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Woods Hole Oceanographic Institution

TECHNICAL PROGRESS REPORT

ADVANCED MARINE TECHNOLOGY

1 August 1972 - 31 January 1973

June 1, 1973

Sponsored by
Advanced Research Projects Agency

ARPA ORDER NO. 293-008

Dr. A. E. Maxwell, Principal Investigator

*Prepared for the Office of Naval Research
under Contract N00014-71-C-0284; NR 293-008.*

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TECHNICAL PROGRESS REPORT
ADVANCED MARINE TECHNOLOGY

1 August 1972 - 31 January 1973

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Approved for Distribution Earl E. Hays

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Report Summary

The work sponsored by ARPA at Woods Hole Oceanographic Institution is having an impact on efforts by those not directly involved in the projects both within and without the Institution.

The navigation system being developed for submersible/mother ship has been recognized as a very useful system by members of the Geology/Geophysics Department and the Department of Physical Oceanography. Each department is now developing their own system based on the work already completed by the Ocean Engineering Department under the ARPA contract.

Through the ARPA contract ComPhibLant (specifically ComPhibRonTen) was shown some of the advantages of doing something new about small boat and heavy object handling at sea and this program is expected to have some direct effect upon methods they will use in the future.

Although the project concerned with developing biological equipment for deep sea work has not continued as part of the ARPA program, the seed was successfully sown and several items are being developed at the Institution under separate funding.

All the projects continued at a fair pace but not without some problems. The Deep Sea Rock Drill had some minor setbacks during operations with ALVIN, and the Air-Sea System (Long Range Echo Ranging) project was hampered by a faulty engine aboard the air craft.

Summaries of progress are given immediately below and more detail is available in the individual reports further on.

(a) Submerged Navigation and Submersible Instrumentation

The submersible navigation system went to the Mid-Atlantic Ridge in November 1972 between 36° and 37° N. This was a test of the system in an area to be visited by ALVIN in 1974. R/V ATLANTIS II was the mother ship and a deep sea camera, and a rock dredge assumed the role of ALVIN. Two transponders were set on the bottom.

The system worked well; the Geology/Geophysics Department who were running the cruise are starting to build a similar navigation system for their own use. The Physical Oceanography Department is also building one.

During this period, the time controller unit was modified so that the system could be operated in different modes rather simply. These modes include:

- (a) Ship/submersible
- (b) Ship alone

(c) Ship/elevator (these do not have a precision
camera clock)
dredge

(d) Ship/sonobuoy - sonobuoy must be relay commanded in and out of system.

The ALNAV system has one 3½" relay rack panel that is custom made at W.H.O.I. - (timing controller), all other units are commercially available. This means that the system can be reproduced simply by other groups needing deep sea navigation.

The precision of the navigation has been improved by expanding from the use of a single sound velocity for an area to a method that uses a sound velocity profile (measured or archival data) and takes the part of the profile that enters into the sound paths involved. This method is not the exact method but a good approximation to it, which fits into the computer capability available.

(b) Handling and Transfer at Sea

The amphibious forces have a continuing small boat/heavy object handling at sea problem. In January of 1973 they were given the opportunity to see how the ARPA work at W.H.O.I. and extensions of it could help solve their problem. Aircraft landing gear, trailer truck wheels, axles and springs, and the large tire-buoy were used with different large ships of ComPhibRonTen to demonstrate the effectiveness of rolling resilient contact between small boat and large ship, and a way to disembark troops into small boats quickly and effectively.

(c) Bottom Reconnaissance and Detailed Site Survey

Hydraulic Impact Hammer

Measurements were made in the lab on the hydraulic impact hammer to determine its relative efficiency in water as compared to air in several modes of operation. The design goal is a hammer that replaces the "geologist's hammer" but with a simple mechanism that is easy to use from ALVIN. One idea being pursued is a plate baffle that uses the surrounding water mass as a momentum absorber rather than weights.

(d) Near Bottom Magnetic Studies Using a Deep Submersible

The magnetometer towed from a floating fish above and behind ALVIN has been field tested in the Gulf of Maine in the fall of 1972. It may now be considered a working system. Some interference is experienced from the use of the underwater telephone and the buoyancy of the fish cable/assembly may be increased, but the total system will be an additional useful tool for ALVIN in operations requiring magnetic field measurements.

(e) Near Bottom Gravity Studies from a Deep Submersible

A final report summarizes the experiments performed and the investigations carried out to determine if a gravimeter could be effectively used in ALVIN without a sizeable investment in special equipment. Unfortunately the answer was negative and future advances in this field must await larger financial investments or some new technology.

(f) A Self Contained Deep Sea Rock Drill

The rock drill was tested at sea from ALVIN and also from a surface ship during this reporting period. Although the last summary in W.H.O.I. Technical Progress Report 73-20 stated that the drill had been debugged and "it is now almost ready for use", this six months period showed that the bugs were not all gone. Basically we need more experience in using the drill under a variety of conditions before we can treat it as a routine tool.

(g) Self Contained Ancillary Modular Platform

The construction of SCAMP is moving ahead on schedule. The plans and designs have generally been discussed in previous progress reports and this period has been used to put them into effect. The clamping of SCAMP to ALVIN by pressurized hoses looks feasible and is being pursued.

(h) Modular Acoustic System

This project, which began in November, is to supply ALVIN with a sonar system that will have a suite of equipment inside ALVIN that can be coupled to a choice of transducers outside ALVIN. Scientists using ALVIN will need a wide range of frequencies, beam widths, direction and signal types (pulse, CW, FM, coded bursts) depending on the mission, and this is an attempt to satisfy many of the desires with a minimum of equipment. This period has been spent on overall design, some detail design, and choice of some equipments.

(i) Air-Seas Systems (Long Range Echo-Ranging)

This project, which is simple in principle, seems to be ill-fated. It consists of dropping a line of sonobuoys and using these as an array to look at echoes from explosives dropped near the array. Distant underwater topography can then be detected. The major problem has been arranging aircraft time. In this period a schedule was made and held to, but a malfunction aboard the aircraft abruptly terminated the experiment.

Submerged Navigation
and
Submersible Instrumentation

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Submerged Navigation and Submersible Instrumentation

Introduction

This is the fourth report of an on going program to develop a flexible submersible navigation system and to test it at sea. A description of the system has been previously reported. This report is divided into seven sections. The first section outlines the milestones reached during the reporting period. A recent unscheduled milestone was a decision by another research activity at W.H.O.I. to reproduce the ARPA system. The proposed ANGUS (Acoustically Navigated Geological/Geophysical Underwater System) system and the growing interest at W.H.O.I. in the ARPA system is commented on in Section II.

In 1972 at sea testing with the basic ARPA submerged navigation system indicated some hardware and software areas that need refinement to provide a more accurate and flexible system. The primary hardware change is a new and more versatile surface ship master timing controller. This unit is described in detail in Section III. The major change required in the software is the addition of the provisions for sound velocity corrections. This is discussed in Section IV.

The 1971 transponder mooring was found to be awkward to handle at sea. A new mooring which has proved to be both functional and convenient to handle is described in Section V.

The ARPA untethered payload elevator which was constructed and tested during 1972 is discussed in Section VI.

The various developments during the reporting period have caused some proposed shifts in emphasis within the proposed ARPA Submerged Navigation Program. This is discussed in Section VII.

I. Reporting Period Milestones

A significant development during the reporting period has been the birth of serious interest in the ARPA Submerged Navigation System within three of the five scientific departments at W.H.O.I. It now appears possible that three ARPA type systems will be operating during the summer of 1973 to solve a broad range of surface and submerged navigation problems.

Additional milestones reached during the reporting period included:

- a) The ALNAV (ALVIN Navigation) system was successfully tested at the Woods Hole Bottom Station No. 1 in October 1972 to an operating depth of 6,000 feet. The depth of the submersible was calculated for the first time using a program solving the intersection of three spheres.

- b) Seven data points of ALVIN to surface to transponder to LULU signals were recorded with ALVIN at 6,000 feet.
- c) The ARPA untethered elevator which is built around a relay transponder was successfully tested at the Woods Hole Bottom Station No. 1.
- d) ALVIN's pressure depth and acoustic depth were automatically transmitted to LULU for data logging. Some difficulties were experienced.
- e) The ALNAV system was tested aboard the A-II in November 1972 at the Middle Atlantic Ridge between 36°N and 37°N. During this Geology/Geophysics cruise the ARPA elevator relay transponder was used to track a towed camera fish and a rock dredge. Operating depths were to 10,000 feet.
- f) A review of the 1972 at sea experiments strengthened the conviction that sound velocity corrections must be included to obtain an accurate survey and position determining capability.
- g) To date a total of 34 transponder moorings have been set with one loss.
- h) The lack of a tape data logging capability in the ALNAV system has required that after-the-fact data reduction be processed by hand which has resulted in a limited amount of refined data.

II. Proposed ANGUS System

The testing of the ALNAV system aboard the A-II during November 1972 was a major turning point in the ARPA Submerged Navigation Program. The ALNAV HP 2570A Coupler Controller was interfaced to the HP 2116 Shipboard Computer System. An outgrowth of the successful results obtained during this cruise was a decision by the Geology/Geophysics Department to construct an ANGUS system patterned directly from the ARPA ALNAV System. A block diagram of the shipboard components of the ANGUS system is given in Figure 1. Construction of this system is scheduled parallel with some modifications to the ALNAV system to meet operational requires starting in the summer of 1973. It presently appears that a third system may be assembled to support the setting of a complex deep sea tri-moor also scheduled for the summer of 1973.

The possibility of investigators from three of the five W.H.O.I. scientific departments pooling their efforts to pursue common submerged navigation equipments and common software is very encouraging. A wide variety of local area tracking problems are being reviewed. These include:

ANGUS

Block Diagram of Surface Components of the Proposed
ANGUS System

Figure 1

- a) Ship (LULU, A-II, and KNORR) tracking
- b) Submersible (ALVIN) tracking
- c) ARPA Elevator tracking
- d) Towed camera fish tracking
- e) Rock dredge tracking
- f) Tri-moor anchor location positioning
- g) Sonobuoy tracking
- h) Survey of reference transponders for a CW phase angle system for measuring the motion of hydrophones attached to deep sea moorings.

III. Description of the New Master Timing Controller

The 1972 at sea experience with the basic ARPA submerged navigation system indicated several areas that needed refinement to provide a truly flexible system. A new multipurpose timing controller has been designed to provide integrated and flexible control of the surface system. This unit will provide ten coded BCD characters to the computer system coupler to permit the operator to setup a variety of subprograms in the computer system.

The timing controller receives 1 sec. time tics from the surface clock. Two digit thumbwheels, 0 to 99 seconds, are provided to permit the operator to set up the signal timing intervals. Typically, interval "A" (determine ship position) is set at 15 seconds and interval "B" (determine the position of the submerged device) is also, but not necessarily, set at 15 seconds.

When operating at maximum range from the reference transponders these settings are increased to accomodate the longer acoustic travel times.

The timing controller contains indicator lights that tell the operator whether the current cycle is "A" or "B" plus indicating the one second time tics.

The mode selector is an eight position switch as follows:

<u>Position</u>	<u>Interval A</u>	<u>Interval B</u>
1	SHIP	None, interval A keeps repeating
2	SHIP	Relay transponder (FISH)
3	SHIP	Remote timed pinger (ALVIN)
4	SHIP	Sonobuoy, adds radio receiver

continued:

<u>Position</u>	<u>Interval A</u>	<u>Interval B</u>
5	None, interval B repeats	Relay transponder repeats
6	None, interval A repeats	Remote timed cycle repeats
7	Spare	Spare
8	Spare	Spare

The position of the mode selector is coded into a BCD character and is sent to the computer coupler for program control. The computer coupler also receives a coded signal which indicates whether the data being received is from interval A or B.

The shipboard acoustic components will be remotely controlled by the timing controller. This includes commands to transmit one of two interrogation frequencies, commands to start the time interval counters and a signal to inhibit the altitude mode of the 205 receiver when in the interval "A" (SHIP) cycle.

To simplify the system cabling the timing controller is used as a junction box to route miscellaneous signals from the 205 receiver to the computer coupler. These signals include the bad data signal lines and the position of the Altitude Delayed selector.

The timing controller contains an audio mixer to mix the analog signals from the 205 receiver for display on an optional graphic recorder.

A two digit thumbwheel switch permits the operator to input to the computer coupler the estimated depth of the submerged device being tracked. The computer program uses this input to solve the "Z" redundancy of the calculated depth of the submerged device.

A battery within the timing controller keeps the timing circuits operating in case of a momentary power interruption.

The A&B interval counters can be reset with a reset pulse. The timing controller contains a guarded "Initial Sync" push button to permit starting the interval counters at 00 seconds on the clock. While the push button is held in, the external one second tic's will keep resetting the interval counters. If the push button is released between 00 and 01 seconds the 00 second sync will be initiated. The push button can also be used to set up two separate systems in a time sync.

The timing circuits include an automatic recycling two minute counter. This counter is reset by the Initial Sync push button. The two minute counter buffered output pulse is connected to a front panel light and BNC connector labeled SYNC OUTPUT. The sync output is used to sync external devices such as the ALVIN clock, future FISH clocks and/or future clock controlled beacons.

When the thumbwheels of the interval counters "A" and/or "B" are changed, the new intervals are no longer uniquely related to the initial sync of the timing circuits. A RESYNC switch is provided which when momentarily pressed will cause the next internal two minute sync signal to reset the interval counters.

Thirteen sense switches are mounted on the timing controller. The position of these switches is coded and sent to the computer coupler. This new feature provides great flexibility in computer subroutine control without having to interrupt the computer program. The projected functional assignments of these switches for the LULU/ALVIN problem is as follows:

- #1 The ship is clockwise or counterclockwise from a two transponder baseline.
- #2 Enables the program velocity filter to eliminate the plotting or spurious positions.
- #3 Average the ship positions before and after a submersible fix and use this improved ship position in the calculation of the submersible position.
- #4,5,6 Use 205 Channels A, B, C to calculate the ship and submerged device positions. For a two transponder baseline problem only two of the sense switches would be enabled. With a three transponder net the operator would select one of four combinations for position calculations - AB, AC, BC, or ABC.
- #7,8,9 Use the surface bounce routines to calculate the ranges for the A, B, or C transponders when the appropriate sense switch is depressed.
- #10 When depressed, log the raw data gathered during each cycle.
- #11 When depressed, print the raw data gathered during each cycle.
- #12 Spare
- #13 When depressed, use the third transponder not selected by sense switches #4 - 6 to automatically solve the "Y" redundancy of the two transponder ship position and to calculate the depth of the ship as an indication of the errors in the calculated positions. The error indicator will be particularly useful in alerting the operator of conditions of poor system geometry.

IV. Sound Velocity Corrections

The 1972 submerged navigation programs used a fixed value for the velocity of sound in water. Because of the nature of the signal paths used this causes unacceptable errors. During the reporting period a

Signal Paths with Arithmetic Average Sound Velocities

Figure 2

study of various approaches to correct for sound velocity was conducted. Sound velocity corrections in the 1973 programs will be made in two steps. The first is to determine the appropriate arithmetic average between the depths of the various transmitters and receivers. The second step is to correct for ray bending. Of the two steps, the first is the most significant. The starting point for all corrections is a predicted, or preferably, a measured sound velocity profile.

Three types of signal paths are used by the submerged navigation system. These are:

- a) Ship to bottom moored transponder where the depth of the shipboard transducer is known and the depth of the transponder is determined during the initial survey of the navigation net.
- b) Submerged device to a bottom moored transponder. The depth of the transponder is fixed while the depth of the submerged device is a variable.
- c) Submerged device to the ship transducer. The depth of the shipboard transducer is fixed while the depth of submerged device is a variable.

Figure 2 illustrates these three signal paths. The arithmetic average sound velocity between two depths is designated as " $\bar{c}$ ". A November sound velocity profile for the Tongue of the Ocean was used to calculate the $\bar{c}$'s illustrated. From the figure it can be seen that the average sound velocities vary from 1508.0 to 1485.7 meters per second. Not correcting for the different sound velocity averages in this case leads to significant position determining errors. When the submersible is operating at approximately the same depth as that of the transponders, $\bar{c}_1$ and $\bar{c}_5$ are approximately equal. The value for $\bar{c}_3$ can be quite different. The conclusion is that for a three dimensional tracking problem each range measurement has its own associated value for $\bar{c}$. Since the depths used to calculate $\bar{c}_1$ are constant after a transponder has been set the value for $\bar{c}_1$ can be determined after the survey of the navigation net and entered into the real time tracking program as a constant. The depth of the submerged device is a variable. The values for $\bar{c}_3$ and $\bar{c}_5$ must therefore be calculated by the real time tracking program using the sound velocity table, the known depth of the transponder and the known depth of the shipboard transducer.

Errors due to neglecting ray bending are generally less than those caused by using erroneous average sound velocities but nevertheless warrant correction. Figure 3 illustrates a typical range of open ocean errors in both meters per second of travel time and slant range error due to ray bending, for a source at 15 meters and a receiver at 1554 meters, plotted against horizontal range. V_e is the effective sound velocity and H is the harmonic average sound velocity between 15 and 1554 meters. From this figure it can be seen that, for the conditions specified, ray bending causes a slant range error of 23 meters for a horizontal separation of 9 km. As a rule of thumb when the depression

Ray Bending

Source @ 15 meters

Receiver @ 1524 meters

Errors Due to Ray Bending

Figure 3

angle between a source and a receiver is less than 20 degrees the effect of ray bending should be evaluated. The effects of ray bending between a deep transponder and a deep receiver are not as dramatic as for the signal paths that pass through the main thermocline. A sample calculation was made with both the transmitter and receiver at a depth of 3000 meters. At a horizontal range of 5 NM the ray bending caused an error in range of 4.2 meters. At 10 NM the error becomes 33.4 meters.

Curves of ray bending caused range error vs slant range have been plotted for sample cases calculated using ray tracing programs. Curve fitting techniques were applied and it was found that a single equation would closely fit the deep to shallow and the deep to deep curves.

This equation is:

$$K = A + B \bar{R} + \bar{R}^2$$

where K is the correction factor for ray bending

$\bar{R}$ is the slant range obtained from $\bar{R} = \bar{c}(t)$

A, B and C are constants obtained from a curve fitting program.

The ray bending corrected slant range, R, is obtained from:

$$R = K \bar{R}$$

The coefficients A, B and C are different for the deep to deep situation and the deep to shallow case.

V. Transponder Mooring Assemblies

The 1971 transponder flotation assembly consisted of a single frame member with two 16" glass ball floats. Some launch and recovery problems were encountered using this float assembly. It was also found that this float assembly did not lend itself to provide the flexibility required for the various transponder and elevator configurations scheduled for use in 1972. Criteria for a new mooring float assembly were established as follows:

- a) The flotation assembly should have a convenient size and shape for stacking on deck, stowage, launch and recovery.
- b) The frame should provide protection for the glass floats during handling, launch and recovery.
- c) The buoyancy should be easily adjustable by adding a third flotation sphere or a ballast weight.
- d) The frame should be made of fiberglass and stainless steel for long life and low maintenance.
- e) The top sphere should be international orange to be seen on the

surface and the lower sphere should be white for maximum visibility of the frame from a submersible.

- f) The frame should permit easy attachment of recovery aids such as a flashing light and a radio beacon.
- g) The mooring float assembly should have sufficient surface stability to keep the recovery aids as high as possible.
- h) A large top bail is desirable to permit hooking the surface mooring with a boat hook.

With these requirements in mind a new float assembly was designed. Figure 4 is a sketch of the float assembly used in 1972. This assembly proved easy to handle and flexible during the 1972 sea trials.

The launch and recovery platform on R/V LULU has a 10 foot maximum height limitation and is equipped with two winches. The mooring strings have a large diameter steel ring every 10 feet to accommodate a hand-over-hand launch and recovery sequence.

Figure 5 is a sketch of the standard transponder mooring. For favorable bottom conditions the transponder is moored 100 feet off the bottom. In difficult terrain this height is increased to 300 feet.

VI. ARPA Untethered Payload Elevator

Figure 6 is a sketch of the ARPA untethered payload elevator. The elevator is built around a relay transponder that is interrogated by the ship. The reply from the elevator interrogates reference transponders. Receipt of the replies from the reference transponders and the elevator permits the location of the elevator to be calculated. Physically the elevator consists of an aluminum pipe frame assembly attached to an AMF Model 324 Relay Transponder. The use of the pipe frame construction permits easy modification of the frame to accommodate a wide variety of items to be carried on the frame. The payload of the elevator is adjusted by adding flotation and/or ballast.

VII. Conclusions

The results and developments discussed above have caused some shifts within the proposed ARPA Submerged Navigation Program. The suggested priorities for the next phase of the program include:

- a) Added effort will be expended to maximize the reproducibility of the system.
- b) Sound velocity corrections will receive added emphasis.
- c) The equipment versatility will be expanded to include capability to track a wider variety of surface and submerged devices.

	<u>Air Weight</u>	<u>Displace</u>
Bail	3.3	1.0
Top Angle	1.2	.8
Radio	1.5	.7
Light	1.2	.8
Ball A	45.0	103.3
Ball B	45.0	103.3
Frame	8.3	5.8
Base Angle	4.9	3.4
Tongue	1.3	.2
	<u>111.7</u>	<u>219.3</u>

Standard Transponder Float Assembly

Figure 4

	<u>Air Wt.</u>	<u>Displ</u>
Float	111.7	219.3
Xponder	<u>153</u>	<u>103</u>
	265	322
		<u>265</u>
Net Positive		57 lbs
Anchor		110 lbs
Net Negative		53 lbs

Estimated Drag, X_{uu} is 2.86
 (lbs sec²/ft²) for an
 estimated down velocity of
 4.4 ft/sec or 6000 ft in
 22.7 min
 estimated up velocity of
 4.6 ft/sec or 6000 ft in
 21.6 min

Standard Transponder Mooring

Figure 5

	<u>Air Wt.</u>	<u>Displ</u>
Float	112	219
3rd Ball	45	101
Rack	85	25
Payload	13	10
Xponder	140	95
	<u>395</u>	<u>450</u>
		<u>395</u>
Net Positive		55 lbs
Anchor		140 lbs
Net Negative		85 lbs

Estimated drag is 6.8 Xuu

Down velocity is 3.5 ft/sec
for 6000 ft in 29 min

Up velocity is 2.8 ft/sec
for 6000 ft in 35 min

Note: Payload in this case is 3 Respirator Jars for measurement of bottom oxygen consumption by sediment life

To use the payload frame with a 100 pound payload, add an additional 2 Ball float above the 3 Ball float shown and an additional 90 pound anchor chain.

ARPA Payload Elevator

Figure 6

- d) The proposed efforts to exploit the surface bounce mode of transmission between the submersible and deep transponders will be continued now that this transmission path has been demonstrated.
- e) The program to forward to SUBDEVGROUPE ONE internal memos and advance copies of reports on the navigation program will be continued.
- f) A paper tape (as proposed) or magnetic tape (preferred option) data logging capability will be added to the ALNAV system to improve the after-the-fact data reduction capability.
- g) To accomodate the above without added funds the proposed efforts in the areas of submersible to surface telemetry and submersible display may have to be reduced in scope.

Handling and Transfer at Sea

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Geology and Geophysics Department

Handling and Transfer at Sea

Purpose

To investigate better ways of handling and operating heavy equipment, deep submersibles, and small boats from ships at sea in normal and rough weather. Sea states three and four with frequent five to eight foot seas that are typical of trade wind areas are considered.

It is believed that present design and operational concepts are seriously limiting research, development and application capabilities at sea, partly in what is being done in a mediocre fashion and partly in what is not attempted.

Methodology

To draw heavily on the extensive experience of other transportation fields such as the automotive and aeronautical fields in lessening interface problems between the moving vehicle and the ground. Particular emphasis is placed on the assumption that a small boat approaching the side of a ship may be quite analogous to an airplane approaching the deck of an aircraft carrier.

Emphasis is placed on applications of the rolling and resilient action of aircraft landing gear and automotive suspension systems to the relative motions between ship and boat.

Progress To Date

Earlier related work reported in earlier progress reports has shown that the use of very resilient fenders and of resilient, free-swiveling aircraft landing gear assemblies mounted off the side of small boats could significantly lessen the danger of hurting either the craft or personnel when coming alongside docks or ships in choppy waters. However no work was done in heavy seas or with very large ships.

Recently effort on this task was intentionally slowed up to conserve funds so that when an opportunity came to work with larger ships such work could be undertaken.

In January 1973 such an opportunity did come up in working for a week with COMPHIBRON TEN during maneuvers in the Caribbean. This work was made possible through the cooperation of COMPHIBLANT Captain K. Carroll (COMPHIBRON TEN), his staff and personnel on the four ships involved. Due to the short time for planning, delivery of equipment and installation, the tests tended to be rather primitive in execution although they were fundamental in character. However they did provide many fleet personnel to see some of the concepts tried out, and the tests provided the Woods Hole representative an opportunity to better understand Fleet problems and the interaction of Fleet problems with each other.

The writer wants to take this opportunity to thank the many commands and ships involved for their excellent cooperation, friendly reception and good advice.

After a considerable group discussion of tests that might usefully be done with the equipment and ships available the following objectives were outlined and carried out.

- (1) Each of the four ships involved:

FRANCIS MARION, LPA 249 (Flagship)

EL PASO, LKA 117

LORRAINE COUNTY, LST 1194

PLYMOUTH ROCK, LSD 29

should carry out one experiment. This would provide the widest variety of circumstances and training possible.

- (2) Operational objectives were summarized as:
 - a) along-side operations
 - b) operations within the well decks
 - c) loading and offloading troops
 - d) might the same resilient methods be logical for 300 ton boats as for three ton boats?
 - e) does it appear that amphibious operations could be conducted in higher sea states than otherwise?

The actual equipment installations and tests were as follows:

- (1) For once the weather was actually too good and only calm seas (sea state two or less) were encountered. As a result the results were not as definitive as hoped for, but on the other hand a wider variety of tests were conducted than would have been possible in heavy weather. Also there was little danger of people getting hurt.
- (2) FRANCIS MARION (LPA 249)

The best engineered and tested equipments taken were the S-2 aircraft nose wheel assemblies that had been extensively used at Woods Hole on the 3-ton work boat described in earlier progress reports. These were installed thwartships on the bow and stern of a 3-4 ton LP boat (Figures 1 and 2). This boat was used and demonstrated in a variety of ways:

- a) coming alongside all the ships forward, amidships and aft on both windward and lee sides.
- b) operating within the PLYMOUTH ROCK's well deck to see if rolling and resilient contact might ease the situation of boats surging in the well deck.

The problem of boat handling within the well deck was considered to be very important, partly because not much is known about it and partly because new amphibious ships will have much larger well decks.

- c) lying alongside on both windward and leeward sides to see if boats can more safely be left out for longer periods to distribute work load on the ship and to have craft in the water.

This installation was inspected by, and described to, Admiral Bell, COMPHIBLANT when visiting the squadron. This installation was also left intact on the ship so it could be used in later tests and operations.

The seas were large enough, and the ships hulls were varied and rough enough so that versatility of the dual swiveling wheels was clearly demonstrated. Also the rolling contact and resilient cushioning clearly demonstrated that added sea-worthiness could be obtained if felt worthwhile.

(3) LORRAINE COUNTY (LST 1194)

The LORRAINE COUNTY attempted to duplicate the work of the FRANCIS MARION but the aircraft wheel assemblies furnished them by Woods Hole were not complete and after a great deal of hard work they had to give up because of lack of time for testing. The ship is to be congratulated for their efforts in trying to overcome difficulties not of their making.

(4) PLYMOUTH ROCK (LSD 29)

Because PLYMOUTH ROCK carried the largest landing craft it was decided to put horizontally axled wheels and springs on one of them to see how it would lay alongside an inner wall of the well or alongside the outside of the ship.

Unfortunately the Lockheed Constellation main landing gear did not arrive from Davis Monthan Air Force Base so axle and wheel assemblies from large trailer trucks were obtained from a local salvage yard. These were temporarily mounted fore and aft on the side of the landing craft. The horizontally axled wheels were very effective at taking vertical motion without catching on projections or causing worry about wear. The assemblies were adequate for the seas encountered but heavier

truck or aircraft units would be needed for more normal trade wind weather.

This experiment was deemed successful and suggested that it be repeated in the Little Creek area with heavier equipment and be exposed to much more rigorous exposure: also to be tested for towing alongside.

(5) EL PASO (LKA 117)

One of the most interesting tests was this simulation of an articulated companion ladder to permit a walkway from deck level down to a floating resilient platform that small boats could come up to, to load or offload personnel (Figures 1 and 2).

The upper portion of the gangway is the ship's regular ladder, the bottom being secured some 10-12 feet above the water. The lower portion of the gangway is loosely suspended from the upper ladder so that it can rotate enough vertically and horizontally to take care of wave motion. The floating fender-platform-tire supports the lower end of the ladder and serves as a transfer platform remaining at boat height.

While it is too early to state whether something like this could replace transfer by cargo net it seemed apparent that further testing in this direction is advisable. One must state again that the weather was so calm that the tests were only suggestive rather than definitive of what would have happened in rougher seas.

(6) Conclusion of PHIBRON TEN Tests

Wide exposure of some of these techniques was given to amphibious forces. More photographs and movies will become available. A continuation of work of this type in the Little Creek-Norfolk area should rather easily permit evolving installations and tests that would be more constructively definitive than these.

Specific discussions and hopefully plans for such tests will be taken up with Amphibious Forces at an early date. Such tests would include the use of much heavier duty aircraft landing gear, some of which is now at Woods Hole and at Little Creek.

(7) About 15% of the funding under this task remains.

Small boat coming up to floating resilient platform.

Figure 1

Small boat alongside floating resilient platform, to load or offload personnel.

Figure 2

Bottom Reconnaissance and A Detailed Site Survey
by Research Submersible

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Bottom Reconnaissance and A Detailed Site Survey
by Research Submersible

Hydraulic Impact Hammer

During the previous semi-annual period the impact hammer underwent its first sea-going tests aboard the submersible ALVIN. On two cruises into the Gulf of Maine during the summer of 1972, the submersible located and occupied a series of bedrock outcrops of granite composition during which the impact hammer was used in an attempt to break off representative samples. From an operational standpoint the impact hammer with its positioning pistons, hydraulic motor, latching mechanism, and self-contained power supply operated without major difficulties. The principal problem encountered was the impacting energy itself. On the support ship, the hammer successfully broke a variety of bedrock samples in air, but when used underwater the hammer was unable to break off samples even after as many as 20 impacts.

With the above experience in hand, the second semi-annual period was spent putting the impact hammer through an extensive series of tests to (1) measure its impacting capability, (2) compare those results with known energies necessary to break granite as well as other igneous rocks, (3) to make a series of design changes to the hammer to improve its energy and (4) to measure the effect of these changes in both an air and water environment.

The hammer configuration used aboard ALVIN in the summer of 1972 was set up in a laboratory on shore and a series of impacts were made in a test specimen of lead. The results show that the energy delivered in air was several hundred foot pounds. This test was repeated in water and indicated a 10% energy loss. Tests were then made with a standard geologic hammer at normal impact speeds which are necessary to break off samples from most igneous rocks. The impact energy was about 500 foot pounds. This energy is substantially greater than the present capability of the hammer in water but is well within the structural capability of the hammer which is greater than 1500 foot pounds.

A variety of experiments were then made with the hammer involving (1) the addition of lead counter weights, (2) increasing the mass of the hammer, (3) removing the chisel assembly all together and hitting the rock directly with the hammer, and (4) increasing the strength of the cocking spring. These changes were made to the hammer followed by impacts into lead test samples. At present these impressions are being measured and their energies calculated. A preliminary analysis indicates that substantial increases in the impacting energy has been achieved, far above that necessary to break off samples in water.

Future plans include (1) replace the counter weights with a much lighter plate assembly which will resist hammer recoil in water, acting much like a sea anchor, (2) construct a large test stand to evaluate the effectiveness of this plate assembly in hopes of greatly lightening the overall weight

of the system, and (3) replace the positioning pistons with a more effective manipulator-type positioning system to add greater degrees of freedom and to give the system additional operational options such as acting as a back-up mechanical arm, etc., (4) once these changes have been made to the hammer system and tested in the laboratory, the unit will be taken to sea for a series of tests in the Gulf of Maine. If these tests prove successful, the final step will be to mount the hammer directly on ALVIN in the same manner the present mechanical arm is attached and the submersible's power and/or hydraulic supply to operate it, thus eliminating a great deal of the systems weight as well as removing its present bulky tray assembly. In addition, the joy-stick controls will be constructed and variety of lesser improvements made to the system.

It is presently planned to use the impact hammer as the primary sampling system for the FAMOUS project in the Mid-Atlantic Ridge in the summer of 1974.

Near Bottom Magnetic Studies
Using A Deep Submersible

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Near Bottom Magnetic Studies

Problem

The principle technical problem approached during this reporting period was complete field testing of the ALVIN magnetometer system described in the previous progress report (W.H.O.I. Technical Report 73-20). Limited field test and dockside test during the last reporting period showed the system to be ready for a geophysical field test.

Method

A region in the central part of the Gulf of Maine over the Fundy fault scarp was selected for a geophysical field test of the magnetometer system. In this region there should be wide excursions of the geomagnetic anomaly field over short distances. This should allow a fair test of the magnetometer's precession signal tracking ability. For recording the observed magnetic variation the output of the Varian V75/85 was input directly to a Brush 8-channel strip chart recorder. Both submarine depth and total magnetic field intensity were recorded as a function of time.

Results

A total of six dives were made with the magnetometer system on board. During the first two dives no data were recorded, however the system performed normally. During the third dive a saltwater leak was observed in the safety "quick" disconnect system. New O-rings were installed and no further problems were encountered during the remaining three dives. A sample record obtained during Dive #427 made on 22 July 1972 is shown in Figures A and B. Close inspection of the magnetic record where the field is not changing too rapidly, say at 1030 Z, shows the general noise level to be about ± 2 gammas. The spurious spikes between 1120-1140 Z are due to interference from the UQC sonar. The signal tracking of the system over a wide range of field values also appears to be good in that the field varied by more than 1000 gammas over a distance of 3 km and did not require operator adjustment of the system's precession frequency tuning.

In regards to operational characteristics of the tow fish/cable arrangement it appears to be adequate for the ALVIN's present normal ascent rate, however under maximum ascent rate conditions the fish did tend to drop below the submarine and some minor entanglement with the submarine was experienced.

Summary

Successful field tests of the ALVIN near bottom magnetometer system were completed in the Gulf of Maine during August 1972. The electronic noise level of the new Varian V75/85 console was found to be equal or better than the previous airborne Varian V4937A unit (less than ± 2 gammas). The tow cable/fish and disconnect system appears to be adequate under most normal operating procedures. However in the event that faster "normal" ascent rates are developed for ALVIN, an even more buoyant, streamlined tow fish/cable arrangement will be required.

Sketch map showing location of ALVIN Dive #427, 22 July 1972.

Figure A

Annotated Gould-Brush strip chart record showing the total geomagnetic field intensity and depth variation along a selected portion of the ALVIN track during Dive #427 of Figure A.

Figure B

Near Bottom Gravity Studies
from A Deep Submersible

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Near Bottom Gravity Studies from A Deep Submersible

This final report summarizes the accomplishments of the experiment to conduct near bottom gravity measurements from the small submersible ALVIN. Greater detail of the historical development of the program is provided in the progress reports of this study available in Woods Hole Oceanographic Institution Reference Reports W.H.O.I. 72-33 (for period 1 February 1971 - 31 July 1971, W.H.O.I. 72-90 (for period 1 August 1971 - 31 January 1972) and W.H.O.I. 73-20 (for period 1 February 1972 - 31 July 1972).

Gravity Equipment Developed Under This Contract

A special instrumentation system was developed for experiments with gravity measurements from a submersible. The sensor for the system is a vibrating string accelerometer (VSA) (type ARMA Lot d) enclosed in a high stability two-stage thermal chamber designed by W.H.O.I. to provide temperature control to a precision of 0.001° centigrade. For the initial phase of the experiment, a simple gimbal was designed to clamp onto the VSA oven (Figure 1). The oven and gimbal attach to the instrumentation relay rack in ALVIN at a point which is near the meta-center of the craft. A VSA readout and real-time clock unit was developed and built for the system by Frequency Devices, Inc., of Haverhill, Massachusetts (immediately below chart recorder in relay rack in Figure 2). This device filters and counts the frequency difference between the two strings of the VSA. Changes in this frequency difference count are proportional to changes in the accelerations sensed by the VSA. Because the sensitivity of the frequency difference to acceleration changes is only 64 Hz/g, considerable effort was required to design the readout system to resolve and display accelerations as small as 10^{-7} g or about 10^{-1} mgals. Submersible space and power limitations required that the unit be small and that its power requirements be minimal. Digital (BCD) output of time and gravity from this device together with BCD data from a precision water pressure sensor (for relative depth measurements) and an optional magnetometer are ordered and formatted by a data coupler-multiplexer (middle unit in relay rack in Figure 2). The data coupler controls the recording of the information on a digital cassette recorder. The information thus recorded may be "played back" at a later time into a shore-based computer for analysis.

The shore-based computer analyses, as planned, would have scaled and biased the readout counter reading for every second from the information recorded on the cassette. The water pressure information for the same one second period would have been converted to vertical displacement and then differentiated twice to provide vertical acceleration of the craft. These vertical accelerations then would have been subtracted from the accelerometer information, providing gravity information needing only the Eotvos correction. Three dimensional acoustic navigational and position fixing system information from the submersible dive would have provided information required for computation of the Eotvos correction and gravity anomalies.

The digital recorder, on loan from another project, was powered by a heavy, heat producing, space consuming inverter. Because its primary power

requirement was 115 VAC 60 Hz and ALVIN has only a 28 VDC power buss, a 28 VDC cassette recorder was to be a future project acquisition. As will be discussed later, an analog strip chart recorder which also required use of the inverter, and which was not part of the optimal gravity system, was used in the experimental dive.

ALVIN Dive, November 1971

In November of 1971 equipment prepared for the attempt to measure gravity in a submersible was shipped to the Bahamas and loaded aboard ALVIN and her mother-ship LULU. For this particular dive series, ALVIN was scheduled to do a series of Advanced Research Projects Agency (ARPA) related experiments which were expected to be scientifically or logistically compatible. The experiments took place in the Tongue of the Ocean area off Clifton Point of New Providence Island. As diving progressed, it became readily apparent that submersible weight and power considerations, as well as turn-around time between dives, would constrain the compatibility and number of experimental dives.

In particular, it was decided that because of the long installation and removal time of the gravity data acquisition equipment, and because the data coupler-multiplexer, as delivered by the manufacturer, was not operating properly, it would not be used. This meant that the gravity-time data would be recorded only a strip chart recorder and depth information would be verbally recorded on a portable audio cassette recorder. It was felt, and later shown to be true, that for the preliminary purpose of demonstrating the feasibility of the gimbal system in ALVIN that this recording method would suffice. Without the data acquisition system, however, it was impossible to obtain high rate information on the vertical accelerations of ALVIN from analysis of variations in water depth pressure.

Examination of the gravity-dive strip chart record (Figure 3) reveals that although there is some correlation between submersible descent and holding maneuvers during the initial part of the dive, meaningful vertical acceleration data is masked by horizontal accelerations from trimming and rudder adjustments which perturbed the gimbal mounted sensor. In general, the chart record is smoothest during times of uniform descent ("floating" downward) with no propulsion steering or trimming taking place. However, this is still quite variable principally because of variations in descent velocity.

The short term variations in the pen trace of oven temperature near the center of the strip chart recording of the dive (Figures 3 and 4) represent only transient electrical noise, whereas the long term average represents absolute inner thermal chamber temperature. The scale factor for temperature trace is not empirically known, but calculations based on the scaling of the amplifiers in the temperature control feed-back loop, and knowledge of the thermistor sensitivity suggest that each small vertical division of the strip chart recorder should be $4 \times 10^{-4}^{\circ}\text{C}$. Because temperature control to 10^{-3}°C is required for VSA gravity operation, it is concluded that temperature control was not a problem in this experiment.

When the desired depth for the gravity traverse was reached (left hand side Figure 4), the submersible proceeded in level flight on a southerly course.

The pilot controlled the craft attempting to eliminate motion of ALVIN other than that in the forward direction; observers made only necessary movements: trimming the craft was minimized, and steering and course error control were optimized. This produced records considerably less noisy than during descent. However, errors of 10 to 100 mgals (most of the noise in Figure 4) were encountered; these were due principally to gimbal-moving horizontal accelerations (jerks) caused by the submersible steering mechanism, effectively masking any trace of gravitational variation due to local topography. When, late in the dive, the submersible turned 90 degrees to the west (towards the right of Figure 4), no discernible Eotvos effect was noticeable. This was not surprising since, at the latitude of the Bahamas, with the submersible speed of a little better than 0.5 knots, the Eotvos effect for this turn should be less than 3 mgals.

As a result of this experiment it has become clear that to measure gravity variations of 0.1 mgals in any small submersible, a stable platform must be developed for the vertical erection of the gravity sensor in the submersible.

Automatic collection of data pertinent to gravity measurements in the submersible is essential. In the experimental dive, maneuvering of the submersible was often not sensed by the observer, and the pilot of the vessel was often too busy with operations to relay intended changes in motion soon enough or rapidly enough for proper annotation. After the disappearance of sunlight as ALVIN descended, the observer on one occasion felt that the submarine was turning over when in fact it was not. In level flight, the biggest acceleration noise appearing on the gravity trace was due to the jerky steering mechanism, but other movements of the craft appear to be large enough in their own right to make gravity measurement to even 1 mgal impossible without a stable platform.

Investigation of Stabilized Platforms

Following the experience of the test dive, we abandoned attempts to use a gimbal suspension for gravity measurements in a small submersible and began studying the feasibility of using instead a miniaturized gyrostabilized platform.

Our investigation included study of three alternate configurations of stabilized platforms. One was a two-degree of freedom platform, the second was a two-degree of freedom slave platform referenced from a three-degree of freedom inertial navigation system, and the third was an inertial navigation system that could contain an over for the VSA gravity sensor. Investigation of the last two approaches included consultation with inertial guidance and navigation groups at M.I.T. Charles Stark Draper Laboratories in Cambridge, Massachusetts.

The first approach appears least expensive, but would provide only vertical stabilization of the gravity meter. Larger platforms of this type, already in use for gravity measurements aboard aircraft, cost approximately \$50K. Estimates of the costs for building a smaller platform with improved specifications on verticality were in the range of \$75K to \$125K. These estimates were received from Aeroflex Corporation, a manufacturer of many styles of stable platforms. However, during maneuvers of the vehicle and for tens of minutes thereafter, the vertical inaccuracy of this type of platform would make it unusable for meaningful gravity measurements.

The second approach would require the greatest amount of space and power. There is an inertial navigation system developed (four are being built for deep submergence recovery vehicle, DSRV) that may not only meet the requirements of verticality and navigational accuracy, but might also fit in ALVIN. It is highly unlikely that one of these systems could be released for use in the gravity program. If available, the resulting system with slave table attached would be relatively large and not as cost effective in the long term as would be either of the other two approaches. Assuming the availability of obtaining one of the miniature DSRV inertial navigation systems (G.F.E.), Draper Laboratory estimated that about \$80K would be required for them to design and construct a slave platform on which to mount the gravity sensor.

The third approach presently appears to offer the greatest advancement. A compact gravity/navigation/data acquisition system could be designed utilizing common gimbals and computer. The portability and performance of such a gravity/navigation/data acquisition system would provide the capability, not possible with present equipment, to obtain gravity measurements in remote areas as opportunities arise to use conventional and exotic vehicles. Unfortunately, this approach is the most expensive. Draper Laboratory estimated a cost of \$535K to design and construct such a system.

During these discussions Draper Laboratory also investigated the Mark IV SINS systems, as a possible lower cost alternative to providing a high accuracy portable gravity navigation system. The size and power requirements of this system would preclude use in ALVIN, but might be an important contribution to the ability of surface ships, large submarines, or aircraft dictates. Draper Laboratory determined that if three Mark IV SINS systems were provided GFE, the costs for modification of the system and reprogramming the computer would be about \$165K for two systems; the third being a source of spare parts. To replace the original computers with improved modern computers would cost about an additional \$20K.

For any of the alternative systems, the costs of field testing, support by the contractor, and W.H.O.I. supervisory efforts would require funding additional to the estimates given above. Because of the high cost of an accurate miniature portable gravity/navigation system, and the inadequacy of a gimbal mounted gravity sensor, further development of a small submersible gravity system is unwise at this time. Therefore, this program has been terminated with the concurrence of ARPA.

We wish to emphasize, as previously stated in other reports concerning this experiment, that considerable care must be given the question of navigation. At present, vertical accelerations of the submersible, for removal from the gravity signal, must be determined by differentiation of vertical position information with respect to time. Therefore, these measurements must be made to an accuracy which equals, and perhaps exceeds, the state of the art in underwater position determination.

Figure 1

VSA Gravity sensor/oven and gimbal suspension for 19" relay rack mounting. Level vials and adjustable balance weights are on the top of the instrument.

Figure 2

Submersible gravimeter and data acquisition package for ALVIN. The gravity sensor/oven is on the left. On the right from top to bottom in the relay rack are the analog strip chart recorder, the real time clock/VSA readout, the data coupler, the oven controller/shoreside power supply, and the digital cassette recorder. The inverter used to power the digital cassette recorder and the strip chart recorder in this version of the system is not shown.

Reproduction of ALVIN dive record for 26 November 1971 during descent and leveling-off in preparation for horizontal flight. During left half of record there were a series of descents with check stops at increasing depths.

Figure 3

Reproduction of ALVIN dive for 26 November 1971 during level flight at depth of 300 m.

Figure 4

A Self Contained Deep Sea Rock Drill

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A Self Contained Deep Sea Rock Drill

Introduction and Background

The second semi-annual report, covering progress through July 1972, described the drill and briefly discussed the modifications and testing required. During the second half of the year, most of the significant modifications were accomplished and extensive testing continued. During the next year we plan to continue a testing program primarily oriented towards improving the drill's reliability with the immediate goal of using the drill in a scientific program on the New England Seamounts.

Testing

An extensive series of tests was conducted in Woods Hole Harbor, followed by one ALVIN open sea dive and an attempted surface ship lowering. The following were the objectives and results of these tests.

The ALVIN attachment system modifications were completed and the system was tested at sea. We can now call this system complete. ALVIN is able to launch, dive, uncouple, recouple and jettison the drill (in emergencies) and then surface and be retrieved, all in moderate seas. Some minor adjustments are planned to make parts of the operation smoother but the system is considered workable and safe.

On our one dive with ALVIN our initial landing on the rock bottom was made with a significant impact. This impact broke off the front leg of the drill and we decided not to completely uncouple the drill for this test for fear we would not be able to recouple. However, this uncoupling and recoupling has been accomplished on several previous dives, and we have no serious doubts about our ability to do it.

The new control instrument and monitoring system was tested in numerous harbor and open-sea tests. The monitoring portion of the system works well and we are now able to monitor battery current and voltage in real time from the escort vessel. Some problems were encountered with the control system. Spurious electronic noise interference caused the automatic control system to operate unreliably. We believe we have this problem cured but on our one dive with ALVIN a bad underwater connector prevented this system from operating at all so it was not given a real test. However, our new system allowed us the option to control the drill from ALVIN and we did operate the drill from inside ALVIN, over-riding the inoperative automatic control system.

During this ALVIN drilling test, the drill was run for 16 minutes and penetrated four feet of granite. Core barrel retraction was difficult because surging of ALVIN with the drill still coupled caused surging of the drill and some binding of the core barrel. However, we were able finally to complete the retraction and returned to the escort vessel with the drill. Unfortunately, even though we know we drilled four feet of granite, no core was found in the core barrel. We had never before had a failure of our core catchers, but apparently it did fail this time. We had used a new

core catcher and close inspection of this core catcher revealed that it did not grab a core as tightly as the others we had used.

Following this, we made a one-day trip on the R/V VERRILL, a small (60 ft.) vessel, in an attempt to test the drill again and hopefully retrieve a core. This trip was plagued by bad weather which forced us into port. We tried drilling in the outer part of the Plymouth, Massachusetts Harbor but the bottom proved to be sand and also we again had difficulties with our automatic controls. During our testing we drilled many feet of granite and collected a wealth of engineering data which we are presently trying to assimilate.

Present Status and Future Plans

At this point we feel that we have a working drill that lacks sufficient reliability to make it a useful tool. It is obvious from the description of the testing that we need more experience running it to debug the drill and all its systems. We plan to do this during the spring and early summer and the participation in the ALVIN/LULU New England Seamount Cruise in August.

Self Contained Ancillary Modular Platform

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SCAMP - Self Contained Ancillary Modular Platform

The objective and description of the SCAMP Program has been reviewed in previous progress reports and will not be covered at this time.

Construction Milestones:

1. Frame

With the exception of the cutting and fitting of the 34 lb. density syntactic flotation foam, the basic frame has been completed. A weight check on the assembly, including the two tubular battery compartments, nose cones, and three suction pod assemblies, indicate a total air weight of 925 lbs. This compares satisfactorily with the original calculations of estimated frame weight. It does not include the ten lead acid storage batteries or the Marcol compensation oil.

One minor modification improvement has been included on the frame. An additional battery saddle mounting plate has been added to the aft port and starboard sides, to provide a method of obtaining a gross adjustment of fore and aft trim.

2. Battery Assembly

Electrical contactors, fuses, and interconnecting battery cables have been requisitioned. Several sections of the relay control packages, located within the two aft nose cones have been packaged and fit into their respective housings. Wiring of the relay boards are continuing, and on completion, a thorough photographic series will be taken to provide detailed assembly and installation information.

Several fractional H.P. printed circuit pancake armature motors have been provided to drive the ball screw battery traverse mechanism. Preliminary tests indicate satisfactory operation in Hoover submersible fluid #2. Experiments will be continued to obtain a clear picture of windage loss, current and voltage characteristics, as well as brush gassing oil. Two 8:1 reduction gear assemblies are presently being fabricated, and will provide the required low rpm necessary to control the traverse mechanism.

3. Suction Pod Assemblies

With the exception of actual on-the-bottom shallow water tests, the three assemblies are considered as complete. However, after the initial in-water test, it is expected that additional work will be performed in an attempt to improve their characteristics through the use of porous stone filters similar to those designed at the University of Rhode Island. The initial design did not include the filter assembly, although the device was constructed in a way that will permit the inclusion of the filter with a minimum effort.

4. ALVIN/SCAMP Interface

Several tests were performed using short lengths of sea water pressurized fire hose to clamp the ALVIN skids to the SCAMP frame. The data obtained provided a sufficiently high confidence level to pursue the clamping method in greater detail. Clamp designs are in process, as well as the piping control and flow circuits. A thorough search of commercially available salt water solenoid operated valves has failed to turn up a satisfactory device that would be tolerant to heavy concentrations of silt laden water. A valve design, using several novel approaches is presently on the design board, and if successful, will be discussed in greater detail in the next report.

The sea water pump and motor combination is being reviewed, and at present tends to indicate a positive displacement Oberdorfer herringbone gear pump, coupled with a direct current permanent magnet motor.

5. Preliminary Test Instrumentation

Several surface mounted control boxes are being constructed, and will provide the surface controller with a means of performing the various functions of battery traverse, suction pod operation, ALVIN/SCAMP interface clamping, and simulated science equipment operation. The control boxes will be mounted in a small support boat, and through the use of a 50 foot umbilical cord, allow preliminary shallow water tests to be performed without the use of the ALVIN submersible.

Modular Acoustic System

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Modular Acoustic System

The general objectives of the project are spelled out in the 1973 ARPA Proposal and will not be discussed here. Only those items which have been clarified by further investigation and/or changed as a result thereof are listed.

I. Basic Approach

Early in the design phase of hardware development it became obvious that building a sophisticated sonar system (at least insofar as flexibility of radiation and reception are concerned) would of necessity include much complex control circuitry to perform the various required tasks. As originally put forth, the idea was a sonar system capable of being operated in any mode under manual control. A computer was to be used as an adjunct device to allow faster shifts of frequency or mode than that of which a human operator was capable. Additionally, the computer would be capable of data manipulation and processing.

Since the digital control circuitry necessary for manual operation in other than relatively simple echo-ranging comprises, in effect, a programmable digital controller, it soon became obvious that the better approach would be to design in manual controls for the simpler operations only. Thus would the system rely on computer control for all complex sonar functions. This is not the drawback that it might first appear since without the computer it is doubtful if complex bursts, sweeps, etc., could be evaluated by a human operator alone.

As of this writing it is planned to have a mini-computer as part of the system for all but the simplest echo-ranging operations. The computer which appears best at this time is the NOVA 1210, manufactured by Data-General in Southboro, Massachusetts. It is a full-blown computer utilizing 16 bit words, will have 8K of memory consuming less than 100 watts power (it operates directly on 28 VDC). It takes 5¼" of rack space.

Programming will be by means of digital cassettes containing pre-generated programs written on a NOVA 1200/DISC System on the surface. Due to the fact that the NOVA is not software compatible with any system at W.H.O.I. (unfortunately), the surface support system must be complete for adequate program generating capability.

Parameter entry and direct communication with the computer will be by means of a 12-button keyboard and thumb wheel switch as well as by the programmers console on the CPU itself. The computer will be able to output to cassette, ½ inch magnetic tape, oscilloscope and a 10 digit LED numeric display.

II. Display

The display will consist of a standard TV monitor display driven by a scan converter (Hughes). The scan converter can be driven in any of

the required modes for generating PPI, A-scope, J-scope, etc. Using the TV monitor for readout enables one to use inexpensive transistorized monitors with very low power consumption to provide as many remote displays as is desired.

Both the master scope and slave monitors will be 5" rectangular scopes. The remote package is hardly larger than the CRT it contains.

III. Packaging

Inboard packaging will consist of five rack mounting assemblies plus a remote auxiliary display.

The packages are as follows: (see attached sketches)

- A. Scope/display: 5½" high panel containing the master scope, recording camera, the image-conversion system and the associated master generation controls as well as transducer training system controls and readouts.
- B. Control: 5½" high panel containing the cassette recorder, keyboard and the thumb wheels for controlling the system in either computer or manual mode.
- C. Receiver/Recorder: 5½" high panel contains the ½" AM/FM recorder, the data logging system and the acoustic receiver.
- D. Synthesizer: 3½" high panel. (Commercial gear)
- E. Computer: 5½" high, NOVA 1210
(Total rack panel height = 24½")
- F. Remote Monitor = Approximately 5" x 6" x 11" remote display for pilot or observer.

Outboard there will be two (Titanium, I hope) pressure cases approximately eight inches OD x 25 inches long containing the sonar power amplifiers and their batteries ($\pm 37\frac{1}{2}$ volts DC). One of them will be mounted outboard on each side with drop solenoids.

The transducer training mechanism is still in the sketching stage except that it will be made of PVC and G-10 epoxy fibreglas and powered by brushless DC stepping motors (operating from their own battery probably).

IV. Electrical

Right now the system requires 12 thru-hull penetrators (electrical). Four more would be highly desirable for more accurate sensors on the two axes of the training mechanisms.

Projected power consumption from the 28 volt bus is as follows:

Tape recorder	45 watts
Synthesizer	25 watts
NOVA 1210	100 watts
Scope Display(approximately)	100 watts
Cassette	<u>10 watts</u>
	270 watts

Note that this is well under the 480 watts for eight hours which we were "allowed". This does not show power for training mechanism or sonar transmitters. Both of these items will have their own battery stacks providing limited operation without drain from the boat or they can be charged from the 28 volt bus.

Inboard Electronics

Air-Sea System (Long Range Echo Ranging)

F. R. Hess

Tel: 617-548-1400, Ext. 275

Ocean Engineering Department

Air-Sea System (Long Range Echo Ranging)

On October 20, 1972 an attempt to conduct the deep sonobuoy/long range echo-ranging experiment under the ARPA (284.09) contract was made.

The New England seamount area was not available for operations due to a previous clearance request by New London.

Arrangements were made to utilize a P3-B aircraft of VP-23 Squadron flying out of Brunswick N.A.S. (Note: earlier attempts, four in all, were cancelled for weather or clearance reasons). This aircraft was loaded with the sonobuoys (SSQ-46), SUS (MK 83) and the heavy ordnance (MK84GP Bombs). It was found necessary to utilize the alternate southern site (30°35'N, 75°20'W) due to lack of adequate cloud ceilings in the primary southern area. Safety requirements dictated a 5000-foot minimum drop altitude for the 500 lb. charges. Visibility adequate to insure freedom from surface shipping in the area was also a prerequisite.

The flight plan consisted of the dropping of a line of SSQ-46 sonobuoys on line-of-bearing 315°, eight buoys to be dropped at one mile intervals. A 1500 foot SUS (1.8 lbs. TNT) to be dropped between each pair of buoys and three specially fitted 500 lb. bombs to be fired at 1500 foot depth broadside to the array. A minimum of 4-5 minutes listening was desired between shots.

Once in the exercise area, considerable time was spent determining wind and drift conditions. After getting five sonobuoys operating (several dudded) it was decided to commence shooting as we were running out of flying time. This loss of time forced a shortened shooting schedule of only five SUS. The first of the 500 lb. bombs was just dropped when number one engine quit. This caused some consternation in the cockpit and as a result, less than three minutes later both the remaining 500 lb. shots were dropped simultaneously. What was not known by science at the time was that as soon as these charges were dropped, all on-board systems were shut down as the aircraft was headed for shore. As a result only a short recording is available.

Preliminary looks at the data show no strong returns beyond multiple bottoms. Reverberation continues for over two minutes however.

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TECHNICAL PROGRESS REPORT. ADVANCED MARINE TECHNOLOGY. 1 August 1972 - 31 January 1973.
Dr. A. E. Maxwell I, Principal Investigator. 51 pages and 15 figures. June 1, 1973. N00014-71-C-0284; NR 293-008.

This is a progress report for the period 1 August 1972 - 31 August 1973 on the following projects in Advanced Marine Technology: (a) Submerged Navigation and Submersible Instrumentation (b) Handling and Transfer at Sea, (c) Bottom Reconnaissance and Detailed Site Survey by Research Submersibles, (d) Near Bottom Magnetics Studies Using a Deep Submersible, (e) Near Bottom Gravity Studies from a Deep Submersible, (f) A Self Contained Deep Sea Rock Drill, (g) Self Contained Ancillary Modular Platform (SCAMP), (h) Modular Acoustic System, (i) Air-Sea System (Long Range Echo Ranging).

1. Advanced Marine Technology
 2. ALVIN
 3. Navigation of submersible
 4. Transponders
 5. Boat Handling Buoys
 6. Small Craft
 7. Geographical Sampling
 8. Magnetometer (deep)
 9. Gravimeter (deep)
 10. Rock Drill
 11. SCAMP
 12. Sonar (Deep Submersible)
 13. Echo Ranging
- I. Maxwell, A. E., a Principal Investigator
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1.	Advanced Marine Technology
2.	ALVIN
3.	Navigation of submersible
4.	Transponders
5.	Boat Handling Buoys
6.	Small Craft
7.	Geographical Sampling
8.	Magnetometer (deep)
9.	Gravimeter (deep)
10.	Rock Drill
11.	SCAMP
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1. Advanced Marine Technology
2. ALVIN
3. Revigition of submersible
4. Transponders
5. Boat Handling Buoys
6. Small Craft
7. Geographical Sampling
8. Magnetometer (deep)
9. Gravimeter (deep)
10. Rock Drill
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13. ABSTRACT

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