R/V LULU

Since LULU has limited sea-keeping and support capabilities (as a function of her speed, size, configuration and equipment) arising from her special mission characteristics, situations will arise in which special support to LULU or the LULU/ALVIN system must be provided to insure the safety of the people involved, and to limit the nature of some risks involved in this complex engineering operation. This Memorandum sets out these situations and provides policy guidance for fulfilling the aim set forth above. It should be followed in such a manner that the means chosen will always increase the probability of a successful and safe operation. Mere pro forma compliance with the requirements set forth below, which might sometimes result in a decrease in the probability of success or safety of the planned operation, would not be in conformity with the intent of the policy.

The policy concentrates on support to LULU and to ALVIN when surfaced, since the principal safety requirements for ALVIN when submerged have been built into ALVIN itself in terms of its capability to surface, and since any rescue or support measures for the submersible while submerged involve requirements that are so massive that they must always be a very special operation.

(a) General considerations affecting the need for an escort vessel include the mission, weather conditions expected in the operating area, proximity of accessible harbors, as well as the availability and proximity of pre-arranged on-call vessels or helicopters to the operating area. The decision as to whether or not an escort vessel is required rests with the Chairman of the Department of Ocean Engineering (subject to review by the Associate Director for Applied Oceanography and the Chairman of the Department of Facilities and Marine Operations) who will operate within the guidelines set forth below. Exceptions to these must be approved by the Associate Director for Applied Oceanography and the Chairman of the Department of Facilities and Marine Operations. Any vessel to be chartered by the Institution must be approved by the Marine Superintendent.

(b) Conventional Oceanographic Cruises (Definition: At-sea operations which involve the collection of oceanographic information using conventional techniques not involving the use of submersibles or diver habitats.) The R/V LULU will require an escort vessel when operating at more than 48 hours steaming distance from an accessible harbor unless prior arrangements have been made for a stand-by vessel capable of reaching the operating area within 48 hours. (When operating at times or in areas where there is a high probability of severe weather, this time limit may, at the discretion of the Associate Director for Applied Oceanography and the Chairman of the Department of Facilities and Marine Operations, be reduced to 24 hours.)

(c) Open Ocean Transits (Definition: Transits between ports or operating areas during which LULU may or may not be carrying a secondary system such as a habitat or submersible.) The same requirements as in the preceding paragraph shall apply.

(d) Submersible Operations (Definition: Operations which involve the launching, surface controlling, and recovery of a manned submersible.) R/V LULU will require an escort vessel during all submersible operations unless:

(1) The dive site is within 30 miles steaming distance of an accessible harbor, or

(2) Prior arrangements have been made for quick reaction support (within 3 hours) to the operational site. (Quick reaction support may be ships or aircraft providing direct rescue capabilities or support to people on the surface, such as provision of rafts/ boats, food, water, etc. as required by the situation on scene.)

When quick reaction support (not an on-scene escort) is to be used, the prior arrangements should include:

(1) Agreement and understanding by the Coast Guard or other agency that the capability is in fact available;

(2) A failsafe communications schedule with a responsible, approved, shore facility, on LULU's part to send a regularly scheduled "operations normal" message, and failure to re-establish communication with LULU immediately thereafter, will result in an automatic request to the Coast Guard or other approved reacting agency for the despatch of search and rescue capability (as pre-arranged) to the last known operations site;

(3) Both LULU and ALVIN will be beaconed so that they will be easy for search and rescue forces to find, and that they have such equipment that the search and rescue force can talk to either when on the surface;

(4) LULU will be provided with a backup search radar capability. This is most important for cases in which we will depend upon backup land-based search and rescue, but should be provided in any case;

(5) When quick reaction support is to be used, there must be firm provisions for best available weather and sea prediction for the area of operations to be available to LULU and ALVIN.

In circumstances where an escort is provided because the entire operation is out of range of easy shore reaction:

(1) The escort should be equipped with an underwater telephone kit (over-the-side transducer) so that backup communication to ALVIN while submerged is available; (The Institution will make such a kit available.)

(2) While failsafe communications arrangements to shore probably cannot be made in all circumstances, there should be an especially strong attempt for regular, more than daily, "ops normal" messages to be sent to someone outside of the immediate operating area.

(e) <u>Diving Habitat Operations</u> (Definition: Operations involving the support of a bottom sitting diver habitat.) R/V LULU will require an escort unless she is equipped with a recompression chamber and qualified medical personnel and is operating within 48 hours steaming distance of an accessible harbor.

(f) <u>Other Operations Requiring R/V LULU to Remain in Operating Area</u> (Definition: Operations such as deep-sea drilling or similar activities in which R/V LULU is not free to leave scene of operation for extended period.) The requirements set down in paragraph (b) shall apply in this case, unless other specifications are made by the Associate Director for Applied Oceanography and the Chairman of the Department of Facilities and Marine Operations.