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Woods Hole Oceanographic Institution

TECHNICAL PROGRESS REPORT
ADVANCED MARINE TECHNOLOGY

1 February 1972 - 31 July 1972

February 28, 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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1 February 1972 - 31 July 1972

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Approved for Distribution

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Report Summary

The two extremes of the program in this six month period were the Submerged Navigation System which was demonstrated to be a successful field system, and the Near Bottom Continuous Gravity System, which was priced out of the market by the acceleration characteristics of ALVIN.

In all the other subjects discussed in summary immediately below and in more detail further on, satisfactory progress was made.

Again aircraft scheduling has held up further work on the Air Sea Systems project, but there is definite hope for some aircraft time in the fall.

The Development of Equipment for Deep Sea Biological Research has been terminated as of the beginning of this report.

(a) Submerged Navigation and Submersible Instrumentation

The use of a deep submersible usually requires precise navigation - either to record where it has been during exploration - or to direct it to certain locations. By doing the navigation aboard a surface ship the pilots and observers are freed to do other tasks. A system to do this is now in being, and has been tested at sea in water depth of 250 meters. This is a severe testing ground as multiple reflections can be a serious problem usually not encountered in deeper waters. The tests show navigation control within a few meters, which is satisfactory for all intended work.

(b) Handling and Transfer at Sea

Handling and transferring large objects or people at sea has been a situation best avoided except in the calmest weather. The use of shock absorbing structures (landing gear from aircraft) and wheels has made some progress in the problem. Although little field work was done this period, arrangements were made to do some testing with Phibron Ten of NOB, Norfolk, Virginia, which should give the system a real test under working conditions.

(c) Bottom Reconnaissance and Detailed Site Survey

Hydraulic Impact Hammer

Precise navigation for (a) photography that is available, and the rock drill (f) increase the worth of bottom geologic studies. However many areas are not adapted to drilling so some other way is required to obtain rock samples. An impact hammer has been constructed and tested but has not met the desired capabilities, however it shows promise with some modifications.

(d) Near Bottom Magnetic Studies Using a Deep Submersible

Unlike the continuous gravity measurements, continuous magnetic measurements from a deep submersible now seem to be in hand. The deficiencies reported in the two previous reports have been corrected and a working system is now available to ALVIN. The submersible schedule prevented any appreciable field testing, but at this time there are no reasons to expect poor results.

(e) Near Bottom Gravity Studies from a Deep Submersible

Continuous gravity profiles near the bottom of the sea in the ridges, trenches, sea mounts, would add considerably to our knowledge of the ocean floor structure. Tests have shown that the accelerations of ALVIN require a sophisticated mechanical system to compensate for these accelerations, and the costs are considerably out of the budget range. This project has been shelved until such funding may become available.

(f) A Self Contained Deep Sea Rock Drill

A drill that can take a two meter length core with a two cm diameter has been constructed, tested and debugged after field testing. It is now almost ready for use. This will prove to be a useful piece of equipment for the submersibles and could be used from a surface ship, although there, successful implantation is more of a problem.

(g) Self Contained Ancillary Modular Platform (SCAMP)

In some applications the payload of ALVIN is not sufficient for the desired task. In others, some operations could be performed by unattended equipment once the equipment has been properly placed by the submersible. SCAMP is an equipment designed to relieve both of these problems. It will supply extra buoyancy and energy in a detachable package and also the ability to clamp to the bottom by means of suction pads. Design and construction is proceeding basically as proposed.

Submerged Navigation
and
Submersible Instrumentation

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Submerged Navigation and Submersible Instrumentation

Introduction:

This is the third report of an on-going program to develop a submersible navigation system and to test it at sea. The system being developed has the unusual feature of requiring a very minimum of equipment in the submersible. The major equipments and the operator remain on the support ship. The system uses a digitizing acoustic receiver interfaced into a digital calculating system which permits automatic real-time printout of both the submersible and the surface ship positions. During the reporting period an Z-Y plotter was added to the surface equipment which significantly improves the utility of the real time system. Sea trials demonstrated that the navigation operator aboard a surface ship could successfully direct the return of the submersible to a fixed point on the sea floor. At sea system repeatability measurements were made and are discussed in this report. Work on an independent elevator system was initiated and is still in progress.

A major activity was to design and partially construct a prototype multi-purpose navigation black-box which will become the heart of the ALVIN installed system. This unit will replace the breadboard equipment used in 1971. Sea trials of this equipment are scheduled for late summer of 1972 and will be reported in the next progress report.

A three month transponder mooring was set in Hudson Canyon. This unit is scheduled for recovery in September 1972. The only equipment casualty was the loss of an acoustic transducer which vibrated loose from its mounting plate on LULU. The transducer mounting is being redesigned.

The acoustic frequencies were revised to better match the capabilities of the AMF equipments.

This report is organized into three sections:

- I. Detailed Description of the Basic System
- II. At Sea Operations and Results
- III. Equations for Two Reference Relative Navigation of A Ship and A Submersible

I. Detailed Description of the Basic System

The discussion that follows describes, in a more complete fashion than previously reported, the system. The method used assumes that two short reference transponder moorings have been planted on the sea floor and that their depths and relative positions have been determined during a pre-dive survey. The system operates on a repeating two step series of cycles. The signal paths used are shown schematically in Figure 1. The output of the system is the position of both the ship and the submersible printed out in real time aboard the surface ship. A block diagram of the surface ship

equipment is given in Figure 2. Both the ship and the submersible contain precision clocks which are synchronized before each dive. The clocks are of sufficient accuracy that their times will not differ by more than 0.1 ms after a 10 hour period following synchronization.

Step I is initiated at time zero when the surface clock commands the ship to transmit 8.1 kHz to interrogate the two bottom moored reference transponders. Also at time zero, all four time interval counters in a four channel digital receiver are started. The transponders reply at individual frequencies (typically 13.0 and 14.0 kHz). The receipt of a transponder reply at the ship stops the appropriate time interval counter in the four channel digital receiver.

The individual channel time interval measurements are automatically entered into the calculator system at the initiation of Step II. The calculator is programmed to calculate the slant ranges between the ship and the respective reference transponders using a stored value for sound speed in water. These ranges are shown schematically as R_A and R_B in Figure 1, Step I. The calculator system also calculates the "X" and "Y" coordinates of the ship relative to the two reference transponders and prints the results on the printer.

Step II is typically initiated 15 seconds after time zero, simultaneously by the synchronized precision clocks aboard the submersible and the surface ship. The surface clock commands all four time interval counters in the digital receiver to start. The submersible clock commands the transmission of an 8.1 kHz transponder interrogation. At time 15 seconds plus a very short fixed time delay the submersible clock commands the transmission of a 13.5 kHz pulse which will stop an appropriate time interval counter of the shipboard digital receiver. The reference transponders reply at their respective frequencies. When these replies are received at the shipboard digital receiver, appropriate time interval counters are stopped. Referring to Figure 1, Step II, the one way travel times for paths R_1 plus R_A' , R_2 plus R_B' and R_3 are thus measured. These measured time intervals are automatically entered into the calculator system at the initiation of the next Step I command from the surface clock, typically at time 30 seconds. The calculator is programmed to calculate R_1 plus R_A' , R_2 plus R_B' and R_3 . For the real time use of the system it is assumed that between time zero and time 15 seconds, that the slant ranges between the ship and the reference transponders is the same. This assumption permits R_1 to be obtained by subtracting R_A from R_1 plus R_A' . R_2 is similarly obtained. With R_1 , R_2 and R_3 , the calculator system calculates the "X" and "Y" position of the submersible relative to the reference transponders plus the depth of the submersible and prints out the results.

The equations for the calculations and comments on the position redundancies when only two reference transponders are used are discussed in a later section of this report.

For after-the-fact data reduction the Step I R_A and R_B slant ranges obtained at the time zero and time 30 second cycles are averaged to obtain better values of R_A' and R_B' to be used to subtract from the ranges measured during the time 15 second, Step II cycle.

The calculator system also corrects for different system fixed time delays during Step I and Step II.

If the depth of the submersible is known and independently entered into the calculator system, the R3 range is not needed to calculate the position of the submersible. In this case the equations required to calculate the submersible positions are simplified significantly. These equations are given in a later section of this report.

II At Sea Operations and Results

LULU and ALVIN conducted navigation exercises in the Gulf of Maine during the reporting period. ALVIN Dive #424 on 14 July 1972 was the last and most successful. It is reported in detail.

Dive 424 was conducted in Wilkinson Basin where the water depth was 250 meters (820 feet). Earlier in the cruise difficulties had been experienced in shallower water where it was found that only relatively short ranges between LULU and the reference transponders could be obtained, beyond which the shallow water transmission paths caused erratic delayed triggering of the acoustic receiver.

This earlier experience indicated that it was highly desirable to at least partially determine the acoustic limitations in a new area, especially in shallow water, before setting a navigation baseline. To make a step in this direction the operations plan for the deployment of the reference transponders was modified. This new plan has become our standard procedure for shallow water work and is described next.

A single transponder is set from LULU and acoustically tracked to the bottom. Instead of immediately setting the second transponder, LULU steams slowly away from the first transponder and keeps going until the acoustic returns from the first unit become erratic. The distance which causes a loss of 30% of good replies is used as the maximum useable range that can be expected for the conditions that prevail.

When this procedure was followed to prepare for Dive 424, it was found that when LULU was 1500 meters from the first transponder that the first late reply was received. The first bad reply arrived 120 milliseconds late, i.e. the direct path reply was too weak to trigger the acoustic receiver and that a later shallow water bounce path was sufficiently strong to trigger the receiver. At 1680 meters a 130 ms late reply was received. At 1770 meters a 25 ms late reply was received. Beyond 1850 meters fewer than 50% of the replies were good. No useable pattern was found in the delays of the late replies indicating a complex system of bounce paths typically found in shallow water.

Having some idea of the local acoustic limitations, a baseline and the second reference transponder was launched from LULU.

Figure 1. Signal Paths

Figure 2. Surface Navigation Equipment.

Because the bottom was flat the ships fathometer records at the time the transponders were launched was used to determine the depth of the transponders. A single baseline crossing was made and indicated a baseline of 1049 meters. The rotation of the baseline was determined by radar ranges and bearings to a local radar buoy during the launching of the transponders and was checked during the baseline crossing.

The objective of Dive #424 was to conduct repeatability and resolution exercises plus to try to determine if it was practical for the surface navigation operator to direct the operation of ALVIN via the underwater telephone.

ALVIN carried three six inch steel triplanes attached to three foot stakes. These triplanes are excellent targets for ALVIN's CTFM sonar. The dive plan called for ALVIN to set the first stake into the bottom, after which she was to drive away and then be guided back to the reference stake following instructions from the surface. When the surface party felt that ALVIN had returned to near the first stake, the second was to be set. The third stake was to be set in a similar fashion. With the three stakes set, ALVIN was to move away until all three stakes could be seen on the vehicle's CTFM Sonar, at which time a photograph of the sonar display was to be taken. An after-the-fact data reduction was planned to compare the relative positions of the three stakes as determined using the ALVIN sonar photograph and the navigation data recorded on LULU. Periodically during the dive ALVIN was to be instructed to sit on bottom to permit collecting data on a stationary vehicle, to evaluate the repeatability of successive individual fixes.

With relatively minor exceptions Dive #424 was conducted as planned. During the dive ALVIN's exercises centered 1100 meters from one transponder and 900 meters from the second. Difficulties were experienced keeping LULU in a favorable position relative to ALVIN and the baseline transponders. This resulted in sometimes operating with erratic transponder returns being received. It was found that even under these poor conditions that it was practical for LULU to remotely guide ALVIN back to a selected point on the bottom.

The raw data obtained during the dive was extensively reworked, largely by hand, which turned out to be very time consuming. It was obvious during this work that if much after-the-fact data reduction is to be done it will have to be automated. Each slant range reading was examined using the graphic recorder records and all bad, late or questionable returns were eliminated. It was found that it was normal for no returns or bad returns to be received during UQC conversations. If the returns from a transponder had a gap of one data point, an interpolated value was used. The time zero and time 30 second LULU reading were averaged and combined with the time 15 second ALVIN readings to calculate the time 15 second LULU and ALVIN positions. ALVIN's depth was assumed constant at 247 meters. The LULU and ALVIN slant ranges were manually entered into the programmed 9100A calculator system which calculated and printed the results.

During the dive ALVIN sat stationary ten times. These stations were labeled A through J and were of varying times. A position fix was obtained every 30 seconds. During each station LULU continued to move. A summary of the 113 fixes obtained during these stations are listed in Table I. The mean

and standard deviations for each station are also given. In all cases the N-S and E-W standard deviations were less than two meters which is better than was expected.

Figure 3 is a partial track plot of ALVIN during Dive #424. The scale is highly magnified to 25 meters per inch (approximately 74 inches per nautical mile). An inspection of the track plotted reveals the high maneuverability of ALVIN. The three triplanes were set at Stations A, D and H. A photograph of the ALVIN CTFM sonar display was taken at Station I. The photograph was measured to determine the relative positions of the three conspicuous sonar targets, Figure 4 permits a comparison of the navigation system data with the photograph of the sonar data. It can be seen that the major discrepancy is a seven meter difference between the center of the triplane cluster and distance to ALVIN when the photograph was taken. The relative positions of the three triplanes in the cluster is remarkably similar. Triplanes 2 and 3 were set after ALVIN had been guided back to the vicinity of the first triplane by instructions from the surface and are indeed near enough to the first to permit refinding an object on the sea floor.

III. Equations for Two Reference Relative Navigation of A Ship and A Submersible

The following discussion develops the equations for the calculation of the position of a submersible using two reference transponders and a surface ship.

The coordinate system is shown in Figure 5. One of the two transponders, normally the more westerly or more southerly, is chosen as the origin. The "X" axis is horizontal and parallel to the sea surface. The "Z" axis is vertical, i.e. perpendicular to the sea surface. In the plan view, the "X" axis is drawn through the second transponder. The calculations assume that A, B, C, D and E, as defined in Figure 5, are known and that R1, Ra and R3, also defined in Figure 5, have been measured. The three submersible position unknowns, X, Y, and Z are found by solution of the following three independent simultaneous equations:

$$\begin{aligned} (R1)^2 &= (X)^2 + (Y)^2 + (Z)^2 & (1) \\ (R2)^2 &= (A-X)^2 + (Y)^2 + (Z-E)^2 & (2) \\ (R3)^2 &= (B-X)^2 + (C-Y)^2 + (D-Z)^2 & (3) \end{aligned}$$

Subtracting (1) from (2) and simplifying yields an equation for X as a function of Z:

$$X = FZ + I, \quad (4)$$

$$\text{where } F = \frac{-E}{A},$$

$$\text{and } I = \frac{A^2 + E^2 + (R1)^2 - (R2)^2}{2A}$$

Similarly, subtracting (1) from (3) and simplifying yields an equation for Y as a function of Z:

$$Y = GZ + H' \quad (5)$$

$$\text{where } G = \frac{-BF - D}{C}$$

DIVE #424, 14 July 1972

Station	No. of Positions Determined	Mean	Positions	Standard	Deviation
		E-W Meters	N-S Meters	E-W Meters	N-S Meters
A	30	326.1	1075.6	1.0	1.1
B	9	369.4	1099.4	1.1	0.5
C	7	339.7	1020.6	0.5	1.0
D	8	324.3	1079.5	1.5	0.8
E	5	319.2	1076.6	0.8	0.5
F	7	314.0	1078.3	1.3	0.5
G	9	324.8	1064.6	1.6	0.5
H	24	320.4	1082.4	1.2	1.6
I	9	304.7	1103.6	1.9	0.9
J	5	318.0	1090.4	1.0	1.8

NOTES:

- a) Triplane #1 planted at Station No. A.
- b) Triplane #2 planted at Station No. D.
- c) Triplane #3 planted at Station No. H.
- d) Photo of CTFM Sonar taken at Station No. I.

TABLE I

$$\text{and } H = \frac{B^2 + C^2 + D^2 - (R_3)^2 + (R_1)^2 - 2BI}{2C}$$

If the depth, and thus Z, of the submersible were known by independent means, the solution for the values of X and Y can be obtained using (4) and (5).

If Z is not known by independent means, it may be calculated. Combining (1), (4), and (5) yields:

$$PZ^2 + S Z + T = 0, \quad (6)$$

$$\text{where } P = F^2 + G^2 + 1,$$

$$\text{and } S = 2 (FI + GH),$$

$$\text{and } T = I^2 + H^2 - (R_1)^2.$$

This quadratic equation has two solutions:

$$Z_{1,2} = \frac{-S \pm \sqrt{S^2 - 4PT}}{2P} \quad (7)$$

To complete the solution of the two beacon submersible problem it is necessary to select the proper Z and disregard the improper one. Figure 6 is useful to visualize the two solutions to (7). The problem being solved is one of the intersection of three spheres with R₁, R₂, and R₃ each as a radius from known points. To simplify the presentation of Figure 6, the two transponders are shown at the same depth. If these depths were not the same, the coordinate system tilts accordingly. R₁ and R₂ as radii of two spheres, intersect in a circle as shown in the side projection of Figure 6. R₃ as a radius of a third sphere, intersects the R₁-R₂ circle at two points for the specific case shown. For the case shown in Figure 6 one of the solutions for the Z of the submersible places the submersible above the surface of the ocean. It is interesting to note that this always happens with a ship installed short baseline, (Range, Range, Range) 3D system where the computer is merely instructed to ignore the in-air solution. A "Z" redundancy also occurs with a three transponder system if an independent measurement of depth is not available.

The selection of the proper Z from the two calculated from (7) takes advantage of the fact that the navigation system operator is not without some independent knowledge of the approximate depth of the submersible. The submersible always reports to the support ship major changes in depth as a standard procedure.

In the practical navigation system, the operator enters into the calculator system an approximation of the depth of the submersible. The calculator solves the following equation to obtain Z est.:

$$Z \text{ est.} = D - D \text{ est.}, \quad (8)$$

where D = D_{T1}, as defined in Figure 3.

The calculator is programmed to select as proper, the Z found from equation (7) that is nearest to Z est. Having selected the proper calculated Z, X and Y are found directly using (4) and (5) respectively.

Because it is inconvenient for the operator to be presented with the Z of the submersible as an output, this is transformed into depth using

$$D \text{ submersible} = D - Z \quad (9)$$

The X and Y of the submersible do not need to be transformed into a surface projection since the X-Y coordinate system used is parallel to the conventional surface referenced coordinate system.

For convenience in plotting and printing, once the submersible X and Y positions are determined in the transponder baseline coordinate system, it is standard practice to transform these to a north-south coordinate system by rotating the position fix to compensate for the azimuth of the baseline relative to true north.

The equations for the solution of a ship's position, when two reference transponders are used, is included below and provides a starting point for a discussion of the "Y" redundancy problem.

The calculation of position of the surface ship uses the same coordinate system that was used to find the submersible position. It is repeated in Figure 7 which also illustrates and defines R_a and R_b . The calculations assume that A, D, and E are known and that R_a and R_b have been measured. The two ship position unknowns, X and Y are found by solution of the following two independent simultaneous equations:

$$(R_a)^2 = (D)^2 + (X)^2 + (Y)^2 \quad (10)$$

$$(R_b)^2 = (D-E)^2 + (A-X)^2 + (Y)^2 \quad (11)$$

Subtracting (10) from (11), and simplifying leads directly into a solution for X =

$$X = \frac{(R_b)^2 - (R_a)^2 + 2DE - E^2 - A^2}{2A} \quad (12)$$

With the value for X determined and (10), Y is found to be:

$$Y = \pm \sqrt{(R_a)^2 - (D)^2 - (X)^2} \quad (13)$$

Referring to Figure 7, the Y redundancy is shown in dotted lines. The use of the two beacon net to determine the relative position of ship requires that the operator must know if he is above or below the baseline of the two transponders. When the ship is on or near the baseline the horizontal projections of R_a and R_b intersect at very large angles which is detrimental to maintaining the highest possible system accuracy. Operationally the ship should not spend much time along the baseline or its extensions.

It should also be noted that operationally, the submersible should not normally operate near the baseline or its extensions because of the loss of

accuracy due to poor geometry and the increased difficulty of selecting the appropriate Z to solve the submersible position equations.

Returning to the "problem" of the Y redundancy of the ship's position, Figure 8 is useful to illustrate what a baseline crossing looks like on an X-Y plot. Assume that a ship steaming North, starts at A and proceeds to B, in the process, crossing a baseline. If a navigation plotter were told always to select a negative Y, he would plot A-O-C which would cause any semi-alert operator to recognize that something was wrong when at point O the ship track plotted suddenly indicates progress on a southeasterly heading when the ship is still steaming north. Our at-sea experience has indicated that provided the ship does not spend extended lengths of time near the baseline or its extensions that it is not at all difficult for the operator of the navigation system to input into the calculator system whether the ship is above or below the baseline thereby instructing the calculator to select either the positive or negative value for the Y of the ship. The information is presently being input as a program change which causes an interruption in the plot. At some future time a sense switch will be added to the clock/controller to input this information without stopping the system.

As mentioned in the previous section, it is standard practice to rotate the transponder baseline coordinates into N-S coordinates for plotting and printing. During this rotation the change of one sign in the program shifts the N-S position to above or below the transponder baseline. As mentioned earlier, if the depth of a submersible is known, simplified equations can be used to calculate the submersible position when the ranges to two transponders is available. The equations presented below were programmed in a previous reported period and were reused during this period. The coordinate system used for the simplified submersible position problem is identical to that previously described. The equations assume that A, D, D_a, and E, as illustrated in Figure 9, are known and that R1 and R2 have been measured. X is found to be:

$$X = \frac{(R2)^2 - (R1)^2 - A^2}{2A} \quad (14)$$

and Y is found to be:

$$Y = \pm \sqrt{(R1)^2 - (X)^2 - (D-D_a)^2} \quad (15)$$

The submersible Y redundancy is shown in dotted lines in Figure 9 and is treated the same as the Y redundancy for the ship position.

Figure 3. ALVIN Track Dive No. 424.

Figure 4. Results of ALVIN Dive No. 424 Triplane Experiment.

Figure 5. Geometry for the Calculation of a Submersible Position.

Figure 6. Intersection of Three Spheres Ambiguity.

Figure 7. Geometry for the Calculation of a Ship Position.

Figure 8. Plot of Ship Baseline Crossing Uncorrected for Above or Below Baseline Program Input.

Figure 9. Geometry for the Calculation of a Submersible Position using Two Ranges and Depth.

Handling and Transfer at Sea

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Handling and Transfer at Sea

1. Objective

To investigate concepts and techniques to improve rough weather capability in handling boats, submersibles and large instruments.

2. General Methodology

The principle concept being pursued is to compare the problem of a small boat approaching the side of a ship with the problem of an airplane approaching the deck of an aircraft carrier. In essence can a judicious injection of resiliency and rolling contact be useful to the problem of handling heavy equipment at sea?

The work has proceeded along three lines:

(a) Conceptual and Theoretical

Primary emphasis is on logical use of resiliency in the approach problem to reduce impact forces from being unacceptable to tolerable. Also, to replace sliding friction of conventional fenders to rolling friction of resilient wheels. Maximum use will be made of existing aircraft landing gear techniques and equipment because they were designed for severe impact forces and their use is generally understood.

From the theoretical side, it is assumed that the assumption of linear deceleration is satisfactory for this level of investigation and funding. Computations indicate that a total resiliency of six to 18 inches is appropriate for initial investigations. For 6" motion resilient materials may be satisfactory while after 18" it would require mechanical energy absorbers. Rolling contact, preferably combined with a free swiveling action, is sought, where practical.

(b) Technique

In the first phase, to utilize surplus aircraft or automotive components for low cost, good design and recognized operational reliability, most testing was done in local waters using a three ton small boat furnished by the Coast Guard, operating alongside docks or local ships (Figure 1). Waves obtained locally are small but are frequently very choppy with high accelerations.

A second approach to the resilient method was the concept and alteration of a large 10' diameter tire into a mannable buoy-fender, also shown in Figure 1.

Description of Work During This Period

Little work was done at sea with the boat equipped with the aircraft landing gear. This was because earlier work with that boat had blocked out

the problem and a more seaworthy boat was needed to conduct tests in more exposed and rougher conditions. Much of the effort in this quarter was unsuccessfully devoted to finding a ship or boat operating group with logical craft that wanted to conduct such tests.

Two types of objectives were considered for handling; first a longitudinal boat-like object and second, a round buoy-like object. As work progressed a further division into two operational modes of usage evolved, namely those problems associated with being hoisted aboard and those problems associated with being able to remain safely and easily alongside the ship. This latter problem and its potential solution and application has been an interesting outgrowth of the study. Of the two concepts, it is believed to be the most fundamental and utilitarian because it may be applicable to ships and equipment of any size.

Local testing and demonstration has continued with both the wheel equipped boat and the large resilient manned fender (Figure 1). These demonstrations were useful in increasing the number of professional people with first hand experience in the possible advantages and applications for improved resiliency in the contact and transfer problem.

Several meetings were attended at which these methods were discussed. Several oceanographers, Dr. C. Cox of Scripps Institution of Oceanography particularly, was very hopeful that work would be successful enough so that he could count on "satellite boats" being available for measurement of large scale thermal and wave problems.

An additional large mannable buoy fender was assembled. However, no other major equipment was altered or built. The major effort in this period was devoted to trying to find an operator with a logical ship and small boat combination who regularly used his small boat and wanted to try to improve the system. An additional and severe criteria was that the funding had to be within the capability of this contract task. Unfortunately no such combination was found although several new contacts within the Navy, the Coast Guard, and the laboratories were made. Formal contacts with pilot boat groups were not made and they may be the most appropriate group if none are found in the military or R&D community.

The difficulty in finding a cooperative partner was a sobering factor and illustrates the magnitude of the overall problem and the degree of pessimism within the marine profession when it comes to small boat handling. Reasons given are:

1. don't normally use boats;
2. people aren't asking to use boats;
3. under emergency conditions we would get them in the water;
4. small boats aren't very seaworthy or at least who would want to be in them?

FOOTNOTE: In early January 1973, a cooperative series of tests was being arranged with PHIBRON TEN out of NOB, Norfolk, Virginia.

This reception was not particularly discouraging because it was expected. It did result in slow progress for this work period. It was decided to find an operational and cooperative partner to best insure that a significant high seas operational test could be obtained with the funding in hand.

Conclusions

The conclusions from this period are essentially a reaffirmation or slight altering of previous conclusions:

1. The technical and operational analogy between the approach problem of aircraft to the landing field and of boats to a ship appears increasingly valid.
2. Wheeled and resilient fendering may permit both boats and small ships to lie alongside larger ships under much rougher and open sea conditions than has been possible to date.
3. The use of a large resilient mannable fender as a transfer platform from a ship to a boat should be of considerable aid in transfer, utilizing unaltered small boats.
4. Larger scale, more open sea testing is required to convincingly demonstrate the above.

Figure 1. Mannable buoy used as a fender and transfer platform between ship and small boat.

Bottom Reconnaissance and A Detailed Site Survey
by Research Submersible

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Bottom Reconnaissance and Detailed Site Survey
by Research Submersible

Hydraulic Impact Hammer

Background

The vast majority of the geologic missions small submersibles conduct involve the use of mechanical arms to obtain representative samples of hardrock outcrops in regions having rough relief. To date a variety of sampling techniques have been used by the submersible ALVIN with limited success. A small spring-loaded electric diamond-bit drill which is held by the mechanical arm has been used on several occasions to drill into granite outcrops. The major problem with this unit is not the drill itself but stabilization of the submersible. If the seafloor is reasonably flat the submersible can land and pump heavy using the variable ballast system (a lengthy process which must be reversed after the sample has been taken). If the outcrop is vertical the submersible must power into the wall during the sampling period. This leads to an unstable condition and frequent jamming of the bit within the hole. Even if the drill operates successfully, the sample obtained is too small for numerous petrologic and radiometric determinations.

A large self-contained rock drill has been developed under A.R.P.A. sponsorship and tested from ALVIN. This system obtains a sample over six feet in length. The major difficulties with this system are threefold; the drill is large and heavy and consumes most of the submersible's available payload; only one sample can be taken per dive; and the mechanical arm must be taken off limiting the usefulness of the vehicle during the dive when the drill is operating on the bottom independent of the submersible. The drill can only be used on flat horizontal surfaces which also limits its usefulness.

To date the most successful sampling technique from ALVIN is the use of pry bars held by the mechanical arm and inserted into rock fractures to pry samples loose. Unfortunately many outcrops are not fractured and those that are frequently are highly weathered.

Based upon this experience it was concluded that the optimal system should be light, work continuously throughout the dive, be able to use when the submersible is neutral and hovering in mid-water on a vertical outcrop, and easily break off crystalline rock samples such as granite and basalt.

Summary

A prototype hydraulic impact hammer was designed, built, and tested during the first half of the contract year. The system consists of five subsystems. Power to run the unit comes from two 6-volt lead-acid batteries which are immersed in an oil-filled fiberglass box with hydrogen gas bleed-off valves. The batteries are charged before each dive and permits near continuous use of the hammer during the course of an eight hour dive. The electric power pack runs a light weight hydraulic aircraft pump which also is mounted in an oil compensated fiberglass box. The pump drives two separate subsystems; a series of four hydraulic pistons which are used to position the impact hammer and a cocking piston which spring loads the

hammer itself. The impact hammer consists of a light weight aircraft piston which moves down and engages a latch assembly, at which time the piston motion is reversed, and the piston moves back compressing a 1000 lb. spring. This motion continues until the latch assembly is mechanically tripped, driving the hammer shaft into a chisel which is wedged against the outcrop. This cycle is repeated every 15 sec. until the rock fails. All four of these subsystems are mounted on a droppable tray assembly which is mounted on the submersible in front of the forward porthole. Electrical leads pass through an oil compensated quick-disconnect to a control box within the pressure hull which permits the pilot to operate the positioning pistons and impact piston.

A variety of problems were encountered during the first field testing period of the hammer in July, 1972. After minor adjustments the hammer operated with a high reliability. When used on the deck of the surface support ship, the hammer was able to break test samples of granite after five to six blows. Underwater, however, the hammer was unable to break off outcrop samples after as many as 20 blows. Subsequent testing of the hammer in the laboratory on lead test samples indicate that the hammer undergoes a 10% energy loss in water but more important, the theoretical impact capability of the system differs significantly with that measured experimentally. At present the hammer is undergoing an extensive testing program which involves a variety of modifications to optimize its impacting ability. Following this test program, the hammer will be used in the summer of 1973 on a series of outcrops in dives in the Gulf of Maine.

Near Bottom Magnetic Studies
Using A Deep Submersible

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Near Bottom Magnetism Studies

Problem

Design and procurement of a new onboard magnetometer electronics console, tow cable/hull "quick" disconnect system were the primary technical objectives during this report period. From field tests near Nassau (Tongue of the Ocean) during the previous period (W.H.O.I. Technical Report 72-90) it was found that although the prototype airborne magnetometer console tow cable/fish arrangement showed noise levels to be sufficiently low for scientific observations, routine operation with this system was impractical because of power/weight consideration for the onboard console, inadequate buoyancy and ascent rate of the tow cable/fish and unreliability of the guillotine tow cable disconnect system.

Methods

- A. External installations: To improve the buoyancy of the tow cable the electrical cable was threaded through a larger diameter braided hollow polyurethane line rather than the $\frac{1}{2}$ " line previously used. A 1" diameter line was chosen. The ascent rate of the tow fish was increased by reconfiguring the syntactic foam into a more streamlined shape to reduce hydrodynamic drag on rising. (See Figure A).

The electrical disconnect problem was approached by design and fabrication of a new type hydrostatic-spring loaded cable coupler (See Figure B). By simply adjusting the spring tension a wide range of pull-apart tension thresholds are available. A hydrostatic O-ring arrangement is used to seal off the electrical part of the connector from seawater. A complete detailed description of this unit is on file with the Department of Ocean Engineering.

- B. Internal installations: A new Varian 75/85 magnetometer console was modified for use with non-chassis ground electrical circuitry. This unit has the advantage over the previous prototype airborne magnetometer by being much smaller, lighter, and less power-consuming. In addition, of course, it operates directly from the ALVIN's 28 volt DC power supply rather than the bulky, inefficient supply system required for the airborne unit.

Results

While a complete field test of the above described system could not be made during this reporting period, installation of the unit on ALVIN was made during July 1972. It was found that the grounding circuitry of the new Varian 75/85 was compatible with the submarine power circuitry and that the ascent rate of the new tow fish/cable was much improved. The cable/hull disconnect system was also found to work satisfactorily. A pull apart tension of 75 lbs. was used in these tests. Full field tests are to be carried out during the next reporting period.

Summary

A completely new onboard electronic signal processing console (Varian model 75/85) has been procured and modified to provide a small, light weight, power efficient system which can operate directly from ALVIN's 28 V DC power supply. A more buoyant tow cable and hydrodynamically streamlined fish have been developed to provide a tow cable/fish system with a fast ascent rate and good operational characteristics. To improve the tow cable/hull safety disconnect system a new hydrostatic-spring loaded "quick" cable connector has been designed and fabricated.

Figure C. Modified Varian Model V75/85 Magnetometer Console.

Near Bottom Gravity Studies
from a Deep Submersible

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Near Bottom Continuous Gravity Profiles from a Deep Submersible

During this period, consultations with several inertial guidance and navigation groups at the M.I.T. Charles Stark Draper Laboratories in Cambridge, Massachusetts have shown that the development of an accurate stable platform and inertial navigation system for gravity measurements in the submersible ALVIN would cost about \$535,000. In the previous progress report we described the reasons for abandoning attempts to utilize a damped gimbal suspension for gravity measurements in a small submersible and described our initial exploration of the feasibility of using miniaturized gyrostabilized platforms for gravity measurements in ALVIN.

Our investigation has included study of three alternate approaches for providing a stabilized platform. One is to develop a two-degree of freedom platform, the second approach is to develop a two-degree of freedom slave platform stabilized by a three-degree of freedom inertial navigation system that provides sufficiently accurate reference signals, and the third approach has been to develop an inertial navigation system that can stabilize directly an oven containing the VSA gravity sensor.

The first approach would be the least expensive, but would only provide vertical stabilization of the gravity meter. Larger platforms of this type already in use for gravity measurements aboard surface ships and experiments aboard aircraft cost approximately \$50K. Estimates of the costs for designing a much smaller platform with improved specifications on verticality were in the range of \$75K to \$125K. These estimates were received principally from Aeroflex. During maneuvers of the vehicle, the accuracy of the vertical stabilization of this type of platform would be degraded. In a small submersible frequent maneuvers would be probable.

The second approach would require the greatest amount of space and power. There appear to be only four inertial navigation systems in existence (being built for Deep Submergence Recovery Vehicle, DSRV) that could perhaps meet the accuracy requirements and fit in ALVIN. It is highly unlikely that one of these systems could be used in the gravity program, and even if available, the resulting system would be cumbersome and not as cost effective in the long term as would either of the other two approaches. Assuming the availability of obtaining GFE, one of the miniature DSRV inertial navigation systems, Draper Laboratory estimated that about \$80K would be required 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 a common binnacle and digital computer. The portability and performance of such a gravity/navigation/data acquisition system would provide a greatly increased capability 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 determined an estimated cost of \$535K to design and construct such a system.

During these discussions Draper Laboratory also investigated the status of 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 to respond to needs for special gravity measurements or the availability of surface ships, large submarines, or aircraft from which gravity measurements might be desirable. Assuming that three Mark IV SINS systems might be provided GFE, the costs for modification of the system and reprogramming the computer were estimated by Draper Laboratories to be \$165K for two systems. The third would be a source of spares and replacement parts for implementing the two other systems. To replace the original computers with improved modern computers, about \$20K additional would be needed.

For all the systems, above the costs of field testing and support by the Contractor and W.H.O.I. supervisory efforts would require additional funding.

Our experiments with a gimbal mounted gravity sensor (November 1971 ALVIN dive) showed that the motion of ALVIN is too great to allow routine accurate gravity measurements with a gimbal suspension. Our discussions with personnel of the M.I.T. Charles Stark Draper Laboratory indicated that an accurate miniature portable gravity/navigation system would have a very high cost. Therefore, it was decided during this reporting period that since the future of the submersible gravity program looked uncertain, any further development of equipment would be unwise. The funded portion of this year's gravity program which was designated for development of a data acquisition system which was to be used in common with several other disciplines in the submarine effort has been assigned to others who have continuing need for such a system. No new gravity instrumentation was developed during this reporting period, and none is anticipated by this program in the next.

A Self Contained Deep Sea Rock Drill

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A Self Contained Deep Sea Rock Drill

Introduction and Background

The first annual report, covering progress through February 1972, described the initial version of the rock drill and briefly discussed modifications and testing required in the second year. During the first half of this year, most of the significant modifications were completed, and an extensive testing sequence was initiated. The second half of this year will involve additional minor changes to the drill and the completion of the testing series.

Systems Design

The rock drill system (Figure 1) is divided into seven subsystems: (1) drive system, (2) power source, (3) drilling system (Figure 2), (4) frame, (5) ALVIN attachment, (6) control, and (7) monitoring and data collection systems. There were no significant modifications required in the drive, power or frame subsystems, but the remaining four subsystems did require changes of varying degrees.

The initial design of the drilling system did not provide the drill bit with an adequate flushing water supply pressure. In addition, it was impossible to determine the orientation of the recovered core sample. In order to correct these deficiencies with this system, it was necessary to incorporate three separate pumps to replace the original single pump. These pumps provide respectively, (1) drill download pressure, (2) drilling fluid supply, and (3) retraction pressure (Figure 1). Using a separate pump for the drilling fluid supply, it is possible to maintain a relatively constant flow rate, with the drilling fluid pressure fluctuating as necessary to sustain this flow. The download and drilling fluid pumps are driven by the main motor, but the retraction pressure pump is driven by a separate motor. Separation of retraction from the main drive allows the core to be broken off without it being rotated, making possible a reliable determination of the original orientation of the core. It also permits retraction of the core barrel long after the batteries are too discharged to operate the main motor. The retraction motor draws only about 10 amps compared to the main motor which draws approximately 150 amps. (The retraction motor is a standard $\frac{1}{4}$ hp, 36 V DC motor that turns at about 1500 rpm in an oil filled pressure compensated chamber).

The ALVIN attachment subsystem was completely redesigned (Figures 3 and 4), due to difficulties discussed in the annual report. The new system overcomes most of these difficulties. One problem developed with this new system is that the lower part of the drill tended to swing out and away from ALVIN, due to wave motion, when the submersible operated at the surface. This presented a very undesirable situation even in moderate seas. A locking device is being developed which will restrain the drill while ALVIN is near or at the surface. Other than this exception, the system proved to be simple, reliable and it met all of ALVIN's safety requirements.

As for the control subsystem, the original control instrument had worked quite well but was essentially a "bread-board" version; difficult to repair, adjust, or change and generally quite vulnerable to damage. A new control instrument has been built which incorporates several improvements, most important of which is the ability to control the drill from inside ALVIN.

Finally, part of the monitoring and data collection system has been completed and tested. Battery voltage and current can now be monitored on the mother ship via an acoustic telemeter. These two parameters allow us to determine how much battery power remains, what drill components are operating and how hard they are working. If the budget permits, a drilling depth sensor will be developed to provide positive indication of how deep the drill has penetrated and when the core barrel has completely retracted.

Testing

A brief series of tests were run in early May at Woods Hole (Figure 5). The new drilling subsystem was tested successfully in shallow water off the W.H.O.I. dock. The ALVIN attachment system was tested with ALVIN in Woods Hole Harbor (Figure 6). Several submerged coupling and uncoupling exercises were accomplished and the drill was successfully jettisoned.

At the end of May two dives were made with the drill in the Gulf of Maine (Figure 7). On the first dive a number of problems were encountered. The visibility was very poor, there was a strong current, and we were unable to find a suitable rock outcrop. On the second dive a rock outcrop was located and ALVIN uncoupled from the drill. The drill only operated for a short period of time, due to a safety shut-off circuit in the control instrument which operated prematurely. The dive was made with out original control instrument so we were unable to restart the drill from inside ALVIN. ALVIN successfully recoupled to the drill and returned it to the surface.

Following this cruise we began an extensive testing series with the following objectives: (1) to increase the reliability of the drill; (2) to test the new control instrument and the new monitoring system; and (3) to vary all of the many drilling parameters through a reasonable range of values in order to determine their optimum value; that which will produce the highest drilling rates and the maximum core lengths. We also began work on the aforementioned modification to the ALVIN attachment system.

Future Plans

In the final half year we plan to complete the above series of tests, hopefully including at least one more dive with ALVIN. It will not be possible to do any deep water drilling because there are no scheduled ALVIN cruises into areas that have deep water hard rock outcrops. In 1973, if possible, we plan to participate in an ALVIN cruise to the New England seamounts.

General Specifications and Description

Height	9'6"
Width (fore and aft)	60"
(beam)	108"
Weight (air)	1500 lbs.
(water)	590 lbs.
Flotation material	150 lbs. of buoyancy
Drilling depth maximum	2 meters
Operating depth maximum	12,000 ft.
Battery Voltage	
(open circuit fully charged)	39.5 volts
(running nominal)	36.0 volts
(running minimum)	25.0 volts
Main Motor current (nominal battery voltage)	
(running in air, no load)	26 amps.
(running in oil, no load)	42 amps.
(running in oil, drilling in air)	~90 amps
(running in oil, drilling in water)	~150 amps.
Retraction Motor current	
(running in air, no load)	2 amps.
(running in oil, no load)	8 amps.
(running in oil, loaded)	12 amps.
Battery Capacity	
25°C @ 20 hour rate	~90 amp hours
25°C @ 25 minute rate	~50 amp hours
0°C @ 25 minute rate	38 amp hours
Maximum battery current(safety circuit shut-off)	250 amps for 8 secs.
Heater Power	50 to 100 watts
Drill bit size	XRT
Drilled hole diameter	1.155 in.
Core Diameter	0.735 in.

Drill bit type	Diamond set 25 stone/carat
Core barrel	7 ft. rigid double tube
Drilling fluid flow rate	1 to 1½ gpm
Drilling rate (sediment)	Highly variable
(hard rock)	1 - 4 in/min (avg 3 in/min)
Core barrel retraction rate	3 ft/min
Maximum core breaking force	>1000 lbs. (at operating depths >300 ft)

Figure 1. Simplified schematic of drill systems.

Figure 2. Internal view of drill cylinder showing (a) core barrel, (b) flushing water coil hose, (c) water entrance chamber shafts, (d) torque transfer rods, (e) piston, (f) upper and lower drill cylinder end caps.

Figure 3. Side view of coupling system.

Figure 4. View through ALVIN forward viewing port showing coupling device.

Figure 5. Drilling hard rock during dock testing.

Figure 6. ALVIN and drill being lowered into Woods Hole harbor for coupling and jettisoning tests.

Figure 7. ALVIN being launched with drill attached.

Self Contained Ancillary Modular Platform

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Self Contained Ancillary Modular Platform (SCAMP)

Abstract

The principle objective of this contract is to design, fabricate and test a self contained platform that can be attached to the ALVIN submersible, effectively increasing the payload capability of the vehicle.

Its proposed use will be to support a wide variety of science apparatus too large or heavy for the submersible to handle with its existing payload buoyancy and power capability.

The platform will have a fixed ballast system capable of supporting science gear having a water weight up to 400 pounds. The payload ballast will be provided through the use of blocks of syntactic foam, an epoxy resin/glass microsphere matrix, that can withstand the exposure and hydrostatic crush pressure of sea water to depths as great as 12,000 feet. The platform will have the capability of providing 30 volt DC power for science apparatus, without becoming a parasite to the submersible power system. It will be capable of anchoring itself to the bottom through the use of electrically powered pumps and three suction pod assemblies.

With proper ballasting and suction pod operation, the platform may be left on the bottom as a long term bottom station. It can be moved, or recovered and returned to the surface by landing the submersible on the platform, remotely latching the submersible skids to the platform landing rails, and flying the device and its science apparatus to the surface. The platform operating depth will be 12,000 feet, making it compatible with the new depth capability of the titanium personnel sphere to be installed in the ALVIN vehicle.

Construction Milestones

1. Frame

Figure 1 illustrates the basic frame of the SCAMP platform. It is a rectangular structure 64 inches wide by 12 feet 6 inches long. It is fabricated of 6061-T6 aluminum I beam, 12 inches high, with 7 inch wide flanges. In the mill condition its weight is 14 pounds per foot. The fore, aft, and center cross members have been constructed of 12 inch channel sections, having a mill weight of 7.41 pounds per foot. In order to provide high strength and solid weld fillets with a minimum of voids between the base materials, all joints were scarfed or mitered prior to welding.

Welding was performed by a certified welding contractor using an MIG welding gun technique. The inert gas used to protect the weld was argon. All welds are considered as having water tight integrity to assure a minimum of sea water seepage or penetration when submerged. Water tight integrity was considered as an important design goal to prevent subsurface corrosion behind weld beads during long periods of submersion.

As shown in Figure 1, all web portions of both the channel and I beams have triangular sections removed to reduce the total weight of the basic frame.

Calculations indicate the total area of vertical strut material in compression is 28.37 in.², assuming equal distribution of the 33,000 pound weight of ALVIN resting on the platform, the compressive stress would be 1163 psi. However, based on the actual landing position of the ALVIN submersible, most of the weight of the vehicle will be on the six central struts. The total area of these struts is 13.37 in.², increasing the maximum compressive stress to 2468 psi. Using a yield strength 35,000 for 6061-T6 aluminum, the factor of safety under static compressive loading by the ALVIN vehicle, is determined to be 14.

Referring to Figure 1, bending calculations were made on the I beam tee section located above each of the triangular cutouts. The span of the beam tee section, or the length between the right and acute angles formed by the altitude of the cutout triangle, is 28 inches. Loading on the I beam is 16,500 pounds/ALVIN skid, with each skid being 96 inches in length. The loading on each 28 inch length of the tee section is 4812 pounds, which gives a static bending stress of 19,810 psi. The factor of safety for each unsupported span of tee section is 1.77.

The beam bending however, is not as severe as shown since the skids of ALVIN overlap the span length, and much of the load is taken by the vertical struts or columns at the end points of the individual spans. These vertical struts are stiffer than the I beam tee sections and thus pick up the load first.

Each skid of ALVIN will overlap at least two and possibly three vertical struts at any time. Assuming only two vertical struts support each skid, with each strut having a cross sectional area of 1.812 inches², the static compressive load on each strut becomes 4450 psi. A more realistic factor of safety for the entire tee and vertical column assembly, is considered to be that for the vertical struts which assume most of the primary load. Based on this the factor of safety has been determined to be 7.8.

2. Battery Assembly

Figures 1 and 2 illustrate the battery saddles used to mount and support the two 14 inch diameter glass/fibre reinforced epoxy resin tubes which house the batteries. Aero-quip band clamps are used to retain the tubes in their proper locations. Each tube contains five 150 ampere-hour lead acid batteries, with each pack wired to provide 30 volts DC.

Figures 3 and 4 illustrate the light weight inner battery rack supporting frames, as well as the slide mechanism used to load the batteries in their tubular housings. The slide mechanism will also provide the platform with a means of obtaining a fine fore-aft pitch control to assist in adjusting for weight of various science apparatus attached to the frame. Figure 5 illustrates the ball screw mechanism that positions the batteries. It will be remotely controlled by the platform operator, and will be powered by a small DC reduction gear motor, with an Electro-Mechanical brake assembly used to lock the batteries in the position selected by the operator.

For design purposes, a total battery travel of 24 inches was selected, with a single traverse from the fore to aft position taking place over a five second period. A maximum up/down pitch angle of 15° was used to match the submersible characteristics. Based on the in-water weight of five batteries and the coefficient of friction for the ball screw assembly, it was determined that a 30 V DC reversible electric motor drive, capable of developing 2.06 inch pounds of torque, would adequately power the assembly at the required speed and torque. The motor drive mechanical design layout has not progressed to a point where a DC motor has been selected. Several motor/gear box assemblies are presently being reviewed, and a final decision will be made shortly.

Considerable difficulty has been experienced in attempting to line up and adjust the three sets of battery rack slides in a series configuration. Manufacturing tolerances and assembly variations have resulted in the movable battery rack jumping the track and jamming up. In view of the existing difficulties, it has been decided to eliminate the three piece construction using the commercially available file cabinet slides, and go to a single piece track. The slide manufacturer was contacted, and has fabricated and shipped a new set of tracks rolled in one continuous length.

As a point of interest, the battery slide mounting rings are held in place through the action of expansion within the bore of the outer tubular shell. Figure 5 illustrates that each ring has been drilled and split at its lower edge, and a neoprene expansion plug inserted in the hole. By rotating the tee handle on the plug, the elastomer expands forcing the ring against the inner bore. This method of securing the battery racks; provides easy insertion or removal of the rack assembly, and preserves the smooth bore integrity of the tubing. Each of the eight rings used in the port and starboard battery compartments have provisions for the expansion lock mechanism, assuring a firm foundation for the battery packs.

Figure 6 illustrates one of the four piston assemblies used to close the tubing ends, retain the pressure compensation oil, and provide the pressure equalization as the platform descends or ascends. The tubing bore has a five to 15 micro inch finish on the inside diameter, with the pistons sealed by a double set of neoprene "O" rings.

The pistons are free to slide in the tubing bore, and will move in or out depending on the compressibility or expansion of the Marcol oil used to fill the battery compartment. A 2.0 pound relief valve will vent any excess pressure resulting from oil expansion or gas generation during the battery charge and discharge cycles.

Figure 7 is an overall view of the basic SCAMP frame, showing the starboard tubular battery compartment mounted on the platform. Each compartment has a removable fibreglass nose and tail cone mounted at its extremes. Each cone is an oil filled pressure compensated compartment, and will house the power control relays and circuits used to operate both the science equipment and the SCAMP electrical system. Snap latches will be used to attach the cones to the tubular compartments, and will provide easy access to the battery compartments.

Figure 8 illustrates a typical fiberglass rack structure mounted within the nose cone. Diodes, circuit boards, relays, and control wiring to complete the assembly of the control package, are presently on order. Figure 9 is an exploded view of the mounting racks, and illustrates the three tier construction that will provide easy access to the relay and other associated circuitry.

A fourteen inch diameter diaphragm, not shown, will be used to seal off the open end of the nose cone. The diaphragm will separate the sea water from the compensating oil used to fill the inner cavity of the assembly. Its flexible characteristics will perform the function of transmitting the external ambient sea water pressure into the oil filled chamber, effectively forming a pressure balanced system. Using an oil filled pressure balanced system approach, eliminates the weight penalty associated with pressure resistant housings usually used to house and protect electrical components from sea water exposure.

4. Suction Pod Assemblies

Figure 10 illustrates the construction of a typical suction pod mounting arm. In its present configuration, it has two fixed positions. Figure 10 shows the arm in its up position, while Figure 1 illustrates the arm in the down position. The arm may be repositioned by removing a ball detent quick release pin, moving the assembly to its new position, and inserting the quick release pin in the proper index hole. The positioning of the pods will be accomplished by the diver crew that normally accompanies the ALVIN while it is on the surface. The knuckle joint at the end of the arm, is typical of the three suction pod assemblies. It provides two degrees of freedom, and allows the pod to assume the best contact position in uneven bottom terrain.

Figure 11 illustrates a typical suction pod assembly mounted at the extremity of its arm structure. The pod is constructed of fiberglass mat and cloth, using a two part catalyst polyurethane resin as the bonding agent. A multi-layer wet lay-up method of construction was used to fabricate the component. It is 14 inches in diameter, and will have a bottom holding power or suction attachment of 500 pounds with a low limit internal suction pressure of 3.25 psig. The high limit, or 14 psi negative pressure will provide a single suction pod anchoring capability of 2000 pounds. Each suction pod is directly connected to a pressure/suction pump mounted on the frame. Figure 2 clearly illustrates one of the three motor-pump assemblies mounted on a bottom saddle. A flexible corrugated teflon tube will be used to connect each pump to its mating suction pod. The tubing is inert to sea water, and is capable of withstanding an internal negative pressure of 29.9 inches of mercury; or, an internal positive pressure of 180 psig.

Assuming a perfect seal at the base of the suction pod anchor, the pump is capable of pumping a closed water filled chamber to a negative pressure of 14 psi; or, a positive pressure of 13.3 psi, indicating a satisfactory safety factor for suction pod tubing assemblies. As a point of information, prior testing accomplished on a prototype suction pod using a similar motor-pump assembly, indicate a perfect seal is not normally obtained in sand or mud bottom conditions when operating in the suction mode. Channeling occurs under the suction pod edges, slightly reducing the negative pressure the pump

can effectively produce within the pod chamber.

The pump flow however, and the self healing characteristics of bottom sand as it attempts to fill the void, will usually provide a low pressure area within the suction pod plenum chamber, assuring a bottom holding force.

The stress calculations for the fibreglass suction pod assemblies, indicate the strength factor of the 14 inch diameter top plate, is sufficient to withstand the effect of a 14 inch vacuum pressure without exceeding a .050 inch deflection. A stainless steel plate has also been molded into the fibreglass shell material, as illustrated in Figure 12. It provides additional strength in the top plate, as well as furnishing a mounting base for the universal joint or knuckle assembly on the movable arms.

The side walls of the suction pod have been constructed in a slight wedge shape, with the sharper edge being the first to contact the bottom sediment. The heavier cross section is at the top, and has been faired into the flat plate section with a generous radius both internally and externally, in order to distribute the loading at the 90° interface.

5. ALVIN/SCAMP Interface

Six rubber covered steel leaf springs have been designed and put into fabrication. The spring guides are identical to the components attached to the existing ALVIN cradle, and used to line-up the submersible during recovery. On the SCAMP platform, they will assist the submersible operator reposition himself when recovering the platform from the bottom, or when landing on the platform when it is secured to the support vessel lift cradle.

Several methods are being examined as a means of attaching the platform to the skids of the ALVIN submersible. No firm decisions have been made at this time concerning the final method of attachment. In their basic forms, they consist of: (1) Solenoid latching devices that will clamp either directly to the top or sides of the existing submersible skids, with either a mechanical safety pull disconnect actuated by the ALVIN manipulator, or explosive bolts as the back-up safety release. (2) A self contained hydraulic actuated piston latch assembly that is powered by a stored pressure system, and pressure compensated to some value above ambient pressure, regardless of depth. Normal or emergency release would be accomplished by a electrical solenoid valve, with back-up being provided by the manipulator depressing a push-button type total discharge valve. (3) The use of a clamp using a hydraulic (sea water) filled hose assembly is also being investigated. In its simple form, it would consist of an elliptical cross section of tubing, having a fire hose type construction. In the expanded or pressurized condition, two seven foot lengths, or one hose clamping to each of the port and starboard ALVIN submersible skids, would have a total clamping force of 21,000 pounds when pressurized to 100 psig. This method of attachment seems to have several good points. For example, it would be a "soft" clamp that could conform to any irregularities in the skid structure. It does not require precise mating or positioning of ALVIN and SCAMP, as its construction characteristics would allow longitudinal positioning as great as 12 inches, and athwartship misalignment as great as three inches.

A small pump, or pressurized reservoir could be used to actuate the device, with the release mechanism being a solenoid operated valve. The back up release could be an explosive burst disc, and/or a manual shut-off valve actuated by the manipulator.

6. Syntactic Foam Flotation

Forty cubic feet of 3M thirty-four pound syntactic foam has been received. It is an experimental foam with characteristics similar, but not identical, to the existing XP 241 thirty-eight pound foam used in the ALVIN submersible. This was the first large batch foam poured in this weight class by the 3M Company. Preliminary discussions have been started to lay the ground work for Navy certification of the foam. A continual effort will be undertaken in letter form, to assure the 3M Company provides both sample batches of 34 pound foam, as well as their own quality assurance data to the appropriate Navy Laboratory.

Samples of the existing foam procured for the SCAMP vehicle will also be submitted to the Navy for testing. Quality Assurance Laboratory reports are being prepared by the 3M Company for the first batch, and copies will be made available to the Navy when the specimens are submitted by W.H.O.I. The foam blocks have been cast in rectangular form of one cubic foot, and are 12" x 6" x 24". Based on the rectangular configuration of the SCAMP platform, it is anticipated that wastage due to cutting and fitting of the foam will be held to a minimum, providing the most flotation possible from the 40 cubic feet originally procured.

7. Electrical Circuitry

Figure 13 illustrates the basic SCAMP electrical system. There are two sets of 30 V DC battery packs, and two main power buses. The "A" battery or port pod assembly can energize the "vehicle power bus" and/or the "science power bus". Likewise, the "B" battery or starboard pod assembly can energize either or both power buses. When both batteries power the same bus, the batteries are in parallel for extended use. However, when each bus is powered separately, there is a minimum interaction of electrical noise impressed on the science apparatus from the suction pod motors, and the battery traverse mechanism.

The vehicle power bus is located in the port aft pod cone. Figure 9 illustrates the internal rack structure used to support the electrical components, and depicts the typical construction features used in both the port and starboard assemblies. The port circuitry provides power and control for the port, starboard and aft suction pods, port and starboard battery traverse motors, rail locks, emergency rail release, and lighting. The science power bus is located in the starboard aft pod cone, and provides power and control for all science loads.

Figure 14, the SCAMP cable diagram, illustrates the physical cable arrangement. The "A" battery is located in the port pod, and is controlled by relays and contactors in the same tube. Likewise the "B" battery is located in the starboard tube and has its control contactors located within the tubular battery compartment.

Battery power from each supply bank is fed to both bus pods via #4 wires. Contactor control is provided via a 9 wire cable from the bus pod to the contactors. The operator control switches are located in a separate box or compartment, and control the bus pod relays via 24 wire cables. The motors, lights, and other loads are connected via one 16 wire and one 14 wire cable to the bus pod relays.

The initial shallow water tests will be performed with the operators control box directly connected and located on the surface. If satisfactory, the deep water design will include a pressure resistant housing for the control functions commanded by the pulsed light transmitting system.

8. Electrical Circuit Schematics

Power control is provided by the relays and contactors illustrated on Figure 15.

- A. Control power enable, is the first step in providing power to the system buses. A latching relay (LR) triangle code 11, is powered by a separate battery in the control box. When the enable switch is activated (momentarily) the latching relay is locked in the ON position, and +30 volts DC is enabled to the control relays via pin 2 of TBA (Terminal Board A). The -30 V DC line is connected to pin 4 of the TBA. An overload protection relay in the -30 line is connected to pin 3. The function of the overload protection is discussed in Section "C".
- B. Contactor control relays, identified as R1, R2 on the schematic, control vehicle power. Relays R3 and R4 control the science power source. The relays R1 and R2 are self holding, and are released by the overload protected -30 V DC line. When +30 volts is enabled, R1 and R3 are energized through the normally closed contacts of R2 and R4.

When the "A" battery to science bus switch is closed on the control box, R4 is energized, thereby energizing the power contactors Ks and K4. When the "A" battery vehicle bus switch is closed, R2 is energized thereby energizing the power contactors K1 and K2. When the control switches are moved to the off position, the corresponding relays and contactors are de-energized.

- C. Overload protection, is provided for the circuitry when the power drain from the batteries exceeds 80 amperes through the overload relay (OL). When the OL relay trips and its contacts open, it releases relays R1 and R3. The released relays cannot be reenergized until the control switches are first turned off, then returned to the ON position.
- D. Power contactors connect the batteries to the load buses. Contactors K1 and K2 provide power to the vehicle bus, contactors K3 and K4 provide power to the science bus, and contactors K5 and K6 allow the batteries to be charged "in-place" from an outside source. While there are no firm plans for charging in water, sketch 20 and the description of a proposed, simple and inexpensive, deep water pressure compensate disconnect is covered in Section 8 of this report.

- E. Battery charging, is accomplished after the control power is disabled, via latching relay (LR). The battery charging apparatus is connected to charge terminals, with the battery charger used as the power source to activate the two contactors K5 and K6.
- F. SCAMP motor controller (SMC) is illustrated schematically on the circuit diagram Figure 16. When the +30 V DC is switched to the FWD control line, the right hand relay is energized and provides current to the motor. The blocking diode prevents the DPDT relay from being energized. When +30 V DC is switched to the REV control line, both relays are energized and current is supplied to the motor with the field reversed, reversing the direction of motor rotation.

Figure 17 illustrates the SCAMP motor controller (SMC) circuit used as a building block component for controlling the various motor loads associated with the platform.

- G. SCAMP light controller (SLC) is shown schematically in the right hand circuit of Figure 16. When the +30 DC is switched to the ON line, the relay is energized and power is supplied to the load. Figure 17 illustrates the SLC circuit used as a building block component for controlling the various lighting or other loads.
- H. Electrical component layout is illustrated by Figures 18 and 19, which physically locate the various SMC and SLC building block component boards located in the aft port and starboard tail cones. They represent the components as they will be mounted in the foundation chassis previously illustrated in Figures 8 and 9.

9. Deep Ocean Technology Implications

As the design of the SCAMP progressed, several areas of investigative interest have been uncovered. The two major points in simplified forms are as follows:

- A. The SCAMP could be considered as a portable power package for use in providing electrical energy to long term submerged electronic devices. In view of this, and to provide a simplified method of attachment for a recharge circuit both to the SCAMP and/or other apparatus on the bottom, the light weight inexpensive pressure compensated quick disconnect illustrated in Figure 20 is proposed.

As noted in the sketch the outer shell is constructed of PVC (polyvinyl chloride). A plastic pressure compensation bellows is attached to this rigid housing, and through a drilled passage, transmits the external sea water pressure to the inner cavity via silicone 200 fluid. The silicone is a dielectric material used to fill both the cavity and the bellows assembly.

A diaphragm constructed of Dow Corning Sylgard #51 is used as the mechanical barrier to separate the external sea water from the silicone

200. The Sylgard #51 material is a dielectric gel that is compatible with sea water as well as silicone 200 fluid. It is a two part potting compound that, when properly gelled, forms a resilient, self-healing, protective cushion. It is a soft, transparent jelly-like mass having excellent thermal and dielectric properties over wide extremes of temperature. Its properties when exposed to high pressure sea water however, will require further investigation.

In use, an electrical probe is inserted through the Sylgard #51 diaphragm, and mated with its female counterpart completing the circuit. The pressure compensation bellows maintains a pressure balance between the inner and outer surfaces of the disconnect.

On withdrawal of the electrical probe, the Sylgard #51 completely reseals itself, preventing the entry of sea water. In view of its simplicity, it is suggested that further investigation be directed toward the design, fabrication, and test of a prototype model.

- B. As discussed in Section 5, "ALVIN SCAMP Interface", the proposed use of a hydraulic (sea water) filled hose assembly to "clamp" the submersible to the SCAMP, could have possibilities in other areas of submersible use.

For example, several proposed projects within the submersible industry, have centered around the underwater recovery of undersea vehicles. Present day operations utilize cranes or cradles to lift the vehicle from the water. Under good conditions these methods have an excellent record of achievement. However, in sea states greater than 4, it becomes difficult to properly mate the submersible with its lifting apparatus due to the surface or wave action having varying effects on both the recovery and to-be-recovered vessel. If a method were developed to fly the submersible to a cradle suspended beneath the surface, then quickly mating the two devices with a simple "soft" clamp type mechanism, the submersible and its cradle could be brought quickly and safely through the sea water interface with a minimum of stress, both mechanical and emotional!

In the event the final method of mating the ALVIN submersible and the SCAMP platform does not follow this method, it is suggested that additional investigations be undertaken to determine its feasibility. As a point of interest, the SCAMP project has purchased two small tube clamp assemblies in order to run preliminary tests. The depth of the investigation will depend on budget and time limitations. The data obtained however, could be valuable as the basis for a decision to follow-on or discard the proposed method of sub-surface vehicle recovery.

10. Conclusions

The SCAMP project is not manned on a full time basis, project engineering guidance as well as the use of shop fabrication facilities are shared by several projects simultaneously. The program however, is progressing well in the design, fabrication and procurement of off-the-shelf hardware. Several

design steps, notably the electronics control package, has become more sophisticated than originally proposed. Considerable thought has been expended on this section, as it was felt complete compatibility with the existing ALVIN submersible system, as well as surface support apparatus, was a high priority goal. The interlocking compatibility of the two systems will reduce the support equipment and hopefully the operational cost of the SCAMP program.

As a point of interest, correspondence between the SCAMP project and Professor Vita A. Nacci of the University of Rhode Island, has developed information that will be useful in the test and final design of the bottom suction pod anchors. The University of Rhode Island has been doing considerable research on hydrostatic anchors under Contract No. N66604-71-C-0080, sponsored by the U. S. Naval Underwater Systems Center, Newport, Rhode Island. A copy of the report entitled "Behavior of the Hydrostatic Anchor in Sands" has been presented to, and gratefully received by, the SCAMP project. Its usefulness will be invaluable.

Two major design points still must be resolved, namely, the method used to attach and detach the submersible and the platform, and the procurement of a satisfactory drive motor for the battery traverse mechanism. Of the two, the attachment method is the highest priority as it must be fail-safe, foolproof, and be compatible with long exposure in sea water.

Due to several delays in both fabrication and manpower, the platform will not be sufficiently far along to perform an in-water test during the calendar year of 1972. Weather conditions will rapidly deteriorate during the month of November, and it is not felt the safety of personnel and equipment would be worth the effort. The platform will be water borne early in 1973.

Figure 1. Basic SCAMP frame illustrating the truss construction of the Aluminum I beam sections.

Figure 2. Support saddles used to mount the tubular battery packs and suction pod motors.

Figure 3. Slide mechanism and internal battery rack assembly.

Figure 4. Overall view of battery tray illustrating light weight construction features.

Figure 5. Ball screw transverse mechanism used to obtain fore and aft movement of battery pack tray.

Figure 6. One of the two plastic pressure compensation pistons located at each end of the oil filled battery compartments.

Figure 7. SCAMP frame with battery compartment mounted on saddles.

Figure 8. Nose cone and fibre glass rack assembly used to mount control relays and electrical contactors.

Figure 9. Exploded view of relay rack assembly frame.

Figure 10. One of the three suction pod mounting arms with swivel attachments to assure level footing on uneven terrain.

Figure 11. Fibre glass suction pod assembly.

Figure 12. Aft suction pod and motor/pump assembly.

Figure 13.

Figure 14.

Figure 16.

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Figure 18.

Figure 19.

Figure 20. EXPERIMENTAL QUICK DISCONNECT

10	LIFTING RAILS, 1/2" x 3/4"
9	TUBING, CORRUGATED TITANIUM
8	MOTOR-PUMP ASSY, 30 VDC, REVERSIBLE
7	BATTERY CONTAINER
6	SUCTION PUMP, 1/2" (5000) (IF PLACES) TOTAL AREA = 1/2" x 1/2"
5	PLATE, 1/2" x 1/2" (IF PLACES) TOTAL AREA = 1/2" x 1/2"
4	CHANNEL, 1/2" x 1/2" (IF PLACES) TOTAL LENGTH = 1/2" x 1/2"
3	CHANNEL, 1/2" x 1/2" (IF PLACES) TOTAL LENGTH = 1/2" x 1/2"
2	BEAM, 1/2" x 1/2" (IF PLACES) TOTAL LENGTH = 1/2" x 1/2"
1	BEAM, 1/2" x 1/2" (IF PLACES) TOTAL LENGTH = 1/2" x 1/2"

SCAMP

FRAME

SCAMP BATTERY CASE

May 1973

Woods Hole Oceanographic Institution

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