UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

REPORT OF THE UNOLS ALVIN REVIEW COMMITTEE

TO THE UNOLS ADVISORY COUNCIL

OF

THE CONTINUED ROLE OF DSRV ALVIN

CONTENTS

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Report of the UNOLS ALVIN Review Committee to the UNOLS Advisory Council on THE CONTINUED ROLE OF DSRV ALVIN

I. BACKGROUND

The UNOLS ALVIN Review Committee functions as a recommending body for the operation of ALVIN as a National Oceanographic Facility under the UNOLS Charter. Under the terms of the ONR-NSF-NOAA Memorandum of Agreement, 7 November 1974, DSRV ALVIN operates as a National Oceanographic Facility for the Calendar Years 1975-1977 with annual support funding provided by those Agencies. Upon entering the final year of the agreement, the ALVIN Review Committee was asked by the UNOLS Advisory Council for recommendations to be developed regarding the future support of ALVIN as a National Oceanographic Facility.

This report addresses and includes recommendations for the scientific uses of ALVIN, the administrative and funding arrangements, and future technical improvements to assure the most effective role of ALVIN as an ongoing and important facility for ocean science and technology. While this report is addressed primarily to the UNOLS Advisory Council, it also is being made available for limited wider distribution.

II. SCIENTIFIC USES

A detailed summary of the scientific and technological use of ALVIN is in preparation at W.H.O.I. under the provisional title of "DSRV ALVIN: A Review of Accomplishments." The following two sections strive to summarize some of the more significant scientific uses of ALVIN.

A. Geological Studies

The use of ALVIN as well as other deep submersibles by members of the geological and geophysical community has undergone considerable evolution over the past five years. With the advent of more advanced instrumentation coupled with a refinement of our basic geologic concepts of the deep-sea floor, we have seen the use of ALVIN change from applications involving the submersible primarily as an isolated observational platform to comprehensive field programs in which the submersible is one of several techniques being used to investigate geologic processes of fundamental importance. Through this evolutionary development, the submersible is presently being used in earth science and technology programs in six basic ways:

(1) The most traditional application of ALVIN has been by geologists interested in investigating stratigraphic sequences of the seafloor and, to a lesser extent, structural relationships. These investigations have been conducted by a variety of direct and indirect techniques such as echo-sounding, seismic profiling, dredging, coring, and photography. Based upon an analysis of these data, specific sites of key importance are selected to determine the geologic history of a region. A quick review of ALVIN's past diving activity shows several such programs: the Gulf of Maine sampling program, the New England seamount study, the investigation of the Straits of Florida, and the recent investigation of the Puerto Rico Trench and Navidad Bank.

An excellent example of the unique role the submersible plays in such an application is the Gulf of Maine program. Seismic reflection profile surveys across this large continental embayment, equal in size to all of New England, were carried out for over ten years. From these profiles a three-dimensional framework of the subsurface geology of the region was obtained. Key geologic units were traced to scattered outcrops as exposed bedrock terrain. The next logical step in this study was to obtain representative samples of the geologic units. Based upon a petrologic analysis of the samples, geologists were able to relate these units to the well-mapped onshore regions nearby. Conventional dredging operations in the Gulf of Maine, however, were impossible. This region, as well as other continental margin areas at high northern latitudes, had experienced glaciation during the Pleistocene. As a result, the seafloor is covered with countless glacial boulders of all sizes and widely varying composition--most of which fail to reflect the true composition of the outcrops. Once the outcrop area had been identified through seismic profiling, the ALVIN was launched, and by use of its sonar, potential outcrop targets were located and, using a variety of sampling tools, representative samples were collected. To prove the superiority of this technique over conventional dredging operations, six outcrop sites were sampled using both techniques. In all six instances the composition of the outcrop based upon dredging techniques was found to be wrong when compared to samples collected by the submersible at the same place.

(2) Another traditional application of ALVIN by geologists has dealt with the investigation of benthic boundary layer sedimentary processes. Of particular interest has been the large submarine canyons off the East Coast of the United States. Numerous dives have been conducted in Hudson, Abaco, Great Bahama, Hydrographer and Oceanographer Canyons. Through direct observations they have studied the role benthic organisms and currents play in the excavation of canyon heads, the nature of sediment transport through the canyons, and its eventual distribution at their mouths. The major contribution of these dives was to define the sedimentary regime and bottom and near-bottom dynamics within the canyon.

systems, thus gaining an understanding of the function of these canyons as natural conduits through which sediment is transported. In the Hudson Canyon program for example, the submersible was used to place a long period recording current meter in the very axis of the canyon to insure that the subsequent measurements truly reflected the bottom circulation system thought to be responsible for the resultant sediment transport.

Another example of the submersible's unique application occurred during the Straits of Florida program. Here for many years geologists had observed through seismic profiling, echo-sounding, coring, and photography the presence of numerous large elongated mounds in the axial region of the Straits. A variety of explanations had been advanced, but not until these features were directly inspected by scientists aboard ALVIN did their origin become evident. Through the entrapment of migrating sediments by benthic growth which acted as snow fences, large accumulations of material occurred. As this material lithified, new growth occurred on its surface resulting in further entrapment. The result was the formation of sedimentary features of considerable size and geological importance. Through the <u>in situ</u> inspection of these features, geologists were able to put the various clues together and develop a model to explain their origin.

(3) With the submersible now having established a high degree of reliability, with a diving depth equal to the average depth of the world's oceans, and with greatly improved scientific instrumentations, ALVIN can now become a part of integrated field programs dealing with the evolving theory of plate tectonics that is of major importance to earth scientists. The first of these comprehensive studies was Project FAMOUS. Here, for the first time, deep submersibles were used in concert with all the other major geological and geophysical techniques. A region of the Mid-Atlantic Ridge rift valley had been selected that was thought to mark the boundary between two segments of the earth's crust that are moving away from one another. Below this valley axis it was further thought that molten magma from the earth's interior was rising from the base of the lithosphere to fill this void, a portion of which is flowing out onto the floor of the valley forming rough volcanic terrain. The purpose of Project FAMOUS was to investigate this valley to better understand not only the genesis of newly-

forming oceanic crust but also its subsequent transport away from the valley axis as a result of sea-floor spreading processes. Using the Navy's LIBEC photography system, Scripps' Deep Tow unit, and conventional surface techniques, the area was intensively surveyed over a three-year period. As these studies progressed, specific problems of major importance were defined that could not be addressed using the above-mentioned techniques. Some of the questions raised were as follows. Where are the primary regions of volcanic activity, and what features are constructed? Once formed, how is the new crust rifted and transported laterally to make room for the next episode of volcanic activity? What is the nature of this faulted terrain, and in what divisable units is the crust being transported out of the rift valley? What crystallization history do the surface volcanic units reflect? Through precisely navigated traverses across the rift-valley floor, geologists were able to observe the associated volcanic and tectonic features and accurately sample the various volcanic flows. From these traverses and the analysis of the samples collected, answers to the questions outlined above have been formulated. At the present time, 15-20 manuscripts have been submitted to the Geological Society of America for publication as an entire issue of the Bulletin dedicated to Project FAMOUS.

In 1976, a major crustal study was conducted in the Cayman Trough. In this program, ALVIN's principal contributions dealt with detailed sampling of a series of fault scarps which expose the various crustal units making up the ocean lithosphere. Surface ship dredging operations on such steep scarps resulted in the collection of a jumbled mixture of rock types. It was impossible to determine from what crustal layer each sample came as well as their various field relationships. A series of 75 documented sample stations were occupied during which the submersible's precise depth and location were known. It appears from preliminary analysis that these samples are the first detailed sequence obtained that reflect the composition of layer 3, the primary oceanic layer.

(4) The use of ALVIN is continuing to evolve. Geochemists will begin a heavy utilization of the submersible as a result of the Galapagos study, which is planned in 1977. Through the adaptation of the GEOSECS package to ALVIN, geochemists will now be able to conduct laboratory experiments on the seafloor. Their present study is aimed at better understanding the nature of hydrothermal activity taking place in a region of crustal formation. Based upon

surface ship studies, it appears the submersible will be able to locate areas of hydrothermal circulation. It particularly is hoped that actual open fissures will be found. The submersible situated at the fissure opening will conduct a variety of experiments ranging from sampling the water emanating from the fissures to collecting potential deposits of material that may have precipitated out of the solution.

(5) Another application of the submersible, which is being thought of for the 1978-79 time period, is using ALVIN to establish a series of geodetic experiments on the crest of the East Pacific Rise. Such studies will be aimed at measuring the amount of crustal uplift in a region of active seafloor spreading. The submersible would be used to precisely position the instruments as well as periodically service them.

(6) In the early 1970's, the use of ALVIN by the geological and geophysical community assumed a new direction. With the expected doubling of ALVIN's depth capability, it became clear that regions of the deep-sea floor where fundamental processes associated with the origin and transport of the earth's lithosphere occurred could now be investigated with ALVIN. Before such investigations could take place,

however, major improvements were necessary in the submersible's scientific instrument systems. Under Advanced Research Projects Agency (ARPA) sponsorship, a comprehensive development program began that eventually led to the development of an advanced acoustical transponder navigation system, a towed magnetometer, a prototype gravimeter, and a variety of sampling tools, which included small and large diamond bit drills and a hydraulic impact hammer. The navigation system, in particular, now makes it possible to recreate the track of the submersible to an accuracy in the range of a few meters. Developments resulting from the ARPA effort, which was a major one, are now a part of many of the subsequent geology programs. During Project FAMOUS, for example, emphasis was placed upon developing a data logging system within ALVIN to record the behavior of the vehicle (depth, altitude, heading, etc.) as a function of time. In this way all observations, samples, and photographs taken from the submersible can now be oriented in time and space relative to the submersible's navigated track and ultimately to precision topographic maps of the regions under study. During the Cayman Trough program, emphasis was placed upon upgrading the submersible's photographic capability, while for the proposed Galápagos study, the emphasis is upon improved geochemical sampling and data logging.

For the geological use of ALVIN the key words are "selective sampling." ALVIN serves the geologist-geochemist most significantly by allowing precise sampling and defining the position of the sample relative to its surroundings. ALVIN provides the <u>only</u> means for the selective sampling required in the types of studies noted above.

Some of the more important scientific problems that have emerged from prior and present studies and which need to be undertaken are summarized in Table 1, at end of the next section. It is emphasized that only selective problems are cited in Table 1, which is not exhaustive.

B. <u>Biological Studies</u>

Recent experiments utilizing ALVIN have revolutionized our thinking about deep-sea biology. Instead of snap-shot views of the bottom from instruments lowered from surface ships and striking the bottom at haphazard places and intervals, we can now repeatedly return to permanent bottom stations both to conduct controlled experiments and to make periodic observations of distribution, abundance, and activity.

Most of the early work with ALVIN has concentrated on the description of undescribed species, spatial pattern of animals, and their movement and behavior as observed from the submersible viewing ports. Increasingly, and partly as a result of the insights gained from direct observation, biologists began using ALVIN to conduct long-term experiments on the seafloor. We are beginning to learn how deep-sea ecosystems function from these experiments.

Two bottom stations were established off New England at depths of 1830 m and 3640 m in areas already intensively studied from surface vessels, and another station was established at a depth of 2030 m in the Tongue of the Ocean. The experimental work accomplished thus far has been conducted primarily on 24 NSF-sponsored dives at these bottom stations. Each of the experiments completed represents the first direct measurement of a biological rate process.

Rates of microbial activity have been shown to be 10-500 times lower than in shallow-water environments. ALVIN has been used to sample bacterial populations in the sediment and in the water column. Following _in situ_ innoculation, the bacteria are incubated with isotopically labeled substrates for varying periods of time up to 15 months on the bottom. Solidified organic materials exposed for 15 months also show little evidence of microbial disintegration. ALVIN is required for the *in situ* innoculation of labeled substrates in selected regions of the water column and sediment surface and for long-term incubation experiments.

Boxes of azoic sediment have been employed to measure rates of colonization and growth of deep-sea infaunal animals. Boxes have been brought back after 2 months, 11 months, 17 months, and 26 months at one or another of the three permanent bottom stations. Rates of recruitment and growth were found to be extremely low in comparison with shallow water. After 26 months on the bottom, the density of life was still an order of magnitude lower than in surrounding sediments and almost all of the animals were juveniles. Of the few adults found after 26 months, all but two belonged to a single polychaete species. This species had not been collected previously in the deep Atlantic. The azoic sediment experiments provide the first direct measurements of the recovery rates of deep-sea communities following disturbance. Disturbances are relatively uncommon in the deep sea, but the effects are present for long intervals. This suggests that disturbance is important in structuring deep-sea communities. In this work, ALVIN is needed to manipulate and retrieve experiments that have been on the bottom for a year or longer.

Respiration measurements have been made at both bottom stations off New England and at the station in the Tongue of the Ocean. Instruments were designed to measure *in situ* respiration of benthic communities. The rates of community respiration are two orders of magnitude lower than in shallow water environments.

Recent *in situ* measurements of respiration rates were made on deep-sea fish and larger invertebrates. The results support the initial findings of low rates of metabolism in deep-sea organisms. ALVIN is needed for selectively capturing organisms, for precise positioning of instruments with respect to organisms and other features of the bottom, and for gentle placement so as not to disturb bottom sediments.

A sediment trap was placed in the Tongue of the Ocean and an array of sediment traps has been placed and retrieved using ALVIN at the 3640 m station off New England. Rates of sedimentation of particulate matter were higher than had been previously thought. Rates of accumulation may determine other rates of biological activity.

Studies of wood panels placed in the deep sea at the three permanent bottom stations providedthe single exception to the generalization that life processes proceed at very low rates in the deep sea. In a period of three months the wood panels became riddled with dense populations of two species of wood borers indicating rates of recruitment and growth closer to those measured in shallow-water environments. The wood habitat of these animals is normally an ephemeral resource in the deep sea and the wood borers are opportunistic species adapted to survive in a short-lived habitat such as the wood that occasionally reaches the deep sea.

The existence of species adapted to use wood as a prime food source suggests that wood may be an important source of organic matter for other deep-sea populations. By leaving wood in place for periods of a year or more, it is possible to follow the sequence of species that may depend on it as a source of nutriment. First the wood-boring molluscs settle followed by opportunistic polychaete species of genus *Capitella*. Simultaneously, or shortly thereafter, a number of predatory polychaetes and crustaceas settle and feed on the *Capitella* and borers.

A number of unique observations of the behavior and habits of bottom-dwelling forms have been published or are in preparation. Our knowledge of locomotion and feeding behavior of the readily observed deep-sea species has been obtained mostly from studies using ALVIN. In many instances unique small-scale features of the bottom have been observed and singled out for special comparative studies. For example, concentrations of organic matter have been seen such as salps drifting over the bottom in the Hudson Canyon or large mats of detritus in the Tongue of the Ocean. Eel grass from shallow water litters the bottom in the deepest diving depths.

Spatial pattern of benthic invertebrates at different depths along the Gay Head--Bermuda transect was analyzed on scales from 20 x 20 cm to hundreds of meters. Each of these areas had previously been the subject of detailed investigations of benthic fauna from surface ships. Unlike most shallow-water and terrestrial populations, most of the large visible animals were randomly distributed at all scales. One species of urchin responded to food aggregations and another moved in herds 40-50 m in diameter. The plankton populations that live immediately above the bottom have also been studied and shown to be quite different from those in the overlying water column.

With increased interest in bottom station work both in the Atlantic and Pacific, an integrated program for the study of benthic boundary layer processes is developing. This program will include large-scale perturbation experiments (applications of concentrations of organic matter, defaunation of large areas, etc.), determinations of the fate of natural and man-made waste materials, introductions of radioactive tracer materials (both to follow the paths of organic compounds and to assess microbial transformations), and fine-scale observations and manipulations of animal-sediment interactions. Several ALVIN capabilities are critical to the success of such observations and experiments and are not easily duplicated by other research vessels or tools:

(1) the ability to selectively and precisely locate samples;

(2) the ability to selectively locate and deploy experimental apparatus;

(3) the ability to relocate, monitor, manipulate and sample experiments on a long-term, open-ended basis. Ongoing and proposed applications which require these functions are outlined in Table 1.

TABLE 1

SELECTED AND ABBREVIATED SCIENTIFIC INVESTIGATIONS THAT REQUIRE SUBMERSIBLES

GEOLOGY

INVESTIGATION	SUBMERSIBLE NEED
Volcanic processes	Inventory, describe, and delineate fine-scale volcanic topography, distinguish volcanic phases of different age; identify axes of intrusion; collect precisely and closely-spaced samples to determine petrologic, geochemical and age gradients showing existence and evolution of magma chambers.
Hydrothermal activity, geochemical processes, and metalliferous sediments.	Locate active vents; determine heat and seawater budgets; quantify fluxes of matter from seawater into rocks during alteration of mid-ocean ridge crust.
Seafloor geodetic experiments.	Select sites, secure ocean-bottom seismometers, acoustic bench marks, and other geodetic instruments to seafloor, and service equipment.
Magnetic experiments.	Investigation of Brunhes/Matayama reversal boundary by detailed sampling of reversely magnetized lavas and by determining crustal polarity.
Transform faults and transform fault-rise intersections.	Sample precisely-identified crustal levels and tectonic situations in complex geologic terrains.

BIOLOGY

INVESTIGATION	SUBMERSIBLE NEED
Metabolic rates and rates of microbial activity.	*In situ* innoculation; precise sampling of layers of water column sediments; *in situ* incumbation over long intervals of time. Place instruments with minimum disturbance of organisms; capture animals.
Rates of recruitment and growth of benthic populations.	Modify bottom (azoic sediments, concentration of organic material such as dead whale) and sample precisely with respect to the disturbance over intervals of time of a year and longer.

TABLE 1 (CONTINUED)

Rates of input and spread of organic materials.	Study of organisms and organic geochemical processes with respect to large concentrations of organic matter such as wood islands or a whale. Collect bottom samples in immediate vicinity of sediment traps; ascertain whether operation is as expected, measurement of spread of labelled compounds.
Sediment reworking.	Use of exotic minerals to study rates of bioturbation.
Fine-scale studies of water movements and sediment transport.	Placement of sensitive current meters with respect to organisms, topography of the bottom and sedimentary structures.

Although the deep-ocean floor is the single largest habitat on the earth's surface, man's potential impact on the deep-sea environment is poorly understood. Disturbances such as the dumping of wastes or deep-sea mining may have a marked effect on the unique fauna of the deep sea. Information on rates of degradation of organic wastes, rates of spread of materials, and rates of recovery of deep-sea populations will have urgent relevance in the future.

III. ADMINISTRATIVE ARRANGEMENTS

A. UNOLS Review Committee

As a National Oceanographic Facility, proposals for use of ALVIN are received by the UNOLS Office annually on a project-by-project basis. The Committee reviews these requests and recommends the accomplishment of selected programs on the basis of:

(1) Scientific merit

(2) Demonstrated need for submersible time

(3) Feasibility for ALVIN operations

Exceptions to the above occur in the terms of the Joint Agreement where NOAA reserves the right to specify its share of ALVIN use, and where the Committee is instructed to give appropriate priority to NSF and Navy projects.

One of the major problems in reviewing projects for ALVIN use is the difficulty in evaluating proposals which have not been previously screened for merit by appropriate scientific peers. There has been too little time for the Committee to have such proposals properly evaluated so that an appropriately funded and well-planned year results.

In 1976, the schedule was pieced and patched as the year progressed. In hindsight, many of the mechanisms that led to this situation should have been implemented a year earlier. It is, above all, very clear that a much extended planning sequence must be initiated, with preliminary screening of initiatives, and idea development in user workshops, particularly where new users are involved. It would be a severe mistake, on the other hand, to make this filtering process exclusive when one is concerned with secondary missions. In fact, the specific policy of reserving a certain fraction of each year's effort for serendipitous project modifications to accommodate unforeseen things is extremely desirable. We must also beware of generalizing too freely on the basis of the present learning curve in use development. As the body of knowledge and expertise grows greater from submersible use by the skilled user community, as well as by the occasional user, fewer promotional gimmicks will be required. Instead, this effort could be directed to ways to protect the individual's initiatives and rights to ideas against loss by diffusive dissipation in the filtering process. A more thorny proposition is to say that only the most qualified users should have access to such an expensive tool, and that anybody who enjoys public support for his or her work has the responsibility to part with whatever precious ideas may have developed in favor of a diffuse group effort in the name of national scientific progress.

The key to improved scheduling lies in the development of programs, while not excluding individual projects of high scientific merit. Such programs must have the benefit of several years' development and a great deal of interaction between participating scientists and engineers. Rather than an annual assemblage of often uncoordinated projects, a science year should begin three years in advance with decisions on the nature of program(s), primary participants, and research sponsors. During the second year occurs the development of the scientific program, its review, further development and the coordination with new, additional projects of compatible and mutual interest. The third year becomes one of logistics and operational planning. This requires a long-term stability to the program to encourage investigations to follow this process. Within the framework of proposed three-year programs, it is understood that an access will be maintained to consider and to incorporate into the program individual projects assigned a high priority by the Review Committee that develop with a lead time shorter than 3 years.

A longer term approach allows a more comprehensive overview by the Committee and will more fully utilize the expertise for which it was appointed. Interaction between the Committee and Federal Program Managers as well as potential users also would be more fully realized. Committee efforts presently are being made to implement this procedure.

B. <u>Communications with Scientific Community/ Scientific Workshops</u>

One of the major shortcomings of the present ALVIN/UNOLS program is that from an organizational standpoint it has isolated the individual users. Each scientist or engineer submits his request to UNOLS unaware of what others are proposing. In addition, many new users of ALVIN are also unaware of the wide variety of instruments and techniques which have been developed by the experienced user. The result is not only an inefficient use of the submersible from an operational standpoint but also from the standpoint of effective scientific utilization.

One way of improving this situation is along the lines of the recent East and West Coast Workshops. Here, potential users assembled to exchange ideas and previous experience, to evaluate what has been learned, and to look into the future. From such meetings come meaningful and well thought out programs. It is suggested that such regional meetings be formulated under UNOLS and that they be held prior to the UNOLS meeting to provide a valuable first cut at future programs.

The reports of the ALVIN workshop held at Woods Hole on May 24, 1976, and the East Pacific Rise submersible workshop held in La Jolla on April 26-27, 1976, demonstrate in detail a continuing need for the ALVIN, as well as for other submersibles, in current U.S. scientific programs originating from many organizations and institutions. It is important to note that these two workshops have addressed only a part of the range of marine science and technology that can be uniquely investigated by the use of manned submersibles. Selected scientific problems abstracted from the reports of these two workshops, together with the proposed solution by deep-diving submersibles, primarily the ALVIN, are included in Table 1.

The workshops were spontaneous in nature and grew out of an interest in reviewing the past utilization of ALVIN and discussing what scientific programs might be carried out beyond the present three-year block-funded period that ends in 1977. Reports summarizing each workshop have been prepared by Dr. F. Grassle (East Coast) and Drs. K. Macdonald and F. Spiess (West Coast) and are available from the UNOLS Office.

In short, both groups developed strong arguments for using ALVIN in the Atlantic and Pacific Oceans each year beginning in 1978. When one reviews a map of the world showing the regions of the seafloor that can be reached by ALVIN, it is not surprising that a combined two-ocean program is being suggested (Figure 1A and B).

In December, while this report was in draft form, a UNOLS-sponsored workshop on ALVIN long-term scientific utilization was held at Stanford. Principal recommendations were five in number, listed in decreasing priority within two major categories:

I. Short-term improvements
   A. Improved surface support for the ALVIN system
   B. Improved submersible instrumentation

II. Long-term improvements
   A. Conversion of ALVIN to a 20,000 ft (6.1 km) diving depth
   B. Construction of a new surface-support ship
   C. Better working relationship between UNOLS and the U. S. Navy submersible program.

After E. R. Anderson
R & D Report 1252 U.S.N.E.L.

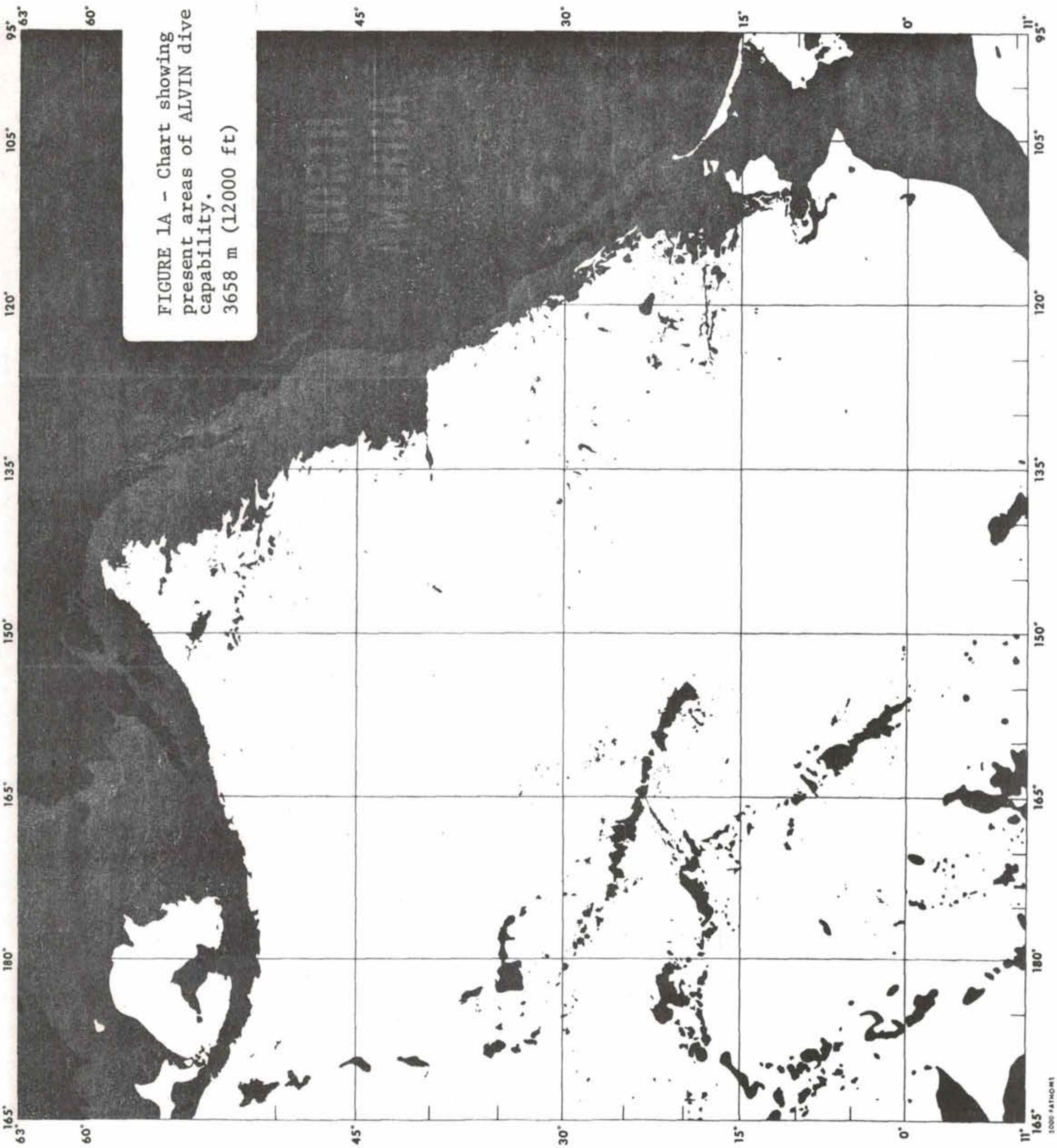

FIGURE 1A - Chart showing present areas of ALVIN dive capability.
3658 m (12000 ft)

After E. R. Anderson
R & D Report 1252 U.S.N.E.L.

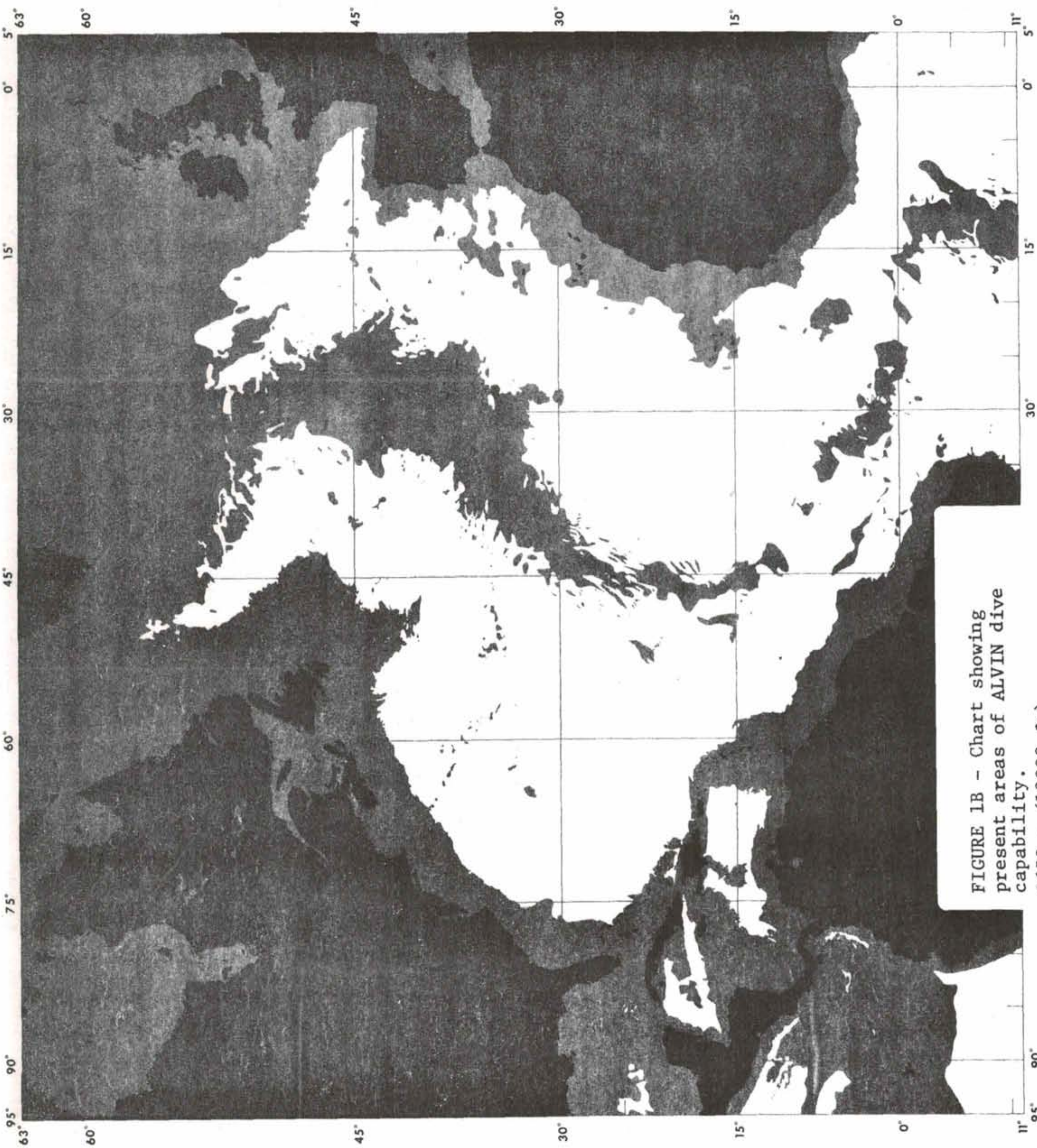

FIGURE 1B - Chart showing present areas of ALVIN dive capability.
3658 m (12000 ft)

All of these recommendations are actively being considered by the UNOLS Review Committee and/or Woods Hole Oceanographic Institution personnel.

IV. FUNDING ARRANGEMENT

A. Present Three-Year Period

From an administrative and operational standpoint, the current ALVIN support arrangement has been a mixed success. On one hand, many scientists have used ALVIN who might not have been able to do so, and the very survival of ALVIN in this period was assured by this arrangement. On the other hand, the arrangement did not achieve the goal of providing full support for the best and most science possible. Failure to achieve this full potential was particularly disturbing because the extra time available would have come at a minimum cost rate. For example, it is currently estimated that $900,000 operations funding will support about fifty actual dives, whereas $1,200,000 would support ninety dives.

Thus, in a large measure, the current support arrangement has had a failing in that it has not fully supported ALVIN for science although it was generally believed that this was the intent. Because the support was "block funding" not linked to any specific project, the result has been a reluctance by a support agency to contribute more on the premise that its programs are, or should be, under block funding. The situation was further aggravated by a defacto rivalry stemming from the days assigned for the projects of each agency although only one, NOAA, had beforehand specified a pro-rata share. In retrospect, it would have been administratively better if each agency had specified a use share commensurate with its funding. However, the quality of the science resulting from such an arrangement would probably not have been improved.

The current support structure for the ALVIN is subject to constraints due to agency missions, which may not be incompatible, but which require careful program planning--if tensions are to be avoided. One wishes in particular to avoid the scratching of approved science or engineering programs because of difficulty to accommodate non-scientific agency missions in geographically incompatible areas. If it is politically essential to include a significant element of service to applied mission aqencies in the total task for the boat, then one should at least strive to achieve equity in use over a several year cycle, rather than within each budget year.

B. Future Support

Any recommendation toward improving the current support arrangements for ALVIN must first deal with the virtues and vices of block funding. The previous section has submitted that the current block funding arrangement has achieved many benefits not previously available (i.e. numbers of projects, labs, scientists, etc.) and has indeed been vital to the very survival of the submersible for academic science. However, the nature of andconstraints to the current support have not realized the maximum use or achieved the best science possible.

Block funding is a luxury difficult to decline regardless of constraints. Nevertheless, if ALVIN is to achieve its maximum potential, its support should in some way be linked to science accomplishments. Furthermore, ALVIN science should be of such calibre and in a time frame such that operational support becomes unquestionable.

What might be envisioned for the future is not a funding agreement by the primary users for specified shares of a block amount, but rather a longer-term commitment in principle to support science and its concomitant operations requirements. Such an arrangement does not guarantee funds, but does convey a commitment in principle to the continued support of ALVIN science and technology based upon the orderly development of first-rate programs.

Agency commitments under this principle would vary from year to year and each Agency would know what ALVIN science its money is purchasing. The key factor is that commitments be made sufficiently in advance to allow for the best possible program development. Elements in this arrangement include workshops, continuing committee review, and negotiations with Federal Program Managers.

Various forms of funding have been examined to achieve explicitly the foregoing principles. Among these is a system of "base funding" of a block nature plus "incremental funding" apportioned explicitly to user projects. Such a method would stimulate use through the inducement of low-cost rates. On the other hand, it is difficult to rationalize how and who pays the base funding for which there is little direct return.

In the final analysis, it is not the role of this report to specify the mechanisms of Federal Agency funding, but rather to recommend that support be continued through the 1978-1980 term on a full-use basis and that the funding be apportioned equitably among the sponsors.

V. TECHNICAL IMPROVEMENTS

A deep-ocean research submersible is a dependent craft that requires a supporting ship. The most effective system capability for at sea operations requires that the submersible and its support ship be complementary. Weaknesses in any part of the system effects the whole. The users of ALVIN are in essentially full agreement that the primary deficiencies of the present ALVIN system are due to the limitations of LULU. This does not imply that LULU is a poor ship. Considering her size she has many outstanding and unusual capabilities. LULU was conceived and built as a low-cost, small, slow, highly-maneuverable, Atlantic-margin submersible support ship. LULU has been a success judged by these criteria. The designers of LULU did not know that ALVIN's capability eventually would be extended to 12,000 feet, that LULU would be asked to operate in increasingly remote areas, including the Pacific Ocean, and that the user scientists would like to use LULU as a conventional oceanographic platform while ALVIN is being serviced.

Viewed from the standpoint of today's experienced ALVIN user the key limitations of LULU are:

(1) Slow speed and limited endurance, which reduce on-station days, i.e. potential diving days.

(2) Marginal habitability for both scientists and crew.

(3) Very limited space and equipment for conventional shipboard oceanographic research.

We recommend that UNOLS seek funding to conduct a study to improve the submersible support system for ALVIN. A new ship designed to support remote area investigations using ALVIN, and at the same time employing the basic shipboard sensors is probably the long term solution. Until this can be accomplished, it may be necessary to consider relatively inexpensive short-term improvements to LULU. Consideration should also be given to effectively integrating ALVIN with another ship, such as the KNORR or MELVILLE, so that a ship could be employed in remote-area ALVIN missions and LULU could be used for more accessible area research.

ALVIN has proven to be an effective research tool and does not require major improvements to conduct the research that is envisioned for the medium term. Relative to the basic vehicle capabilities an increase in energy capacity would be advantageous in that it would permit more on-the-bottom time per dive. As with nearly all research platforms, there is a continuing need to keep improving the instrumentation. The new underwater cameras on ALVIN were purchased with funds from the NSF Office of Facilities & Support following a strong recommendation by the Review Committee. In a continuing effort to broaden user clientele, probes and sensors for water chemistry (such as recently used in a GEOSECS package), measurement of sediment density, shear strength, and pore water characteristics should be developed. An ongoing program to continue improving and adding to ALVIN instrumentation is important and submersible instrumentation would be an appropriate topic for a future workshop.

It is not too early to begin seriously thinking about the next generation of ocean research submersibles. Inputs are needed from the user-scientists, engineers, and operators, and a rational development schedule should be formulated. Recommendations made by personnel attending the Stanford Workshop address these problems. The report of this Workshop may be obtained from the UNOLS Office.

VI. SUMMARY OF RECOMMENDATIONS

1. There is a demonstrated continuing need for a deep submergence research facility available for academic research. Of presently available submersibles, ALVIN most nearly meets this need.

2. To gain the most widespread and effective use among university researchers, ALVIN should be continued as a UNOLS

National Oceanographic Facility.

3. The best use of ALVIN should be achieved by longer term (three years) and more coordinated planning than at present.

4. Funding support for ALVIN as a National Oceanographic Facility should be continued for the period 1978-1979-1980 on a basis to ensure full use of ALVIN throughout the period. Actual yearly funding should be apportioned between the sponsoring agencies in accordance with the actual benefits received.

5. The present support ship (LULU) is becoming obsolete and inadequate for the fullest possible use. A plan should be developed for the replacement of the support ship within a three-to-five year period. Upgrading the LULU may be required for operations in the next few years. Furthermore, a plan should be developed for continuing technical improvements to the ALVIN and its systems and ultimately leading to replacement of ALVIN.

VII. ACKNOWLEDGEMENTS

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