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Woods Hole Oceanographic Institution

Advanced Marine Technology

TECHNICAL REPORT
ARPA PROGRAM FINAL REPORT
1 FEBRUARY 1971 - 31 DECEMBER 1975

By

Dr. E. E. Hays, Principal Investigator

February 1976

TECHNICAL REPORT

*Prepared for the Office of Naval Research
under Contract N00014-71-C-0284; NR 294-017
Contract N00014-75-C-0681; NR 294-017.*

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WOODS HOLE, MASSACHUSETTS 02543

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Approved for Distribution Earl E. Hays
Earl E. Hays, Chairman
Department of Ocean Engineering

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ARPA PROGRAM FINAL REPORT

I Summary

A program in Advanced Marine Technology was carried out at the Woods Hole Oceanographic Institution, under ARPA sponsorship from February 1971 until December 1975. The program consisted of thirteen projects with a total funding of \$1,993,000.

Most of the projects improved the surveying, sampling, and measuring capabilities of deep submersibles using ALVIN as the test vehicle. The capabilities required to evaluate an area of the ocean bottom for deployment of large pieces of equipment or arrays included precise three dimensional navigation (page 12), photography (page 16), acoustic mapping (page 15), sampling of materials (page 12,14), and magnetic and gravity field measurements (page 13). In addition to the submersible oriented projects there were projects on Handling and Transfer at Sea (page 11), Deep Sea Biological Equipment (page 13), and Offshore Industrial Waste Monitoring (page 14). Submerged navigation, a Modular Acoustic Suite for ALVIN, and ALVIN operation expenses each accounted for about 20% of the total budget.

Section II points out the relevance of the thirteen projects to future military requirements and the technical problems of each. Section III describes the history of the program and its relation to the Woods Hole Oceanographic Institution, and lists the project leaders.

Section IV of this report gives a brief description of the results of each project, and in Section VII there is a listing of publications that have resulted from the program as well as a table of pertinent information about the diving schedule of ALVIN.

II The Problem

Many parts of Marine technology have advanced as peripherals to scientific and engineering projects for specific purpose. As a result, these phases of development have been sporadic and not coordinated. This program was undertaken to advance the usefulness of deep submersibles to future military requirements.

II.1 RELATION OF PROGRAM TO MILITARY REQUIREMENTS

The ARPA program at the Woods Hole Oceanographic Institution had a central theme of improving the technology available for deep diving submersibles. Deep submersibles have had a very limited role in defense, being generally limited to recovery of important defense related objects on the bottom and visual survey of bottom areas.

We decided to concentrate on those problems of a small deep submersible, attempting to make a comprehensive survey in an area of some 10x10 miles in extent. In addition, installation and servicing of any deep equipments by a small submersible requires many of the same techniques.

We can propose a specific example. Suppose we wish to place an array with the dimensions of hundreds of meters in an area where the topography is rough, with steep slopes, and undetermined bottom types. First a narrow beam echo sounding survey, and surface ship lowered cameras are used to give a gross picture of the area and selection of potential sites. Then the deep submersible is used to examine the site in detail. To do this it needs:

- (a) Good underwater navigation.
- (b) Good illumination of photographic capability.
- (c) Sampling equipment.
- (d) Geophysical equipment.

The usefulness of the submersible during and after installation depends upon the type of equipment installed and will require some special tools.

In the ARPA program we have made advances in the following which improve the capability of deep submersibles as related to the above.

- (1) Submerged navigation - A pulse system and a pulse Doppler system for navigating in an area 8x8 miles to within several meters in rough country from dive to dive or to within 10 cm on a single dive.
- (2) A system that increases energy supply for special bottom tasks. Self Contained Auxiliary Modular Platform (SCAMP).
- (3) A modular acoustic system that gives the submersible a sonar suite that can be used for bottom and subbottom profiling, topography delineation by transducers variable in elevation and azimuth, volume scattering studies.

- (4) Wide area illumination - remote placing of lights to eliminate back scatter and increase visual range.
- (5) A rock drill capable of obtaining samples of .735" diameter 40" long.
- (6) A hydraulic hammer to break off pieces of rock and serve as a mechanical arm. (Short coring equipment already existed)
- (7) A magnetometer system that can be used by the submersible close to the bottom in rough country.
- (8) Determined that the normal accelerations of the submersible were too high to permit use of small gravimeter systems except when on bottom.

In addition to the submersible related effort there were several other subjects addressed.

- (9) Handling and transfer at sea - concerned with the problem of bringing a smaller boat alongside a ship in rough weather - an important assault problem.
- (10) Development of Deep Sea Biological Equipment.
- (11) Offshore monitoring of industrial waste.

The latter two were short term investigations, but acted as seed money for work that has continued elsewhere.

The Navigation System - especially the pulse Doppler system can have direct application in monitoring the geometrical shape of suspended arrays or use in synthetic aperture arrays.

II.2 State of Technology at Program Inception

SUBMERGED NAVIGATION

Generally deep submersibles navigated by a slant range to mother-ship, a crude azimuth measure by mother-ship and bottom contours. Hundreds of meters was good navigation relative to the mother-ship; the relation to the bottom depended on the ship's navigation or in special cases to topography. Chester Buchanan at NRL had developed a three point array on MIZAR that was used to navigate a towed camera to tens of meters in relation to the ship. Others had navigated in relation to fixed bottom arrays.

The concepts for a pulse system existed. In 1972 a Doppler navigation system was developed under an ONR contract. The Doppler system alone gave good relative navigation (10 cm) in any single run, but position relative to

the net was poor (lane definition).

ILLUMINATION

Illumination for small submersibles consisted of a high energy light source rigidly mounted to the submersible. Mechanical restraints on mounting usually resulted in appreciable back scatter and bright areas which reduced the ability to see long distances. A large uniformly lit area is desirable. No such system existed.

SONAR SUITE

The use of acoustics in deep submersibles was restrained by the wide range of frequencies, signal waveform, beam width and variable direction desired by different potential users. Each experiment required packaging of inboard and outboard equipment to match submersible space and safety requirements. The development of a suite that would answer most of the needs was required.

SAMPLING

A small rock drill existed that took short unoriented rock cores. It could be used in the mechanical arm of the submersible. It took one half hour to obtain the core.

Prying with bars held by mechanical arm was the only way to sample outcrops. This was frustrating to the geologists in many instances as samples just could not be obtained.

MAGNETICS

Deep magnetometers towed from ships existed. No system existed that could be used from a deep submersible. The problem was to have it as close to the submersible as consistent with the magnetic field of the submersible.

GRAVITY

Gravity measurements had been made from large submarines, and from small submersibles when at rest on the bottom. The hope was to develop a system that could be used while the submersible was making transits. The space restraints and accelerations of the submersible when underway made this impossible without an expensive development program.

ENERGY

Energy and time are two constraints on the use of small deep submersibles. Batteries are used and are the prime energy source. An auxiliary power supply that could be placed on the bottom, left to perform a task and then recovered by the submersible was desirable. High energy density sources still need to be developed for small submersibles.

HANDLING AT SEA

Two surface craft brought together in a sea way create problems that are dangerous and often damaging. Bumpers and fenders are a start on the energy absorbing requirements but often fail to perform satisfactorily. A skillful coxswain is a present requirement for safety. The use of aircraft landing gear techniques to cushion impact seemed worth investigation for certain uses.

BIOLOGY

Before deep submersibles became available, biologists were working in the deep ocean on the end of long wires, with some control on sampling depths, but almost blindly in regards to sampling and measuring processes on the bottom. Dredges, samplers, free fall devices had all added to the knowledge of benthic biology, but controlled experiments were difficult or impossible.

WASTE MONITORING

Analytical techniques developed for the identification and measure of hydrocarbons in seawater offered promise for similar work in the identification of industrial wastes. A short investigative project was performed on this ARPA project and then terminated as it did not match the general goals.

II.3 Specific Technical Problems Addressed by ARPA Program

SUBMERGED NAVIGATION

The submerged navigation system development required performance of the following tasks:

- (1) Development of a computer system to identify and measure travel time of acoustic signals, to apply proper sound velocity corrections, and to calculate geometrical locations in relation to transponder net on the bottom and display these positions, as well as log them versus time. The inclusion of the Doppler system meant that acoustic phase had to be tracked and horizontal and vertical movement derived from it.
- (2) Design and development of transponders, release and mooring system.
- (3) Inclusion of surface bounce paths in rough terrain, primarily an identification and processing problem.

ENERGY

The Self Contained Auxiliary Modular Platform required development of:

- (1) Suction pods that would exert downward pull on platform/submersible and hold it in location during coring or drilling operation.
- (2) A reliable connect/disconnect system with submersible.
- (3) A communication link between platform and submersible without wire connections.

SONAR SUITE

The modular acoustic system required:

- (1) Trainable mounts in azimuth and elevation for readily interchangeable transducers.
- (2) Electronics for driving transducers with a wide variety of frequencies and wave forms that could be easily programmed.
- (3) Recording for permanent record and on site display for use in the submersible.

ILLUMINATION

Wide area illumination required a deployable floating light with tension controlled disconnect to release light in case of fouling.

SAMPLING

- (1) The major tasks in designing a deep sea rock drill were determining proper bit type, drill pressure, and fluid flow rates, and developing control and power system.
- (2) An impact device to simulate a large geologist's hammer was required. It was necessary to be able to position the striker at almost any angle, that it have little recoil on the submersible, and that the sample be retrieved.

MAGNETOMETER

The technical problems here were well defined. A magnetometer had to be modified for high pressure operations, and a suitable recording system developed. The design of the cable/tow body for safe ascent/descent and emergency disconnect were major items.

HANDLING AND TRANSFER AT SEA

The major problem was to determine what accelerations could be considered acceptable in the alongside condition and then to size the equipment to various boat sizes.

DEEP SEA BIOLOGY

The monitoring of biological reaction rates at or near the deep sea floor required instrumentation development to:

- (1) Collect samples at pressure, introduce specific reactants into controlled volumes at specific times, and measure the effects of these reactants on the samples.
- (2) Collect essentially undisturbed samples.
- (3) Monitor the environment.

Each of the projects mentioned above required the solution to technical/engineering problems. Common problems for all objects to be attached to the submersible at anytime are:

- (1) Need to jettison in emergency.
- (2) Need to connect and disconnect at depth.
- (3) Need for communication with object.

Because of shape, weight, power and information rates, there was no universal solution. The shape and space restraints inside the submersible, and the limited AC power available often meant repackaging and some modification to equipment that otherwise would be "off the shelf" items.

II.4 The ARPA program began when a major refit program for ALVIN was underway. This was the replacement of the HY100 hull with a titanium hull and the accompanying modifications in other equipment to change ALVIN from a 6000 foot to 12,000 foot submersible. The plan was to do the actual replacements to ALVIN during the winter of 1972. Slippage of delivery time of the hull began in October 1972 just as ALVIN was being torn down. The slippage continued and ALVIN was not operational again until January 1974, so a whole year of diving was lost. The hull design has proven to be exceptionally good. A twin to the one in ALVIN has gone through many cycles and has been held at 22,500 foot equivalent depth for some time. Titanium can be worked and welded in thick sections and offers new dimensions in submarine construction.

III The Program

From the preceding it is seen that although the program was mainly concerned with developing technology for small deep submersibles, it was in effect a collection of smaller programs about this common theme. During the four plus years of existence, the program included 13 smaller projects, starting with nine in year one and ending with four in year four. This is outlined below.

Year 1 February 71 - January 72
 Year 2 February 72 - January 73
 Year 3 February 73 - January 74
 Year 4 February 74 - July 75

	<u>Years</u>
Handling/Transfer at Sea	1, 2
Submerged Navigation	1, 2, 3, 4
Deep Sea Rock Drill	1, 2, 3
Bottom Reconnaissance and Site Survey	1
Deep Sea Magnetometer	1, 2
Deep Sea Gravimeter	1, 2
Deep Sea Biological Equipment	1
Off Shore Industrial Waste Monitoring	1
Air, Seas System	1, 2
Self Contained Auxiliary Modular Platform	2, 3, 4
Modular Acoustic System	2, 3, 4
Hydraulic Impact Hammer	2, 3
Wide Area Illumination	3, 4

The Deep Sea Biological Equipment and Off Shore Industrial Waste Monitoring were terminated after one year as not being appropriate for ARPA. The small Air, Seas System project was dropped because of unavailability of aircraft support. Handling/Transfer at Sea was developed to the state where it could be passed on to COMPHIBLANT for continued work. The Deep Sea Gravimeter work was ended because any effective development looked exorbitantly expensive. The other projects were completed to satisfactory systems.

All of the shore side work proceeded on independent schedules. Testing of equipment with ALVIN depended upon the ALVIN schedule. Most of this work was done in the summer months when ALVIN was working out of Woods Hole. As mentioned above, the refit of ALVIN with a titanium hull eliminated its use from October 1972 until January 1974. The first ARPA dives with ALVIN were made in August 1971. (Dive schedule in Section VII.)

III.1 Program Objectives

- (a) Handling/Transfer at Sea - Demonstrate that use of shock absorbing systems such as aircraft landing gear could be used to good advantage on landing craft and other small craft to eliminate the danger and damage of coming alongside.

- (b) Submerged Navigation - Develop navigation system for deep submersibles that has an error of about five meters throughout the water column in an area of 8x8 nautical miles where the bottom may be quite rough.
- (c) Deep Sea Rock Drill - Develop a means of obtaining a hard rock oriented sample about two meters long.
- (d) Bottom Reconnaissance and Site Survey - Assemble instrumentation suite required to choose locations for submersible operations for specific missions.
- (e) Deep Sea Magnetometer - Modify commercially available equipment so that magnetic field measurements could be made from the submersible to an accuracy of 10 gammas.
- (f) Deep Sea Gravimeter - Develop a gravimeter sensitive to a few milligal that could be used while underway from a small submersible.
- (g) Deep Sea Biological Equipment - Develop O₂ respirometer, sediment trap, in situ pressure recovery system for fauna, all to be used with a deep submersible.
- (h) Off Shore Industrial Waste Monitoring - Develop techniques for identifying and measuring industrial organic waste material in coastal waters.
- (i) Air/Sea System - Demonstrate that arrays of sonobuoys in conjunction with explosive sources can be used to identify significant topographic features over wide areas of the ocean.
- (j) Self Contained Auxiliary Modular Platform - Design and build a platform to be placed and retrieved by ALVIN that could grip some bottoms, supply extra energy and be used as operating platform for some unattended functions (coring, drilling, lighting).
- (k) Modular Acoustic System - Develop a sonar suite that covers a frequency range 2-45 kHz with variable azimuth and elevation with a wide variety of wave forms and display modes, so that most acoustic needs could be obtained from one system.
- (l) Hydraulic Impact Hammer - Develop an equivalent to a large geology hammer that could be used from a hovering submersible.
- (m) WideArea Illumination - Develop an overhead lighting system for deep work so that a large area (60 foot radius) can be viewed from submersible.

III.2 Program Organization

The Woods Hole Oceanographic Institution's operating funds come primarily through Grants and Contracts from the U. S. Government. A directorate of seven people oversee the scientific and business operations of the Institution in toto; the scientific and technical work takes place in five departments each with a Department Chairman. Multi-project contracts often have a department chairman or a director as principal investigator; smaller contracts usually have a member of the scientific staff as principal investigator.

The Institution is one of the major oceanographic organizations in the world and is well equipped with laboratories, shops, ships and support personnel to perform scientific and technical work.

For the first two years A. E. Maxwell, Provost, was principal investigator for the ARPA work, for the last two years, E. E. Hays, Department Chairman of Ocean Engineering, was principal investigator.

Each of the projects of the ARPA program was under the direct control of a member of the scientific or technical staff. These individuals were the people who presented the proposed work to ARPA and ONR personnel in yearly site reviews, were well qualified in their special subjects and were motivated because of their own interest in that particular work. Quarterly and semiannual reports were prepared by these individuals and coordinated by the principal investigator.

Principal Investigator, E. E. Hays, Senior Scientist, Ph.D. Physics

Project:

Handling/Transfer at Sea
Submerged Navigation
Self Contained Auxiliary Modular Platform
Deep Sea Rock Drill
Bottom Reconnaissance and Site Survey
Deep Sea Magnetometer
Deep Sea Gravimeter
Deep Sea Biological Equipment
Off Shore Waste Monitoring
Air/Sea System

Project Leader:

Allyn Vine, Senior Scientist, M.S. Physics
W. M. Marquet, Research Specialist, M.S. E.E.
C. L. Winget, Research Specialist
R. von Herzen, Senior Scientist, Ph.D. Geophysics
E. Uchupi, Associate Scientist, Ph.D. Geology
J. Phillips, Associate Scientist, Ph.D. Geophysics
C. Bowin, Associate Scientist, Ph.D. Geophysics
P. Wiebe, Associate Scientist, Ph.D. Biology
O. Zafiriou, Associate Scientist, Ph.D. Chemistry
J. Heirtzler, Senior Scientist, Ph.D. Physics

Project:

Modular Acoustic System

Hydraulic Impact Hammer

Wide Area Illumination

Project Leader:

P. McElroy, Assistant Scientist,
Ph.D. Physics

R. Ballard, Assistant Scientist,
Ph.D. Geology

D. Hosom, Research Associate,
M.S. E.E.

IV The Scientific and Technical Results and Accomplishments

This is a brief account for each project in the ARPA program. Details are available in the semi-annual reports and special reports listed in the references.

HANDLING/TRANSFER AT SEA

Several installations and tests of special energy absorbing devices on amphibious boats from four to 300 tons have given insight and design data on possible transfer of aircraft landing gear technology and concepts to boat handling to obtain safer and more reliable operations in rough seas.

Aircraft landing gear nosewheel assemblies mounted thwartships from the boats have formed the major starting point for these experiments. The landing gear contain the two requirements for alongside work-shock absorption and rolling. In addition they have been available from surplus and they are of very rugged construction.

Two S-2 nosewheel assemblies that were originally tested on a USGS 24 foot three ton work boat were later mounted on the four ton PL boat of the FRANCIS MARION (COMPHIBRON TEN). Approaches to the side of FRANCIS MARION were made at 10 knots and 20° closing angle. The boat was held for long periods both alongside and in the center well. The assemblies appreciably reduced the shocks and thumping that is usually encountered for such a boat using normal fendering procedure. This resulted in a much greater freedom to remain alongside.

On a 300 ton LCU of PLYMOUTH ROCK the after portion of five ton truck chassis with dual wheels, tires, and springs were mounted fore and aft with wheels mounted to roll vertically.

This arrangement greatly reduced the shock of the LCU on the mother-ship when lying alongside although it lacked the casting capabilities of the aircraft nose wheels.

KC-97 nosewheel assemblies were tested on a 120 ton M-8 with SHREVEPORT. Again the results showed that such fendering is far superior to the ordinary type used.

The conclusions of this work as forwarded to COMPHIBLANT were that current fendering practices could be improved considerably by introducing rolling surface shock absorbing devices to give decelerations over about one foot. The aircraft assemblies are an overkill but served to demonstrate that technical improvements might improve the safety and operational options of the Amphibious and Service Force Navy.

The cooperation of PHIBLANT staff and fleet units was excellent and the success of the tests was a tribute to their efforts.

SUBMERGED NAVIGATION

The distance between two points in the ocean can be determined by measuring the time it takes sound to travel from one point to the other. As the propagation speed of sound in the ocean is not constant, and the paths are not straight lines, accurate measurements of distance must take these variations into account. The navigation system for a submersible in deep water is in principle quite simple. Transponders, which are devices that emit a sound pulse when they receive a sound pulse of a certain frequency, are located on the bottom. The submersible periodically emits sound pulses which trigger the transponders and measures the time it takes to receive the responses from them. From these times the distances to the transponders are calculated, and from the known locations of the transponders and some trigonometry, the location of the submersible in reference to the transponder net is known.

If the transponders are also emitting a continuous sound wave the submersible can be tracked continuously by measuring the relative phase change of the received signals in reference to a precision oscillator aboard the submersible.

An operational system developed under this program, based on the pulse technique, is being used routinely with ALVIN. It differs from the "in principle" system above in that the main navigation center is aboard the mother-ship where there is room for the necessary data processing equipment, displays and the operator. Corrections are made for the sound velocity changes with depth from profiles obtained on location or historical data. The system also works on surface bounce paths which is necessary in rough terrain where the submersible is out of direct line to the transponders. In exploratory work the submersible's track is used to correlate photography and sampling areas. In other work the submersible is vectored to specific locations by the mother-ship. In an 8x8 miles net the accuracy of location is estimated to be about 5 meters - the repeatability in the net is several meters. This difference is due to uncertainty in the location of the transponders.

A combined pulse/Doppler system has been used to track hydrophones as a preliminary to use with the submersible. Here the accuracy of location to the net is about the same as above, but relative tracking during any one dive is within tens of centimeters.

DEEP SEA ROCK DRILL

Sampling of the rocky portion of the ocean bottom has always been difficult and uncertain, especially in obtaining oriented samples. A rock drill has been built and used that can obtain hard rock cores .735" in diameter and up to one meter in length.

This drill has been constructed so it can be either placed in position and recovered by ALVIN or used from a surface ship.

Six sites were drilled on the Mid-Atlantic Ridge during the FAMOUS expedition in 1974. Previous rock sampling of this ocean feature had only been done by dredging before the use of this drill.

DEEP SEA MAGNETOMETER

An airborne type proton precision magnetometer was modified to work at high pressures, and the associated electronics and recording system was made compatible with ALVIN. The magnetometer is towed behind and above ALVIN by a buoyant package and cable with a tension safety release. The noise in the total system is about 2 gammas. This system enables measurements to be made close to the bottom in high relief areas where towed systems are very difficult to use. The closer an anomaly can be approached the better is the definition of its shape.

DEEP SEA GRAVIMETER

As with magnetics, gravity anomalies are better defined the closer one can approach to them and it was hoped a gravimeter could be developed that would be useful in ALVIN within a relatively low cost budget. The desire was to measure gravity to about 0.1 milligal. To assess the problem, a vibrating string gravimeter in a temperature controlled oven was mounted on gimbals at the meta center of the craft with necessary auxiliary equipment. Tests showed that the accelerations of the submersible were too large to permit effective use of such a gravity system. Investigations were made into miniature gyrostabilized platforms for the gravimeter. While such devices are within the present state of technology the funding requirements are too high.

DEEP SEA BIOLOGICAL EQUIPMENT

The one year venture by ARPA into deep sea biology was very worthwhile to the Woods Hole biologists. Several instruments were developed and this impetus started several new lines of investigation that are continuing. Evidence from food that remained on ALVIN for approximately one year at 4500 foot depth indicated biological activity was very slow at those depths. A series of respirometers to measure O₂ uptake were constructed with the provision to selectively poison the bacteria and the fauna, so that the O₂ uptake by bacteria, the fauna, and the sediments could be measured separately. Measurements show that the uptake is an order of magnitude less than in shallow water. As a follow on to the ARPA work, instruments have been built to recover bacteria and fauna at depth under pressure and to maintain them in the laboratory that way, so that effects of variations in environment can be studied under controlled conditions.

A Longhurst-Hardy Plankton Recorder System was constructed for use with ALVIN. This instrument essentially stores plankton strained from the water in such a way that the type and number can be related to the volume of water swept clear, the temperature, salinity and pressure.

A sediment trap was constructed. This collects the sediment that rains

down to the bottom in the sea and forms the basis for petroleum deposits that are found.

These three items above tie together much of the biological energetics of the ocean, the light dependent plankton above and the benthic systems below. The complicated relation between these and its sensitivity to man-made influences is a long term goal of the biologist.

OFF SHORE MONITORING OF INDUSTRIAL WASTES

This was a small effort applying techniques developed for analysis of organic substances in oceanic water to the determination of concentrations and sources of pollution in harbors. Over 150 gas chromatographic analyses were performed on samples from cruises in New Bedford Harbor. The technical results were:

- (1) Strong indications that samples altered between collection and final extraction in the laboratory. (Collection technique needs modification.)
- (2) All samples yielded large total signals.
- (3) The material in the samples, on the basis of known biogeochemistry does not arise from natural processes.
- (4) The samples were all extremely complex in composition showing a partially resolved suite of peaks ranging from low to high molecular weights.

This chromatographic analysis method has received considerable attention since this early work (1971) here and elsewhere, and now serves as the basis for identification of certain types of spills and pollution.

AIR/SEA SYSTEM

The purpose of this system was to map major topographic features over large areas of the ocean using an array of sonobuoys and explosive charges. The ARPA program was to be a small effort - essentially testing the system. Unfortunately when the logistics for the test were finally completed (Navy aircraft were used) the test was aborted because of a failure aboard the aircraft. The unavailability of aircraft put the next test well into the future. The development of long towed arrays about the same time superseded the need for the sonobuoy array and the project was dropped.

HYDRAULIC IMPACT HAMMER

A surveying geologist's indispensable tool is his rock hammer. Each outcrop is sampled and the geologic structure and its history is based on the analysis of the samples. Sampling the rough or sloping areas of the ocean has the same goals, but the mechanics are much more difficult. The tool must deliver a substantial impact at different angles in relation to the submersible, work with little recoil on the craft, be releasable in case

it becomes wedged in the rock, and match all safety requirements for deep submergence. Such a tool has been constructed. It consists of an arm mechanism for positioning, a hydraulically cocked-spring loaded hammer drive using a baffle to absorb the recoil by water. The hammer drive can be jettisoned, the arm can be jettisoned, as well as the sample basket and electric-to-hydraulic power conversion unit.

SELF CONTAINED AUXILIARY MODULAR PLATFORM

A platform has been constructed to extend the energy supply and payload capabilities of ALVIN. It is designed to add nine kwh of energy and 400 pounds of payload. It can be carried by ALVIN to a location on the bottom, detached, perform the mission and be reattached and carried back to the surface by ALVIN. It is capable of clamping itself to most bottoms by suction pods. An optical command system with 100 commands forms the communication link between the platform and ALVIN. This system includes a read-out to the pilot to show the command has been executed.

MODULAR ACOUSTIC SYSTEM

An acoustic suite has been designed and constructed for ALVIN that should answer most user requirements for acoustical transmission and reception. Depending on the mission the requirements can vary greatly. Different frequencies and wave shapes are needed with different orientations of the transducers. This system has a transducer mount trainable in azimuth and elevation. Three transducers are available to use in the frequency range from 2 to 45 kHz. Simple wave forms and frequency selections are available manually in the submersible. More complicated wave forms are arrived at by preloading the wave form into a digital computer, programmed by prewritten cassettes which can then be used to control the output during the dive. All signal returns are recorded on magnetic tape in correlation with the important navigation information so that the dive can be reconstructed. Visual display is available on a small video screen (several choices of mode) so interesting events can be investigated; a camera is available to record the display. Seismic profiling, side looking sonar, three dimensional topography mapping, volume reverberation and scattering studies can now be performed using this basic system.

WIDE AREA ILLUMINATION

Lighting for deep submersibles is usually supplied by several high intensity lamps mounted directly on the submersible or on protruding booms. The zone of visibility is reduced by two effects - the large intensity contrast with range, and back scattering by small particles in the high intensity regions near the lights and viewing ports. A package has been developed to put the light source above the submersible (20 feet) so that the net effect is much like a street light. This has been constructed so it can be used with the submersible moving slowly.

BOTTOM RECONNAISSANCE AND SITE SURVEY

During the first year of the contract, appreciable effort went into acquiring and testing equipment to use with ALVIN and the mother-ship LULU. The most important pieces of equipment were a calibrated photographic system, a subbottom profiler for the submersible, a seismic profiler for the mother-ship and an Omega navigation unit.

V Considerations for the Future

The Advanced Marine Technology program did not attack the two major problems in the use of deep submersibles. These two problems are: 1) the limitation of energy and power and 2) the slowness of submersible delivery and weather limitations to launch and recovery operations. The technology for solution of the former problem is nearly in hand, in the form of the Brayton or Stirling engine and in fuel cells. Ranges of hundreds of miles and speeds up to 10 knots are not unrealistic to consider. For the second problem, launch and recovery of a small deep submersible from a conventional size submarine can be done now, and is the best for certain military operations. However rapid delivery to destinations thousands of miles away and then launch and recovery (or tending) from locally available surface ships is in an unsatisfactory state.

A development attacking the two major problems is a multimillion dollar undertaking, and the end product tends to be an emergency device (although the increased energy/power development would make all small submersibles more effective). Technological developments in circuits and data processing continually reduce space and power requirements for submersibles excluding the main propulsion. A vigorous program in submersible development exploiting the technology of the last five years would produce a craft considerably different from ALVIN. The W.H.O.I./ARPA program was primarily concerned with improving the capability of ALVIN (and deep submersibles in general) to survey areas of the ocean from a scientific or applied purpose rather than submersible development per se.

The ALVIN/LULU system has become a UNOLS facility (90% supported by ONR, NOAA and NSF) and is serving a wide spectrum of scientists, and all ARPA developed equipment is available for their use. The immediate military implications of this work is small, but any pressing military needs have high priority. Below are some of the military related operations carried out during the period of the ARPA program.

1971

December 8-9	Dives 389-390	Ordnance recovery dives for Navy
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1974

January 1	Dive 487	Recovered current meter array for NUSC
January 15-17	Dives 488-490	Inspected disabled AUTECH array for NUSC
July 28	Dive 531	Inspection of AFAR sonar tower.

1975

May 15	Dive 567	Search and Survey of a high interest area for NUSC, TOTO.
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VI Impact of the ARPA Program

As listed in Section IV the technology for deep submersibles has been considerably improved by the ARPA program. The navigation system is the most important of all the improvements. Other systems copied from it are now in use by the Geology and Geophysics Department, the Physical Oceanography Department, and essentially the same system is being marketed commercially by American Machine and Foundry (AMF). SUBDEV GROUP I is using this commercial system. Discussions have been held with Naval Underwater Systems Command, New London, concerning the application of the navigation technology to problems in the development of acoustic arrays under an ARPA program.

All of the equipment developed specifically for deep submersible use will be under the management of the Woods Hole Oceanographic Institution's Deep Submersible Group and will be maintained by them.

Some of the sampling technology developed under this program was applied to the NR-1's missions by Woods Hole personnel. The Deep Sea Rock Drill can be used separately from a ship and is under the management of Dr. R. von Herzen of the Geology and Geophysics Department.

The developments made in Handling and Transfer at sea have been transferred to COMPHIBLANT for further improvement and use.

The small impetus to deep sea biology has resulted in several new research programs at the Institution with equipment developments. Several devices for recovering samples under pressure with the capability of maintaining them at high pressure for controlled work in the laboratory have been constructed. A system for multiple-selective depth samplings of plankton with appropriate measurements of temperature, salinity and other quantities has been built and used. The "deep station" at which biological experiments are set up and revisited for recovery is continuing at several places.

VII References and Dive Schedule

A chronological description of the program is found in the semiannual reports as follows:

Woods Hole Oceanographic Institution Technical Progress Reports - Advanced Marine Technology.

<u>Report</u>	<u>Period</u>	<u>Issue Date</u>
W.H.O.I.-72-33	1 February 71 - 31 July 71	29 February 72
W.H.O.I.-72-90	1 August 71 - 31 January 72	30 November 72
W.H.O.I.-73-20	1 February 72 - 31 July 72	28 February 73
W.H.O.I.-73-37	1 August 72 - 31 January 73	1 June 73
W.H.O.I.-73-92	1 February - 31 July 73	1 December 73
W.H.O.I.-74-27	1 August 73 - 31 January 74	15 May 74
W.H.O.I.-74-100	1 February 74 - 31 July 74	December 74
W.H.O.I.-75-40	1 August 74 - 31 January 75	July 75

Reports and papers of interest to special topics are as follows:

Handling/Transfer at Sea

W.H.O.I.-74-92	Handling and Transfer at Sea Section A. C. Vine	13 December 1974
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Deep Sea Rock Drill

W.H.O.I.-75-28	Technical Report - ARPA Rock Drill Report R. Davis, D. Williams, R. von Herzen	June 1975
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Submerged Navigation

A High Resolution Pulse-Doppler Underwater Acoustic Navigation System;
R. C. Spindel, R. P. Porter, W. M. Marquet and J. L. Durham,
(In preparation).

A New Geological Undersea Survey Tool: ANGUS; J. Phillips, W. M. Marquet,
K. R. Peal and A. H. Driscoll, (In preparation).

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R. P. Porter, R. C. Spindel and R. J. Jaffee, "CW Beacon System for Hydrophone Motion Determination", J. Acoust. Soc. Am., 53, 1691-1699 (1973). W.H.O.I. No. 2995.

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Date	Dive No.	Location	Sponsor/ Purpose	PIC/CP	Obs.	Time			Depth M/Ft.	Remarks
						Dive	Surf	Sub.		
8/13/71	345	39-46N 70-40W	ARPA Biology	V. Wilson E. Bland	R. Turner	1038	1849	8-11	1810m	
8/25/71	346	39-46N 70-41W	ARPA Biology, Navigation	E. Bland R. Weaver	J. Teal	1140	1944	8-04	1825m	
8/31/71	347	W.H. Harbor	ONR/ARPA Nav. system check out	V. Wilson J. Donnelly	W. Marquet	1103	1302	1-59	70'	
9/7/71	350	42-23N 70-00W	ONR/ARPA Geology, Navigation	E. Bland	W. Marquet R. Oldale	1355	1730	3-35	210m	Strong current low visibility
9/8/71	351	42-23N 70-00W	ARPA Navigation	V. Wilson J. Donnelly	W. Marquet	1017	1138	1-21	89m	
11/12/71	371	24-56.9N 77-39.2W	ARPA Biology, Navigation	E. Bland J. Donnelly	W. Marquet	1136	1731	5-55	1770m	Search for location bottom bio station.
11/13/71	372	24-57N 77-39W	"	V. Wilson	T. Smith J. Houbrock (SMITHSONIAN)	1003	1704	7-01	1799m	Unable find triplane
11/15/71	373	25-00N 77-35W	ARPA Biology, Geology	E. Bland	R. Ballard G. Rowe	1042	1718	6-36	1048m	Hard rock bottom steep hills
11/16/71	374	25-00.2N 77-35.5W	ARPA Geology	V. Wilson J. Donnelly	R. Ballard	1151	1536	3-35	650m	Climbed up cliff face 650 to 16 meters.

11/17/71	375	25-00N 77-35W	ARPA Biology	E. Bland	G. Rowe J. Teal	1251	1736	4-45	662m	Unable find xpndr; box cores
11/18/71	376	25-00N 77-34W	ARPA Biology Navigation	V. Wilson J. Donnelly	J. Teal	1115	1638	5-23	749m	Planted bell jar
11/19/71	377	25-00N 77-34W	"	E. Bland J. Donnelly	W. Marquet	1027	1523	4-56	687m	Captured 2 specimens of new genus of sea worm
11/24/71	378	25-00.2N 77-32.5W	ARPA Rock drill test	V. Wilson J. Donnelly	None	1532	1615	0-43	18'	Tested drill release while submerged
11/25/71	379	25-00.2N 77-32.5W	"	V. Wilson J. Donnelly	None	1025	1354	3-29	42'	Unable to back clear of drill
11/26/71	380	24-58.2N 77-34W	ARPA Gravity test VB tests	E. Bland J. Donnelly	T. Aldrich	1406	1712	3-06	309m	Gravity profiles
11/27/71	381	24-58.6N 77-59.6W	ARPA VB test; nav. test	V. Wilson J. Donnelly	None	1200	1633	4-33	1821m	Precision nav. test
11/28/71	382	24-58N 77-39W	ARPA Biology	E. Bland	P. Weibe R. Steer (FREQ. DEVICES INC.)	1210	1722	5-12	1830m	Test plankton net at deep depths
11/30/71	383	24-57.8N 77-37.7W	ARPA Magnetics, Navigation	V. Wilson	B. Luyendyk A. Eliason	1127	1140	0-13	15m	Aborted - ground in magnetometer

11/30/71	384	24-57.8N 77-37.7W	ARPA Magnetics, Navigation	V. Wilson	B. Luyendyk A. Eliason	1408	1622	2-14	373m	Magnetometer not func- tioning
12/1/71	385	25-00N 77-33W	ARPA Rock drill tests	V. Wilson	A. Barrs	1252	1708	4-16	53'	Successful test
12/2/71	386	25-00N 77-34W	ARPA Biology, Magnetics	E. Bland	R. Steer D. Williams	1351	1657	3-06	301m	Successful magnetometer test
5/24/72	398	W. H. Harbor	ARPA Rock drill test	V. Wilson E. Bland	None	1445	1727	2-42	45'	Successful hook up
5/26/72	399	"	"	V. Wilson E. Bland	None	1101	1210	1-09	40'	Test sat- isfactory
5/27/72	400	42-31N 69-37W	"	V. Wilson	A. Barrs	1318	1330	0-12	300'	Aborted due to grounds
5/28/72	401	42-51N 68-52W	"	E. Bland	D. Williams	1037	1642	6-05	595'	Unable un- hook drill
5/29/72	402	42-51N 58-52W	"	V. Wilson	D. Williams	1010	1251	2-41	320'	Drill mal- functioned
5/31/72	403	42-38N 69-38W	ARPA Biology	E. Bland	G. Rowe R. Haedrich	1330	1431	1-01	920'	Trim problem
6/1/72	404	42-38N 69-38W	"	V. Wilson	G. Rowe R. Haedrich	1103	1502	3-59	925'	
7/7/72	417	42-31.5N 69-38.1W	ARPA Geology	E. Bland	A. Malahoff (ONR) R. Ballard	0901	1536	6-35	232m	Magnetometer runs. Rock hammer

7/8/72	418	43-09.5N 69-22.5W	ARPA Geology & Navigation	V. Wilson	J. Carlmark (ONR) W. Marquet	1348	1410	0-32	175m	UQC failed
7/9/72	419	43-09.5N 69-22.5W	"	V. Wilson	R. Ballard M. McCamis	0929	1605	6-36	130m	Rock hammer failed
7/10/72	420	43-10.5N 69-21.5W	ARPA Navigation	E. Bland J. Donnelly	W. Marquet	0957	1452	4-55	255m	Rough bottom

7/11/72	421	43-11N 69-21W	ARPA Geology	V. Wilson	R. Ballard D. Porter	1302	1830	5-28	159m	Rock hammer failed
7/12/72	422	43-10.5N 69-21.5W	ARPA Navigation	E. Bland J. Donnelly	D. Hosom	0835	1448	6-13	182m	Low vis- ibility rough bottom
7/13/72	423	43-13N 69-20W	ARPA Geology	V. Wilson	R. Ballard D. Porter	1132	1557	4-25	150m	-26-
7/14/72	424	42-43.5N 69-47.8W	ARPA Navigation	E. Bland J. Donnelly	J. Porteous	1029	1454	4-25	375m	Bottom nav. experiments

8/24/72	442	42-50N 68-55W	ARPA Geology Navigation	V. Wilson	W. Bryan J. Heirtzler	1412	1839	4-27	380'	
8/25/72	443	42-50N 68-55W	"	E. Bland	R. Ballard G. Bellaiche (CNEXO - France)	1129	1804	6-35	414'	Recovered xponder
8/26/72	444	42-50N 68-55W	"	V. Wilson	W. Bryan R. Ballard	1040	1637	5-57	390'	

8/27/72	445	42-50N 68-55W	"	V. Wilson	R. Ballard G. Bellaiche	0946	1515	5-29	400'	Navigation runs
8/29/72	446	42-50N 68-55W	ARPA Navigation	J. Donnelly	D. Foster A. Eliason	1028	1650	6-22	300'	Noise tests Nav. runs
8/30/72	447	42-50N 68-55W	ARPA Geology Navigation	J. Donnelly	W. Bryan G. Bellaiche	0958	1631	6-33	453'	
8/31/72	448	42-47.5N 68-52W	ARPA Navigation	E. Bland	D. Foster W. Page	0830	1315	4-47	501'	Nav. runs

10/11/72	460	39-46N 70-41W	ARPA/NSF Navigation Biology	E. Bland	F. Grassle J. Drogou (CNEXO - France)	0926	1815	8-49	1830m	Nav. ex- periments. cores
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5-6-75	562	24-52.8N 77-40W	ARPA Engineer- ing	V. Wilson J. Donnelly	L. Cole	1050	1207	1-17	1265m	Light tests UQC problems
5-6-75	563	24-52.8N 77-40.1W	"	V. Wilson J. Donnelly	L. Cole	1340	2123	7-43	2054m	Light Tests
5-8-75	564	24-53.1N 77-40W	"	L. Shumaker D. Foster	R. Turner	1157	2132	9-35	2077m	Light Tests
5-14-75	565	Autec Harbor	ARPA Scamp	V. Wilson J. Donnelly	D. Hosom	1135	1203	28	25'	
5-14-75	566	Autec Harbor	ARPA Scamp	V. Wilson J. Donnelly	D. Hosom	1336	1554	2-21	25'	

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Section II points out the relevance of the thirteen projects to future military requirements and the technical problems of each. Section III describes the history of the program and its relation to the Woods Hole Oceanographic Institution, and lists the project leaders.

Section IV of this report gives a brief description of the results of each project, and in Section VII there is a listing of publications that have resulted from the program as well as a table of pertinent information about the diving schedule of ALVIN.

(Cont.)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A program in Advanced Marine Technology was carried out at the Woods Hole Oceanographic Institution, under ARPA sponsorship from February 1971 until December 1975. The program consisted of thirteen projects with a total funding of \$1,993,000. Most of the projects improved the surveying, sampling, and measuring capabilities of deep submersibles using ALVIN as the test vehicle. The		

capabilities required to evaluate an area of the ocean bottom for deployment of large pieces of equipment or arrays included precise three dimensional navigation (page 12), photography (page 16), acoustic mapping (page 15), sampling of materials (page 12, 14) and magnetic and gravity field measurements (page 13). In addition to the submersible oriented projects there were projects on Handling and Transfer at Sea (page 11), Deep Sea Biological Equipment (page 13), and Offshore Industrial Waste Monitoring (page 14). Submerged navigation, a Modular Acoustic Suite for ALVIN, and ALVIN operation expenses each accounted for about 20% of the total budget.

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