DESSC Working Group Meeting

Washington Courtyard by Marriott
The Oak Room
1900 Connecticut Ave, NW
Washington D.C.
March 20, 1997

Appendices

I. Agenda
II. Attendance List
III. Background Information regarding SEACLIFF Transition
IV. Update from ONR
V. DESSC Preliminary Response Regarding Long Range Plans
VI. Deep Submersibles and Potential Marine Geological Research
VII. Questionnaire Results

The following minutes represent a summary of the activities and discussions that took place at the DESSC Working Group meeting held at the Washington Courtyard by Marriott, Washington, D.C. on March 20, 1997. The meeting followed the agenda except as noted in these minutes, see *Appendix I*.

Introductory Remarks - Mike Perfit, Deep Submergence Science Committee (DESSC) Chair, called the meeting to order at 8:30 am. Working Group members introduced themselves. The attendance list for the meeting has been included as *Appendix II*.

Background Information - Mike Perfit provided the Working Group with the background on the Navy's plans to retire SEACLIFF and TURTLE, see *Appendix III*. The plans call for the retirement of TURTLE at the end of FY97 and SEACLIFF at the end of FY98. DESSC has been asked by the Navy for input regarding utilization of the Navy's deep submergence assets and an assessment of deep submergence research objectives for the next few decades. The Navy also approached WHOI requesting the cost implications for the Deep Submergence Group to transition SEACLIFF into the National Facility. DESSC sent a questionnaire to the community to solicit their views regarding these matters. A summary of the responses will be provided during the meeting.

Update from ONR - Sujata Millick (ONR) was unable to attend the meeting, but provided a written outline updating the background and status of SEACLIFF, see *Appendix IV*. Eight options for transitioning SEACLIFF have been discussed and are included in *Appendix IV*. Based on recommendations from UNOLS/DESSC, WHOI and

and *Appendix VII* includes the results from these surveys). Annette provided a series of viewgraphs displaying the survey results graphically, see *Appendix VII*.

Of the people submitting surveys, the largest number of responses came from biologists and marine geologists. The most popular research areas for both now and the future were for the mid-ocean ridges and the continental shelf/slope. The surveys showed that eighteen different ROV/tethered vehicles had been used. ROPOS and Jason were used most often by the survey group. Approximately 50% of the people submitting surveys indicated that they had not used ROVs in the past five years. ALVIN was by far the most used HOV with almost 50% of the total use of those responding to the survey. Twelve different HOVs were indicated as being used.

The survey showed that there is a good deal of interest to have access to a maximum depth range of 6,000m by deep submergence vehicles for the next twenty years. HOVs were shown as being very important to critical for depths to 4500m. They surveys showed that many thought there would be an HOV need to 6,000m. At depths greater than 6,000m, HOVs were less important as a scientific tool. Comments suggested that international assets should be considered for accessing deeper depths. There is no substitute for human presence and there is still a need for HOVs up to 4,500m. Work in the Western Pacific will require an HOV with deeper depth capability than 4500m. ROVs should be used for work at the deeper depths when feasible and development efforts should be made to make these vehicles more science capable. Responses were evenly dispersed between critical and not important when asked the degree of importance of having a human submersible between the depths of 4500 to 6,000m. Many of those who felt it was critical worked on the mid ocean ridges and in the Western Pacific. Also, many did not wish to lose the National capability for HOV access to 6,000m. Many of the people indicating that HOVs were not important at depths greater than 4,500m felt that the tasks could be handled by ROVs.

When asked to what extent could current and future science objectives be met at depths >4,500m, most indicated that between 50% and 100% of their work could be done by either HOVs or ROVs. Many felt that less than 10% of their work could be accomplished by AUVs. This was largely due to unfamiliarity of the AUVs and the fact that many of these vehicles have not been proven as mature science tools. Payload and sampling capabilities of HOVs and AUVs were pointed out as concerns. Some commented that both HOVs and ROVs are needed as deep submergence tools. There was also a comment regarding the bottom time limitations of HOVs at greater bottom depths.

Next, the survey results of Category B questions were reviewed. Many responded by answering "unsure" since they were unfamiliar with SEACLIFF or they were concerned with the financial implications of the option and could not answer with confidence. Many felt that SEACLIFF and ALVIN should be merged with the result being a 6,000m depth capable submersible. Others indicated that the systems should not be merged and that the systems should be kept intact as is. Others were concerned about SEACLIFF's capabilities and recommended that ALVIN's capabilities be preserved.

shore staffing. SEACLIFF modifications would be the same as those required in Option 4. Other issues to consider would be funding constraints and science demands.

Option 6 indicates that SEACLIFF and ALVIN would be operated alternately. The ATLANTIS modifications identified for Option 4 would also be required for this option. SEACLIFF modification for science and overhaul would be required. An additional maintenance crew would be required to retain the vehicle certifications during "off duty." Time would be necessary for changeover between the two vehicles and science equipment. The A-Frame and cradle would need adaptation. Sea Trials and training would be required after any extended lay-up of a vehicle. Spare parts for SEACLIFF would be needed.

Option 7 recommends modifying SEACLIFF using ALVIN equipment. Suitable ALVIN equipment may include its propulsion system, manipulators, video/lighting/imaging systems, power distribution, data logger, science basket concept and weight droppers. Conversion issues include engineering planning/funding and documentation. Spare parts quality and quantity needs to be defined. The manpower needed to handle the conversion may have an impact on ROV operations. Both vehicles would be off-line during the conversion. Eighteen to 24 months are estimated for the conversion effort.

Option 8 calls for modifying ALVIN with SEACLIFF's sphere and components. Suitable SEACLIFF components might include the variable ballast system, sonars, hydraulic system, unique Navy spares, UQC and similar equipment, instrumentation (depth, heading, voltages and altimeter), explosive bolts and syntactic foam. Conversion issues would be the same as those identified for Option 7. The conversion would take approximately eight months to complete.

WHOI is also considering an Option 9 which was not suggested by the Navy. This option would combine the best features of both ALVIN and SEACLIFF. It would require a frame-up redesign of the vehicle. The submersible would retain ALVIN's science capabilities and SEACLIFF's 6,000m depth capability. The new vehicle would have better hydrodynamics and be significantly lighter than SEACLIFF but still heavier than ALVIN. This option would require a major engineering effort. Consequences to be considered include a bigger and heavier vehicle in the end.

Dudley outlined WHOI's initial plan of action. They will work with Portsmouth Naval Shipyard on information transfer and provide ONR, DESSC and the Working Group with pertinent information regarding the costs, efforts and feasibility of the various options presented above. An update on the status of their study will be provided at the next general DESSC meeting in July. WHOI will plan for implementation of the recommended option during the next scheduled refit in the year 2000.

The Group strongly recommended using the funds saved by pursuing this option and new funding for development of a new ROV(s) for science with a depth capability of 6,000 to 9,000m and more payload capability. This would allow the scientific community to access nearly all of the areas of scientific interest and would represent a military contribution to the betterment of science and public welfare.

Other important points that were brought up during the discussion included;

Concerns about losing existing maneuverability and science capabilities,
Impact on science during conversion,
Funding for conversion and maintenance,
Extent of engineering effort required, and
Trade-off between 6000m capability and bottom-time.

The Group agreed that WHOI and DESSC must work together with the Navy to gather more specific information regarding the costs in time and money that options 7, 8, 9 and 8A represent and what the science capabilities of a merged vehicle are expected to be. A proposed ONR funded engineering study by WHOI of these options was recommended.

Working Group response and report to ONR: The Group outlined the major points and structure for the response letter to ONR. Justification of the important science needs supported by the results of the survey need to be included. There should be a link to the critical technical capabilities available. The structure of the Working Group report was outlined:

1. Working Group Task/membership
2. Questionnaire developed and distributed
3. Important science at 4,500m+
    - Support abyss report - improvements needed in ROVs
    - Address NRC report?
4. Results of questionnaire: Critical technical capabilities
    - Need for multiple platforms
    - Nested survey/science technology
5. Working Group response to Options 1 through 8A.
6. Recommendation of Working Group:
    - Preserve ALVIN's capabilities
    - Cost in dollars and time are critical
    - Preserve SEACLIFF assets for future
    - Science - DESSC/WHOI collaborative on long term plan.

Final Discussion: The meeting concluded with a discussion on the role of DESSC in serving as the community representative for all academic deep submergence facilities in

APPENDIX I

DESSC Working Group Meeting

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8:30 am **Start of Meeting (Juice, coffee, assorted pastries)**

- Introductions (M. Perfit)
- Brief review of background information
- Update from ONR
- Initial DESSC response to ONR
- Charge of Working Group

9:00 **Individual discussion (Group Members)**

Each member will be allotted a short time to provide his/her perspective on the important scientific objectives to meet at depths from 4500 to 6000m and the best tools to accomplish these objectives.

10:45 **Coffee break**

11:00 **Presentation of Results of Questionnaire (DeSilva/Perfit)**

Discussion of results

12:00 **Lunch (Everyone is on their own)**

1:00 **Presentation of current status of WHOI engineering study re: SEA CLIFF/ALVIN conversions/ upgrades (D. Foster)**

Questions/Discussion

2:00 **Open discussion regarding deep submergence needs for the 21st century and SEA CLIFF's role**

3:00 **Working Group response and report to ONR**

4:00 **Final discussion of Report**

5:00 **End of Meeting**

APPENDIX II

SEA CLIFF - March 20, 1997

Name	Institution	Phone/Fax
Kier Becker	U of Miami/RSMAS	305-361-4661/305-361-4632
Jim Bellingham	MIT	617-253-7136/617-258-5730
Annette DeSilva	UNOLS	401-874-6825/401-874-6167
Don Elthon	NSF	703-306-1586/703-306-0390
Bob Embley	NOAA/PMEL	541-867-0275/541-867-3907
Dan Fornari	WHOI	508-289-2857/508-457-2187
Dudley Foster	WHOI	508-289-2273/508-457-2109
Jeff Fox	Texas A&M/ODP	409-845-8480/409-845-1026
Patty Fryer	U of Hawaii	808-956-3146/808-956-6622
Paul Johnson	U of Washington	206-543-8474/206-543-0275
Marv Lilley	U of Washington	206-543-0895/206-543-0275
Peter Lonsdale	SIO	619-534-2855/619-534-6849
Mike Perfit	U of Florida	352-392-2188/352-392-9294
Karen Von Damm	U of New Hampshire	603-862-0142/603-862-2649

APPENDIX III

DESSC Preliminary Response Regarding Long Range Scientific Objectives and Vehicle/Facility Requirements for Deep Submergence, and Transitioning of Sea Cliff for use by Academic Research

- **September**: DESSC/UNOLS meeting S. Millick announces plans to retire DSV Sea Cliff and Turtle
- **October 7**: Letter from ONR (F. Saalfeld) to M. Perfit requesting DESSC input regarding utilization of the Navy deep submergence assets and preliminary assessment of deep sea scientific research objectives for the next few decades. List of 8 options.
- DESSC forms Working Group to address future directions and facility requirements for deep submergence
- **October 11**: Navy/ONR/NAVSEA reps. meet with WHOI-DSOG to discuss options provided by ONR and initial assessment of cost and effort required to transition Sea Cliff into the National Facility
- **November:** Meeting of Working Group delayed until community input can be solicited and feasibility study done by WHOI is complete.
- **December**: Initial deliberations by DESSC and preliminary response to Saalfeld.
- **December 13:** DESSC meeting. Discussion/input from community.
- **Early February:** A more formal and comprehensive assessment of these issues will be carried out by a working group comprised of experienced users of deep submergence facilities.
- Report to ONR March 1997.

• *A Single National Facility*

Adequate and long-term funding of a National Facility such as that currently at WHOI. Given the current federal funding constraints for both basic research and facilities support, and the level of technical knowledge and experience to operate deep diving submersibles, it would not be prudent at this time to consider developing additional National centers for operating deep submergence vehicle facilities.

• *Vehicle Systems*

To meet present and future research and engineering objectives, particularly with a multidisciplinary approach, deep submergence science will require a mix of vehicle systems. Vehicle depth capability should be to ~6000 m to allow for research over the widest range of tectonic, sedimentologic and geographic environments that will be investigated in the decades to come.

The DESSC endorses the plan for WHOI to provide a technical assessment and costing of how to best integrate Sea Cliff into the National Deep Submergence Facility, and believes that the deep submergence technical expertise at WHOI and their operational knowledge of Navy DSV systems makes this the logical approach to evaluating the technical and cost issues.

The DESSC feels that of the options provided by ONR, combining the best attributes of Alvin and Sea Cliff to produce a cost-efficient and capable deep diving submersible with a depth range of ~6000 m. Ignoring, for the moment, the considerable technical and budgetary issues that must be addressed in accomplishing this integration, the committee notes that if such an option is considered, that it will be important for the resulting submersible to retain all of the excellent science capabilities and operational characteristics (safety, reliability, maneuverability, bottom time) which Alvin currently has.

APPENDIX IV

DSV SEACLIFF & TURTLE BACKGROUND

- Navy (N873) intends to de-activate DSV TURTLE at the end of FY 97 and DSV SEACLIFF at the end of FY 98.

- The FOFCC FOCUS group convened in Sept 96 and decided to focus primarily on whether DSV SEACLIFF should be incorporated into the current capability.

- List of 8 possible options was generated by the Co-ordination Board.

- The Board requested UNOLS to evaluate the scientific need for such an asset, and WHOI (current ALVIN operator) to evaluate the technical feasibility of the options.

DSV SEACLIFF UPDATES

- DESSC has developed a survey questionnaire to poll the scientific community on future reqmts for vehicles and research directions.
- Report due by April 1997 to ONR, NSF, and NOAA

- WHOI is evaluating last 5 options. Will begin detailed engineering evaluation of the options this summer.
- Portsmouth Naval Shipyard will assist in the evaluation
- Analysis is due to be completed by Sept of 97, with report due to the agencies by Oct 97.
- Agencies will evaluate options, and make final decision by Dec 97.

APPENDIX V

UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

An association of institutions for the coordination and support of university oceanographic facilities.

MEMORANDUM

Date: December 5, 1996

To: Dr. F. E. Saalfeld, ONR

From: The DEep Submergence Science Committee (M. Perfit- Chair, J. Bellingham, R. Collier, P. Fryer, M. Lilley, H. Milburn, D. Orange, C. Van Dover, C. Wirsen)

Subject: Preliminary Response from DESSC Regarding Long Range Scientific Objectives and Vehicle/Facility Requirements for Deep Submergence, and Transitioning of SEACLIFF for use by Academic Research

The following assessment is in response to your request for input from the DEep Submergence Science Committee (DESSC) regarding utilization of the U.S. Navy's deep submergence assets. The DESSC has deliberated via electronic mail and telephone to provide a preliminary assessment of deep sea scientific research objectives for the next few decades, and the projected requirements for deep submergence vehicle systems and facilities to meet those needs. In accordance with the DESSC's overall plan to include the perspectives and requirements of the deep submergence research community in this planning process, a more formal and comprehensive assessment of these issues will be carried out by a working group comprised of experienced users of deep submergence facilities. This ad hoc group will meet in early February and will submit a report to you in the Spring of 1997. In the interim, the DESSC considers it important to provide you and the agencies with a written statement concerning these matters that would help guide your policy decisions in the near-term.

We hope that this preliminary assessment is useful to you and welcome your comments. We will keep you appraised of our progress in getting community input on these important issues and plan for it to be an agenda item for discussion at the upcoming DESSC meeting at the San Francisco AGU.

Best Regards,

Mike Perfit, DESSC Chair

Copy to:
WHOI
NOAA
NSF
N096
N873

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Phone: (401) 792-6825
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Present Status and Future Deep Submergence Vehicle and Facility Requirements

The U.S. academic research community has routine, observational access to the deep ocean and sea floor down to 6000 m depth via the National Deep Submergence Facilities operated for UNOLS by the Woods Hole Oceanographic Institution. The vehicle systems of the National Facility currently include the submersible ALVIN which can dive to a depth of 4500 m, and the remotely operated vehicle (ROV) Jason, Argo II imaging system, and DSL-120 sonar which can work at depths as great as 6000 m.

Over the past 5-7 years the U.S. Navy submersibles SEACLIFF and TURTLE, and ROV ATV have been made available for limited academic research through a cooperative arrangement between NOAA and the U.S. Navy's Submarine Development Group 1 in San Diego, CA. These vehicles have expanded opportunities for peer-reviewed deep submergence research off the U.S. west coast. SEACLIFF and ATV have provided the science community with some additional access to the deep sea and permitted observations to depths ~6000 m, a depth range otherwise only available by using ROV Jason or the other tethered vehicles of the National Deep Submergence Facility. This increase of 1500 m over ALVIN's limits provides access to 37% more of the sea floor which represents an area that is greater than 90% of the surface area presently exposed on the continents.

A very limited amount of additional submersible diving by U.S. scientists to depths as great as 6000 m has been carried out in the southern East Pacific Rise, Mid-Atlantic Ridge, Hess Deep, and southwest Pacific using the French, Japanese or Russian submersibles Nautile, Shinkai-6500, and MIRs, respectively. Experience over the past few years has shown that the use of foreign submersible assets, while conceptually appealing, is hampered by conflicting foreign national interests and differences in scheduling and funding processes. Consequently, access by U.S. investigators to those facilities is limited and will likely remain so.

These facts, coupled with the Navy's decision to decommission SEACLIFF, provide an important opportunity to define and plan the future vehicle composition of the U.S. National Deep Submergence Facility to meet the projected scientific objectives of the coming decades. The DESSC believes that there are three critical areas which must be addressed if the U.S. is going to continue to be a leader in the science and technology of deep ocean research. They are:

- A focused, cost-effective, and technically capable national deep submergence facility and operator,
- An integrated mix of vehicle systems including submersible(s), ROV(s), tethered mapping systems and AUVs, and
- A stable, federal funding base to support science, technology and enabling vehicle and ship facilities in the deep ocean.

effective exploration and detailed investigation and sampling of remote sea floor areas. AUVs, both smaller, faster designs like the MIT-Odyssey, and the slower more maneuverable type WHOI-ABE vehicle will provide unprecedented access to the deep ocean and sea floor without dedicated support of a surface ship. They will not, however for the near future, be able to complete the essential manipulative tasks that submersibles or ROVs effectively accomplish nor will they be able to operate at depths greater than ~6000 m.

The committee understands that the Navy and NAVSEA have requested WHOI to provide a technical assessment and costing of how to best integrate SEACLIFF into the National Deep Submergence Facility. The DESSC endorses this plan, and believes that the deep submergence technical expertise at WHOI and their operational knowledge of Navy DSV systems, and how they differ or are the same as ALVIN's, makes this the logical approach to evaluating the technical and cost issues. Based on scientific and programmatic considerations, the committee believes that only a few of the many options presented by Dr. Saalfeld in his letter to Dr. Perfit, could be viable. Probably the most cost-effective and advantageous of these options would entail combining the best attributes of ALVIN and SEACLIFF to produce a cost-efficient and capable deep diving submersible with a depth range of ~6000 m. Ignoring, for the moment, the considerable technical and budgetary issues that must be addressed in accomplishing this integration, the committee notes that if such an option is considered, that it will be important for the resulting submersible to retain all of the excellent science capabilities and operational characteristics (safety, reliability, maneuverability, bottom time) which ALVIN currently has. We say this because it is likely that the principal operating range for a majority of peer-reviewed deep submergence science will continue to be in the range of 2500-5000 m water depth.

The various options presented by Dr. Saalfeld as well as other options proposed by DESSC and the science community will be discussed and evaluated and reported on in the Working Group report.

Funding Support

Perhaps the most serious and biggest impediment to integrating SEACLIFF into the US deep submergence program is the lack of an adequate and stable funding base. To their credit, the federal agencies and WHOI were able, in this restricted funding climate, to bring to fruition a new deep submergence support ship - R/V ATLANTIS, which will provide integrated deep submergence vehicle operational capabilities that are unique in the world. However the DESSC believes in order to successfully utilize and maximize the scientific assets of SEACLIFF, ONR, NSF and NOAA must work together with the community to ensure that adequate funding is provided to support the operational, engineering and ship facilities required to carry out the science and engineering programs. NSF has largely shouldered the burden of support for the facilities and science programs in recent years. In this time of fiscal restraint, funding is clearly not available for an additional facility to maintain and operate SEACLIFF,

APPENDIX VI

Deep Submersibles and Potential Marine Geological Research

by Dr. Patricia Fryer
SOEST/Planetary Geosciences

1. Ridge Crest and Related Studies

Ridge Crests

The recent focus of interest on mid-ocean ridge processes has emphasized the advances made by the marine geological community in understanding the processes of formation of oceanic lithosphere. Yet, the community recognizes the continuing need to explore aspects of ridge crest morphology, structure, and composition which remain poorly understood. Many advances in the understanding of ridge-crest evolution were the result of investigations of seafloor morphology that came about with the advent of side-scan sonar imaging and bathymetry systems, such as the U.S. Navy multibeam systems of the 1960's, and the proliferation of similar and related imagery systems in the 1970's (e.g., Sea Beam, DEEPTOW, GLORIA, SeaMARC I, SeaMARC II, and various commercial systems [see Vogt and Tucholke, 1986]). With detailed data on morphology and results of numerous geophysical and geological research cruises to the ridge crests, it is possible not only to identify those ridge crest regions whose direct exploration with submersibles would most benefit the science, but also to make most effective use of dive time. Many ridges are deeper than 4,000m, esp SW Indian Ridge.

Propagating Rifts

Propagating rift tips are deeper than 4 km. The composition of the lavas that erupt at the tips of propagating ridges is unusual (Christie and Sinton, 1981). It has been suggested that these lavas are generated as a consequence of the interaction of magmas residing in the magma chambers of the ridge segment with the thick oceanic lithosphere through which the ridge is propagating. The effects of these interactions are likely to be reflected in the distribution, composition, and morphology of lava flows emanating from a ridge tip. The fact that the ridges are propagating into older crust is interesting in itself because fundamental problems of the mechanics of spreading ridge propagation can be addressed through studies of the structures that form in the microplates adjacent to propagators. These microplates show rapidly evolving complex deformation (Searle et al., 1989) and we know little of the details of how these deformational structures form. Direct observation and detailed sampling from submersibles is the most straightforward way to investigate the petrology and structures which will explain these enigmatic ridge-crest features.

2. Evolution of Oceanic Lithosphere

Petrologists, studying the genesis and evolution of igneous rocks of the oceanic crust and upper mantle, are interested in the details of exposures of sequences of lavas and depths of the ocean basin, as well as along the active ridge crest transforms. Whereas transform valleys allow a look at what is happening very early in the formation of the oceanic lithosphere, the deep mid-plate troughs are a potential window onto the aging of the crust. In places like Kings Trough in the eastern Atlantic, west of Portugal (Cann and Funnel, 1967), the Emperor Trough in the western Pacific, etc., it is possible to study composition and structure of the oceanic lithosphere. The Kings Trough has been recently examined by Soviet scientists using the MIR 6 km submersible for petrologic and stratigraphic details (A. Malahoff, pers. comm.).

In addition to allowing us to explore the composition of the lithosphere, deep exposures at transforms, fracture zone escarpments, and mid-plate troughs would, if accessible, be of tremendous help in deciphering geophysical observations. Recently it has become clear that seismic properties of the upper crust are strongly affected by cracks, fractures, porous layers of breccia, and other void space (Fryer and Wilkens, 1988; Fryer, et al., 1990; Moos and Marion, 1990). Lateral variability of seismic structures, as well as age-dependent increase in seismic velocities, is primarily controlled by the degree of cementation and hydrothermal deposition in this void space. So far, the relationships between such large scale porosity and seismic structure have been investigated primarily by appeal to ophiolite sequences (sediments, lavas, feeder dikes, underlying magma chamber sequences, and upper mantle rocks that are exposed on land in many part of the world), by assuming the porosity structure that can be inferred from extrusives in ophiolites are applicable to the oceanic crust in general. However, that approach gives little indication of the age dependence of that porosity. What is desperately needed is direct observation of sections through the extrusives. Submersible investigations of fracture zones and mid-plate troughs are really the only option.

Submersibles will assist in seismic investigations in another way; in the conduct of on-bottom seismic experiments. To measure the seismic structure of uppermost crust demands on-bottom seismic receivers and near-bottom or on bottom sources (Purdy, 1987), especially on young or uncemented crust. But a complete understanding of crustal structure will never be achieved until the anisotropic effects of flow layering and tectonically-controlled fractures are also considered. Such studies of anisotropy effects will require tightly navigated arrays of ocean-bottom seismometers and careful deployment and operation of shear-wave sources. Running such experiments would be beyond the capabilities of present ROV's and would demand a submersible or upgraded capabilities of the existing ROV's.

Mid-plate Volcanism

Studies of mid-plate volcanoes in the ocean basins, and of their underlying "hot spot" sources, have focused on investigations of subaerial lava flows, dredged samples, and on the general structures of the oceanic plate in the vicinity of the volcanoes. The best studied of these volcanoes are those associated with the Hawaiian hot spot. For many of the volcanological problems related to these volcanoes, the depths accessible to 4 km submersibles would be quite adequate. Recent studies of the abyssal depths surrounding information regarding the origin, growth and evolution of mid-plate volcanism and regarding the workings of hot spots.

Incipient Subduction Zones

Many earthquakes in the Western Pacific cause substantial ground motion and generate local tsunamis, but go undetected by the world-wide seismic network. Apparently, because these earthquakes are located within the oceanic plate, their seismic energy propagates very inefficiently to stations of the network, which tend to be concentrated on the continents, across the convergent plate boundaries at the margins of the Pacific. If less than a certain magnitude, the energy from these earthquakes is not propagated across these plate boundaries and the earthquakes are not detected on the network (Walker and McCreery, 1985; 1988). These earthquakes have, however, been detected by hydrophone arrays in the Pacific. Epicenters of these "unreported" earthquakes define a zone stretching from Guam, past Ponape, and further southeastward (Kroenke and Walker, 1986). The small number of these earthquakes detected by the world-wide net all have thrust mechanisms, suggesting that the Pacific oceanic plate is being thrust down under the southwestern Pacific. The implication is that subduction is being initiated all along this zone creating a new trench (Kroenke and Walker, 1986). There is morphological evidence from geophysical profiling in the vicinity of the earthquake zone that supports the new trench hypothesis. The existence of a newly forming trench is one of the most exciting and controversial discoveries of recent years. If the zone of earthquakes and the features observed in geophysical surveys of the region are indeed effects of a newly forming trench, we have available to us the first natural laboratory for the study of the processes of the earliest stages of subduction of oceanic plates. We know very little of how trenches form and how plate subduction is initiated. Several in situ experiments could be run to examine the structures and processes related to the earthquake zone. These experiments might allow the first glimpse of the incipient stages of formation of convergence plate margins. It would be possible to deploy arrays of ocean bottom seismometers to monitor low level earthquake activity and thus to examine the interaction of the two converging plates. It would be possible to set up experiments to study the structures indicative of the early stages of deformation within the new trench. It would be possible to study details of the escape of fluids from deep sea sediment, a common phenomenon observed on convergent margins of oceanic plates (e.g. Kulm et al 1986; Fryer et al., in press). Venting of fluids at convergent margins is a phenomenon of global proportions about which we know very little. Marine geologists are interested in determining the nature of the escaping fluids in order to study the cycles of a variety of constituents of these fluids that are part of the global budgets of various elements. The cycles of these elements carry implications for global patterns of tectonic processes, volcanism, and even climatic change. Unfortunately, the hypothesized new trench is in abyssal depths, beyond the reach of 4 km submersibles.

Convergent Plate Margins

accumulated sediments are subjected to changes in temperature, pressure, and stresses. Several researchers have begun the study of the dynamics of these accretionary wedges (e.g. Barr et al., 1989; Hoffmeister et al., 1989) and have discovered that as the wedge evolves, routes for the migration of various constituents of the wedges are established and these routes can, at least theoretically, be predicted. As biogenic components in the sediments are distilled into hydrocarbons, the wedges become sites of oil formation and seeps of pore fluids that are observed in many of the convergent plate margins around the world could be monitored using deep submersibles. In this manner the nature of the transport of hydrocarbons through the accretionary wedges could be studied.

Sediments in nonaccretionary convergent margins are derived from the adjacent continental land mass or from the adjacent oceanic arc volcanoes. The transport mechanisms of sediments may be quite different in non-accretionary margins. For example, skeletons of delicate, shallow water foraminifera (carbonate secreting, one-celled organisms) have been recovered from cores taken from greater that 6 km depth in the Peru-Chile Trench (Coulbourn and Moberly, 1977). These skeletons had to have been transported to the deep trench sites fast and then been buried rapidly, otherwise, they would have been destroyed by dissolution in the deep, cold waters. The rapid transport of sediment across the South American overriding plate margin presents a number of problems. What's the mechanism of this transport? Is it related to the process of tectonic deformation of the outer edge of the plate? If so, how? What structures influence the distribution of sediments and how? We can answer part of some of these questions already. Complex channels have been discovered using side-scan sonar imagery and bathymetry of the South American plate margin (Bartlett, 1987). The results of investigations of cores taken from near these channels indicate frequent large volume transport along the channels. Detailed studies of sediment distribution within the channels would facilitate understanding the mechanism and rates of transport of the sediments. Such studies could only be undertaken with deep submersibles.

The non-accretionary convergent margins also provide the opportunity to investigate directly the interactions between the outer toe of the forearc and the subducting plate. As the downgoing plate bends and fractures the stresses being imposed on the plate also disrupt ridges and seamounts that are riding the plate down. Several studies have shown that the seamounts on the downgoing plate are severely deformed as they are subducted (Fryer and Smoot, 1985; Yamazaki and Okamura, 1989). It also appears that as ridges and seamounts are subducted they uplift the inner toe of the forearc, producing vertical tectonic deformation over a region at least as large as the feature being subducted. Other structural changes may also occur as the subducting feature, interacts with and disrupts the brittle outer toe of the overriding plate. Clearly, the additional disturbance caused by the subduction of a large ridge or seamount could accelerate the erosion of the outer edge of the overriding plate. The excess mass of the feature may act as a rasp to scrape off portions of the deep forearc wedge producing deep down-faulted blocks (grabens). The walls of forearc grabens expose thousands of meters of crust. These exposures provide an exceptional opportunity to explore the structures and composition of forearc crust and grained serpentine that makes up the bulk of the flows. Fluids of an extremely unusual composition are seeping from carbonate and silicate chimney structures at the summit of the seamount. The fluids are very slightly cooler than ambient temperatures, by 3/100th of a degree, measured with the ALVIN low temperature probe. These fluids have a very high PH of about 12.5, have low chlorinity, and they have high methane contents and contain propane as well as higher hydrocarbons. Where these fluids are coming from, we are not absolutely certain, but the oxygen and carbon isotopic signature of the chimney material with which the fluids are associated suggest that it is from the deep mantle (Haggerty 1987a and b). We think, in fact, that these may represent fluids that are coming out of subducted sediments. If so, they are coming 30 kilometers straight through the outer forearc. Most likely, these fluids find routes of escape from depth along deep forearc faults. Where these fluids escape to the surface they carry the powdered serpentine up along with them to form serpentine mud flows on the seafloor. Repeated eruptions over hundreds of thousands to several millions of years probably resulted in the formation of the seamount. Deep sea drilling of this seamount recently provided supporting evidence for this interpretation (Scientific Shipboard Party, ODP Leg 125, 1989a and b). The studies of the fluids associated with the serpentine mud flows and those escaping from the central conduit of the seamount have shown that the fluids must reflect maturation of biogenic components in the subducted sediments to form hydrocarbons (Scientific Shipboard Party, ODP Leg 125, 1989a and b). We believe the seamount is still active. Seismic studies of the seamount could test current activity, however the magnitude of any seismic activity associated with this seamount is probably quite low because the flow materials are so ductile. A very carefully controlled series of seismic experiments to examine the natural seismicity of the seamount and to run small scale seismic refraction studies would allow us to examine both the activity and fine internal structure of the seamount. Such experiments would require deployment of ocean bottom seismometers on the seamount and around its base. The continued study of these seamounts is severely constrained by the fact that their flanks and bases are beyond the reach of 4 km submersibles. Without deeper capability the kinds of studies which submersibles would allow us would be impossible.

Arc and Backarc Regions

The island arc volcanoes of the interoceanic convergent margin systems are generally shallow features and are well within the reach of 4 km submersibles such as the ALVIN. In fact, much of the active portion of the arc volcanoes can be adequately studied with 2 km submersibles of the PISCES type. A great volume of the active volcanism associated with many arc system, however, takes place within spreading rifts behind the volcanic arc, in the backarc environment. Studies of ophiolite sequences exposed on land in many part of the world indicate that many such sequences were probably formed in arc or backarc basin environments. These portions of crust and mantle are emplaced as slivers or large masses of exotic terranes within the convergent margins of many continental blocks. Thus, they contribute to the growth of continents. Apart from the purely scientific objectives of studying these exotic terranes, they are important as potential reserves of a variety of economically valuable ores. Clearly, the slivers of forearc wedges may be

The new discoveries of active serpentine mud volcanoes and complex suites of rocks within the overriding plates in these convergence zones can only be explored fully if deep submersibles are available. The actively spreading backarc basins of convergent margin regions are the sites of production of a unique oceanic lithosphere and form some of the potentially richest reserves of metallic ores on Earth. The study of the formation of lithosphere in these basins is very poorly understood and without detailed investigations of stratigraphy and structures, attempts to develop models which will allow us to extrapolate in situ studies to interpretation of subaerial exposures will remain inadequate. Most of the ridge crests within these basins are too deep to be accessible to 4 km submersibles. The marine geological community will heartily support the development of deep submersibles, and as each new dive series has proven, will continue to make discoveries which further endorse the need to explore in greater depths.

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APPENDIX VII

SURVEY RESPONSES
106 QUESTIONNAIRES SUBMITTED

April 1997

Category A - Future Directions in Deep Submergence Science (indicate all that apply)

Note: The survey response totals and comments are indicated in **bold print**.

1. What is your primary field of research? **See *Figure 1*.**

- ◊ **(33)** biology (**(2)**physiology **(9)**ecology **(4)**microbiology)
- ◊ **(19)** chemistry
- ◊ **(7)** physical oceanography
- ◊ **(6)** sedimentology
- ◊ **(30)** marine geology
- ◊ **(8)** petrology
- ◊ **(18)** geophysics
- ◊ **(13)** tectonics/structure
- ◊ **(6)** engineering
- ◊ **(8)** other:
  - ⇒ **Marine Archeology**
  - ⇒ **Physics**
  - ⇒ **Bathymetry**
  - ⇒ **Biogeochemistry CNS Cycling**
  - ⇒ **Economic Geology**
  - ⇒ **In Situ Chemical Sensing Instrumentation**
  - ⇒ **Science Education**
  - ⇒ **Evolutionary Genetics**

4. How many times (cruises) in the past 5 years have you used deep submergence vehicles for your research? See *Figures 3 and 4*.

ROV/tethered vehicles?

Jason - 19
ARGO II - 6
ARGO - 1
DSL120 - 7
ATV - 12
ROPOS - 20
VENTANA - 6
MPL Deep Tow - 3
MPL Control Vehicle - 5
HBOI ROVs - 5
Minirover - 1
Scorpio - 2
Voyager - 1
Phantom HVS4 - 14
TOSS (NAVO) - 1
NURP ROV - 1
Heat Flow Probe - 1
Scampi - 1
Name of Vehicle not indicated - 6
None Used - 54

Manned submersibles?

ALVIN - 115
SEA CLIFF - 11
TURTLE -14
NAUTILE - 12
SHINKAI 6500 - 10
PISCES V - 13
PISCES - 3
MIR - 1
DELTA - 1
SDL-1 (Canadian Navy) - 7
NR-1 - 7
Johnson SEA LINK - 38
Name of Vehicle not indicated - 8
None Used - 23

7. On a scale of 1 (critical) to 5 (not important), how important is it to your present or future research to have a human-occupied submersible capable of working between the depths of 4500 and 6000(+) m? See *Figure 7*.

CRITICAL			NOT IMPORTANT	
1(18)	**2(20)**	**3(25)**	**4(17)**	**5(20)**

Summary of Comments:

<u>HOV is critical</u>: A US platform with a proven performance record is needed. It is essential as a nation that we not lose the 6km capability. Because much of scientifically interesting seafloor falls between 4500 and 6000 m, this direct observation function is critical. While ROVs and AUVs can replace many of the functions of manned submersibles, direct observation of the seafloor is critical for many biological and chemical studies of soft-sediment habitats. Work in the Western Pacific is >4500m deep and work on mid ocean ridges has axial depths in the 4000-5000m range. Tectonics/petrology studies of transforms and ridge-transform intersections will also require submersible depth capabilities in this range. Extensive fine-scale manipulations, to date, can best be carried out only by manned submersible; without this capability, work at 4500-6000m depths is limited.

<u>HOV is not important</u>: A 4500m HOV depth capability is sufficient. Most deep tasks can be handled by ROVs. Many aspects of this research support are already covered by ROVs.

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8. To what extent could your current and future science objectives at depths greater than 4500 meters be accomplished by human operated vehicles (HOVs), remotely operated vehicles (ROVs) or autonomous vehicles (AUVs)? See *Figure 8*.

	100%	75%	50%	25%	less than 10%
HOV-	**25**	**18**	**20**	**12**	**9**
ROV-	**20**	**22**	**30**	**12**	**6**
AUV-	**6**	**7**	**6**	**18**	**34**

Summary of Comments:

The HOV offers sampling capability and an in situ observation (3D visualization) that is not yet possible with other vehicles. Bottom time of HOVs, however, were noted as a limitation. Both HOVs and ROVs are needed to do the job adequately. High resolution detailed sonar mapping benefits from the unlimited power on an ROV tether, but detailed sampling and seafloor instrument set-up is better done from an HOV. Most ROVs are too light to do good coring. ROVs and AUVs are adequate for camera and bathymetry surveys.

Many surveys indicated that not enough is known about AUVs to rate them. AUVs are not yet proven. However, there was one comment that an AUV such as ABE should be incorporated in the National Deep Submergence Facility. It provides an electromagnetically quiet platform for near-bottom magnetics studies, as well as survey flexibility, duration, and efficiency that currently are not available with HOVs and ROVs.

Do not merge SEA CLIFF and ALVIN:

- **The 4500m capability should be kept intact. It will be needed more than the 6000m capability in the near future (~10 years).**
- **This approach is recommended only if SEA CLIFF cannot be operated reliably by another institution (e.g., HURL). Two vehicles are more versatile. Both submersibles should be maintained. Modernize SEA CLIFF, make it a science platform, and operate it separately.**
- **If funding allowed, it would be ideal to upgrade ALVIN to the same depth capability or build a new vehicle -- if for no other reason than to have a viable US rescue capability. What is needed is a new generation of HOV submersibles; smaller, lighter and less logistically challenging.**
- **ROVs and AUVs hold more promise than increased capability to put a human at 6000m. Use money to replace Jason with an ROV designed for science research.**
- **This effort is beyond the capabilities of the DSOG at WHOI. If it is going to be undertaken it should be elsewhere, or under a new and revitalized DSOG management, and with a revitalized team and a long term commitment from the sponsors. Since a DSOG restructuring is unlikely, or that a revitalized funding commitment is in the cards, this level of effort is impractical.**

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2. Should SEA CLIFF replace ALVIN as the primary research submersible for US scientists?

Yes	No	Unsure
7	**53**	**40**

Summary of Comments:

Surveys overwhelmingly indicated that SEA CLIFF SHOULD NOT replace ALVIN.

SEA CLIFF should NOT replace ALVIN:

- **ALVIN is a much more supportable, effective, mature vehicle than SEA CLIFF. If ALVIN can be readily modified for 6000 meter operation by cannibalizing SEA CLIFF, great, but replacing ALVIN with SEA CLIFF would be a disaster for the community! ALVIN has a much higher productivity (dives/year) and has been outfitted specifically for science research.**
- **SEA CLIFF has suffered extensively from reliability problems (poor track record), while ALVIN continues to be an incredibly productive workhorse. SEA CLIFF is much less capable than ALVIN for seafloor sampling and observing. SEA CLIFF (aside from depth advantage) would require major modification to be as capable as ALVIN. It is too expensive to operate. The sphere is the only useful thing on SEA CLIFF.**
- **Although there is certain value in diving beyond ALVIN's limits, the problem is one of ALVIN availability not diving capability or depth limits. Simple replacement of ALVIN with SEA CLIFF is very risky, and does not solve the growing problem if insufficient submersible access to US scientists. Two vehicles would add versatility.**

Conditional Yes: **SEA CLIFF should replace ALVIN if all ALVIN's capabilities and operational procedures/crew are transferred. The reliability and performance record of ALVIN must be continued with a 6000m vessel. Capabilities should be merged so that the net result is just one HOV that can dive to 6km.**

4. Should SEA CLIFF equipment (e.g. manipulators, electronics, sonars, vehicle systems) be transferred to the National Deep Submergence Facility at Woods Hole to enhance ALVIN while the 6000 m SEA CLIFF titanium sphere is preserved for possible future replacement for the existing 4500 m depth rated ALVIN sphere?

Yes	No	Unsure
58	**14**	**26**

Comments:

Transfer SEA CLIFF equipment to the National Deep Submergence Facility:

Many of the surveys indicated that this would be the most attractive option for a variety of reasons

- **This sounds like the best compromise with shrinking support. It leaves the 6000m option open, but doesn't throw away a high productivity resource. Combining the best attributes of ALVIN and SEA CLIFF has many attractions.**
- **This option makes the best use of Navy facilities and equipment for academic science and is the most cost-effective.**
- **This seems to be the best alternative even though loss of any submersible capability is bad for the entire community.**
- **This seems like the do nothing default approach and probably the right approach unless DSOG and the funding base can be revitalized sufficiently to undertake a major revision of ALVIN, including a 6000m capability.**
- **ALVIN plus present ROVs can address a larger range of relevant problems than can presently be funded. Therefore, competitive funding of another deep-sea asset is unwise at this time.**
- **This seems like a good way to go for the near future and if funding and a good scientific rationale were generated a couple of years hence, it would be appropriate to make the conversion when ALVIN comes due for the next major overhaul.**
- **For reference, see the article: Deep Sea Research by Manned Submersible, J.R.Heirtzler and F. Grassle, Science, v. 194, 294-299, 1976**

Do NOT transfer SEA CLIFF equipment to the National Deep Submergence Facility:

- **This may be a practical short-term solution but is does not address the basic issue that the ALVIN-class vehicles are obsolete... they are very costly to operate ... and should be replaced by HOVs utilizing modern materials and technologies. We need to build a sub that can go to 6000m.**
- **Both SEA CLIFF and ALVIN should be maintained separately while pushing for additional funding or inventive ways for this to occur, such as porting SEA CLIFF to an already established submergence facility. This options should be pursued only if SEA CLIFF conversion/update is deemed unfeasible. Keeping SEA CLIFF operational separately sounds preferable as long as it does not endanger ALVIN.**
- **This should be done only after moneys from other agencies are provided to support the vehicle.**
- **Proceed with merging ALVIN and SEA CLIFF before the opportunity is lost. There will probably not be another such opportunity to bring such a facility on line for many years.**

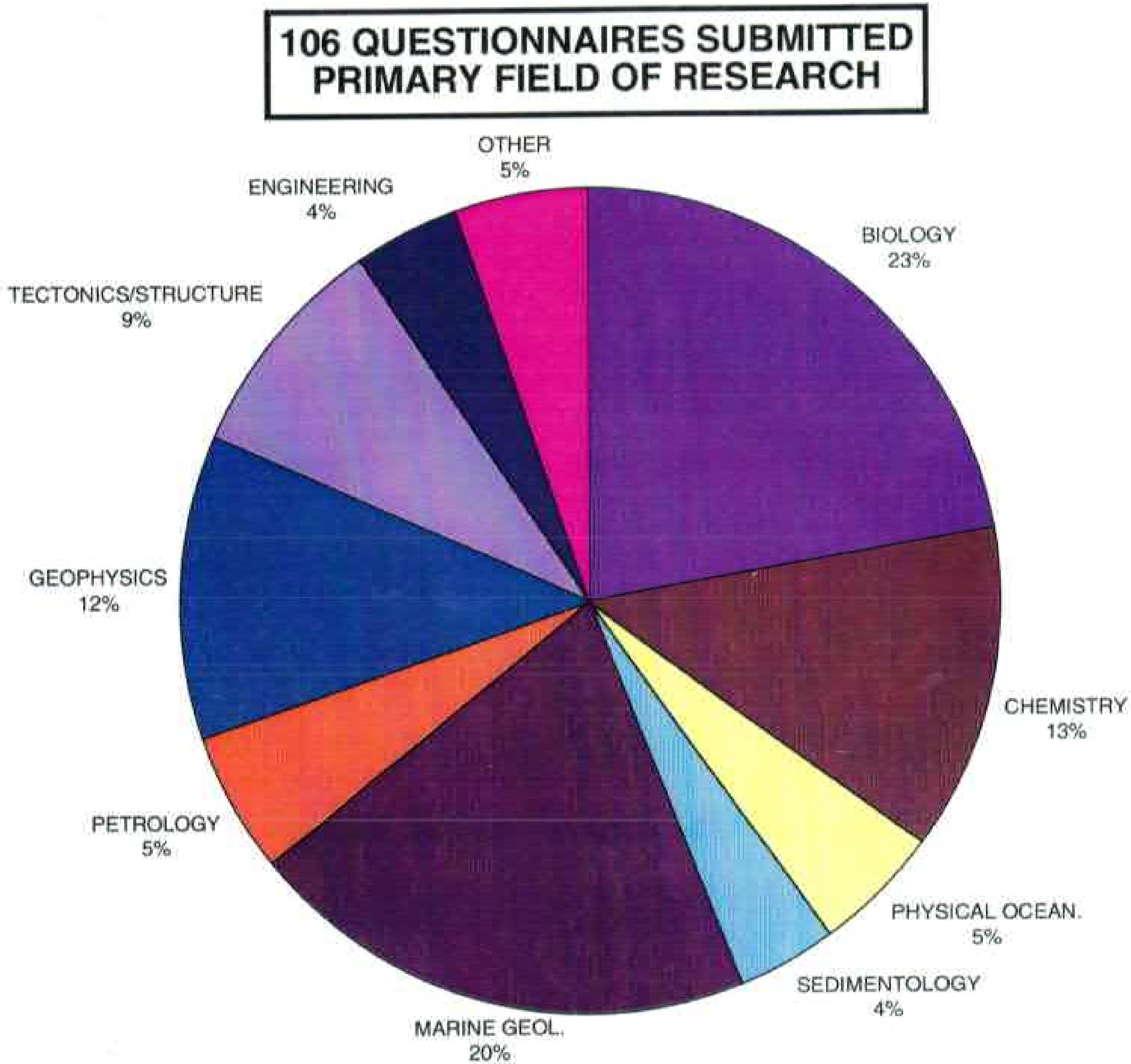
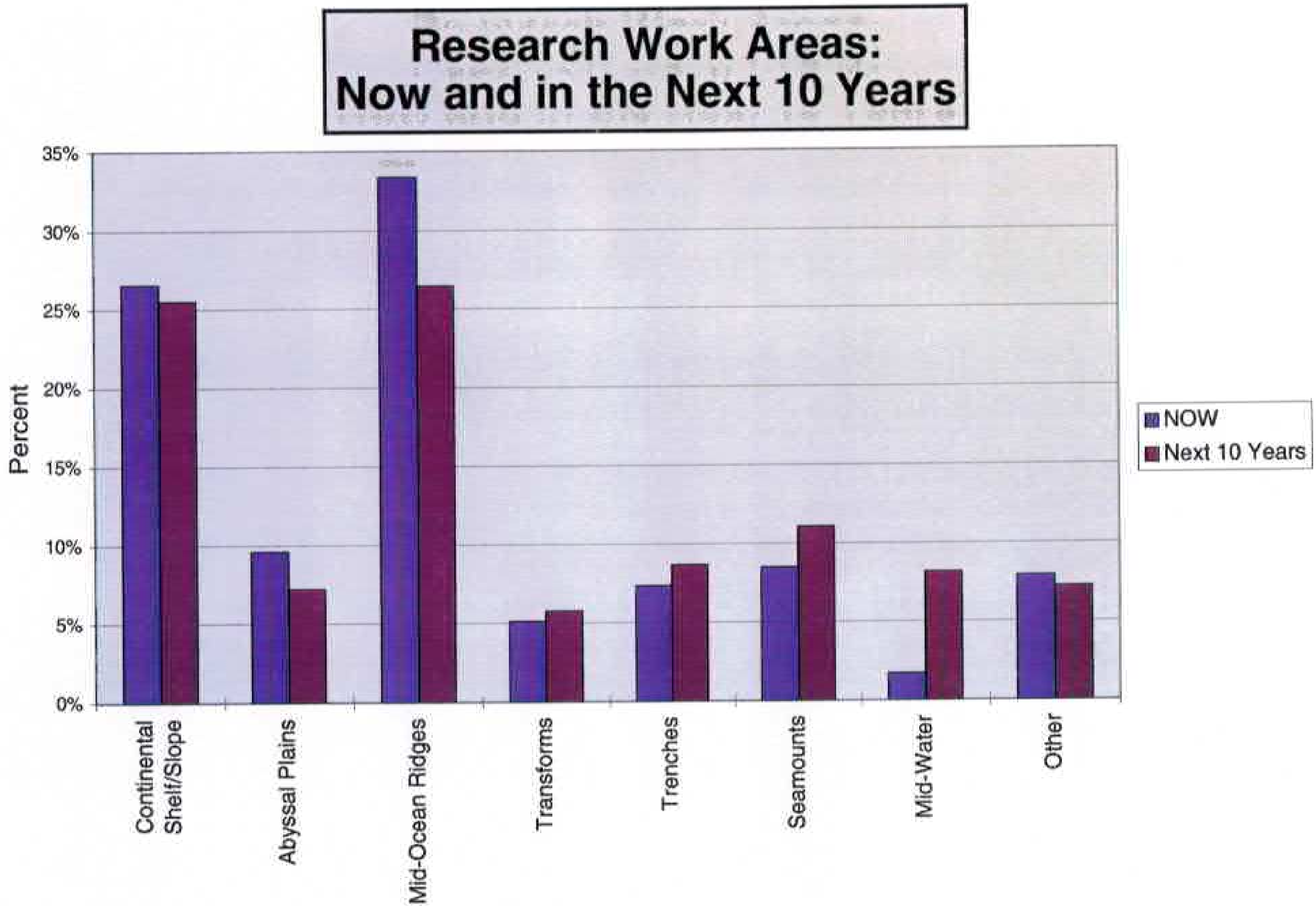

106 QUESTIONNAIRES SUBMITTED
PRIMARY FIELD OF RESEARCH
OTHER 5%
ENGINEERING 4%
BIOLOGY 23%
TECTONICS/STRUCTURE 9%
GEOPHYSICS 12%
CHEMISTRY 13%
PETROLOGY 5%
PHYSICAL OCEAN. 5%
SEDIMENTOLOGY 4%
MARINE GEOL. 20%

FIGURE 1



Research Work Areas:
Now and in the Next 10 Years
35%
30%
25%
20%
15%
10%
5%
0%
Percent
Continental Shelf/Slope
Abyssal Plains
Mid-Ocean Ridges
Transforms
Trenches
Seamounts
Mid-Water
Other
NOW
Next 10 Years

FIGURE 2

ROV/TETHERED VEHICLE USE

VEHICLE	CRUISES
ROPOS	20
JASON	19
PHANTOM	14
ATV	12
DSL-120	7
ARGO II	6
VENTANA	6
OTHER*	28
TOTAL	**112**

* Twelve other vehicles were listed as being used.

51% of those responding to the survey had not used an ROV

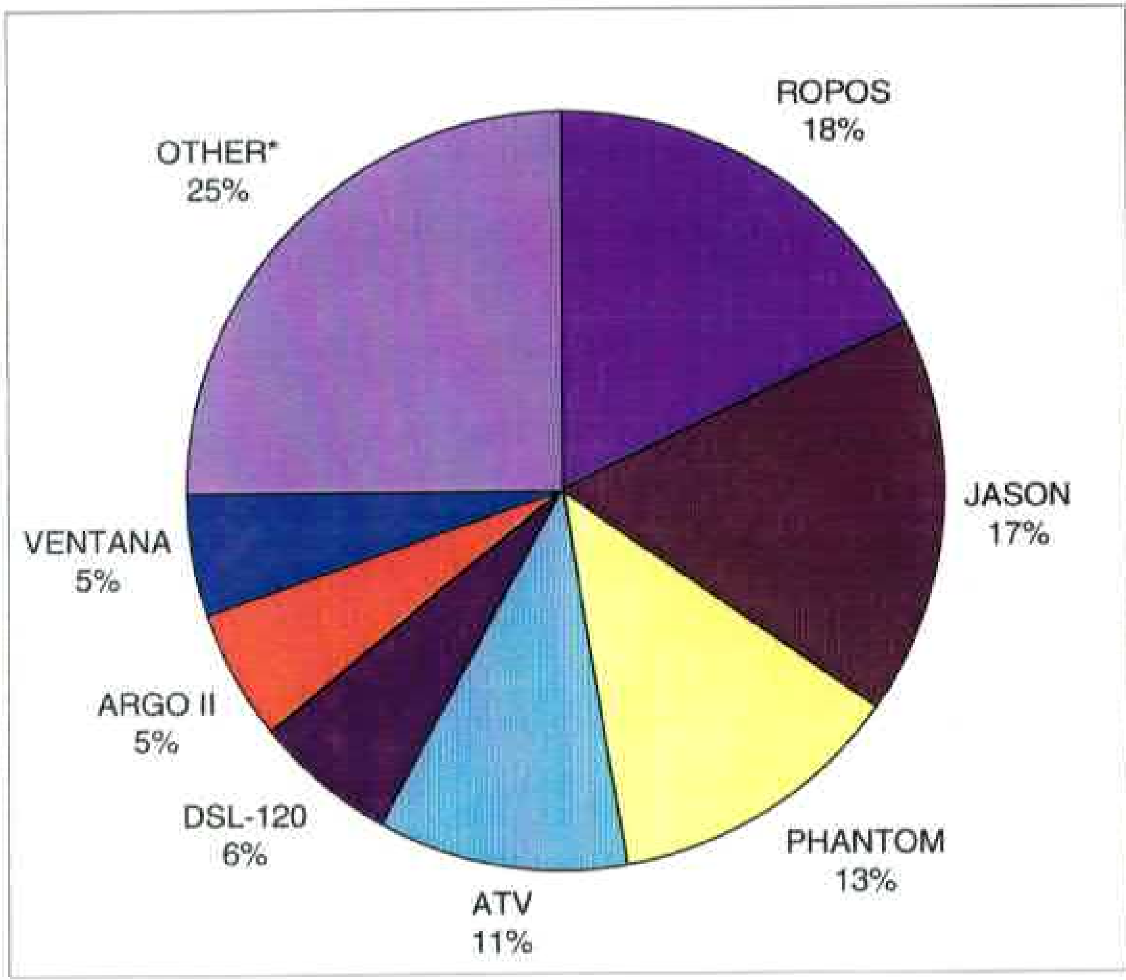


FIGURE 3

HUMAN OCCUPIED VEHICLE USE

VEHICLE	CRUISES
ALVIN	115
SEA LINK	38
TURTLE	14
PISCES V	13
NAUTILE	12
SEACLIFF	11
SHINKAI 650	10
OTHER*	27
TOTAL	240

* Six other HOVs were listed as being used.

22% of those responding to the survey had not used an HOV.

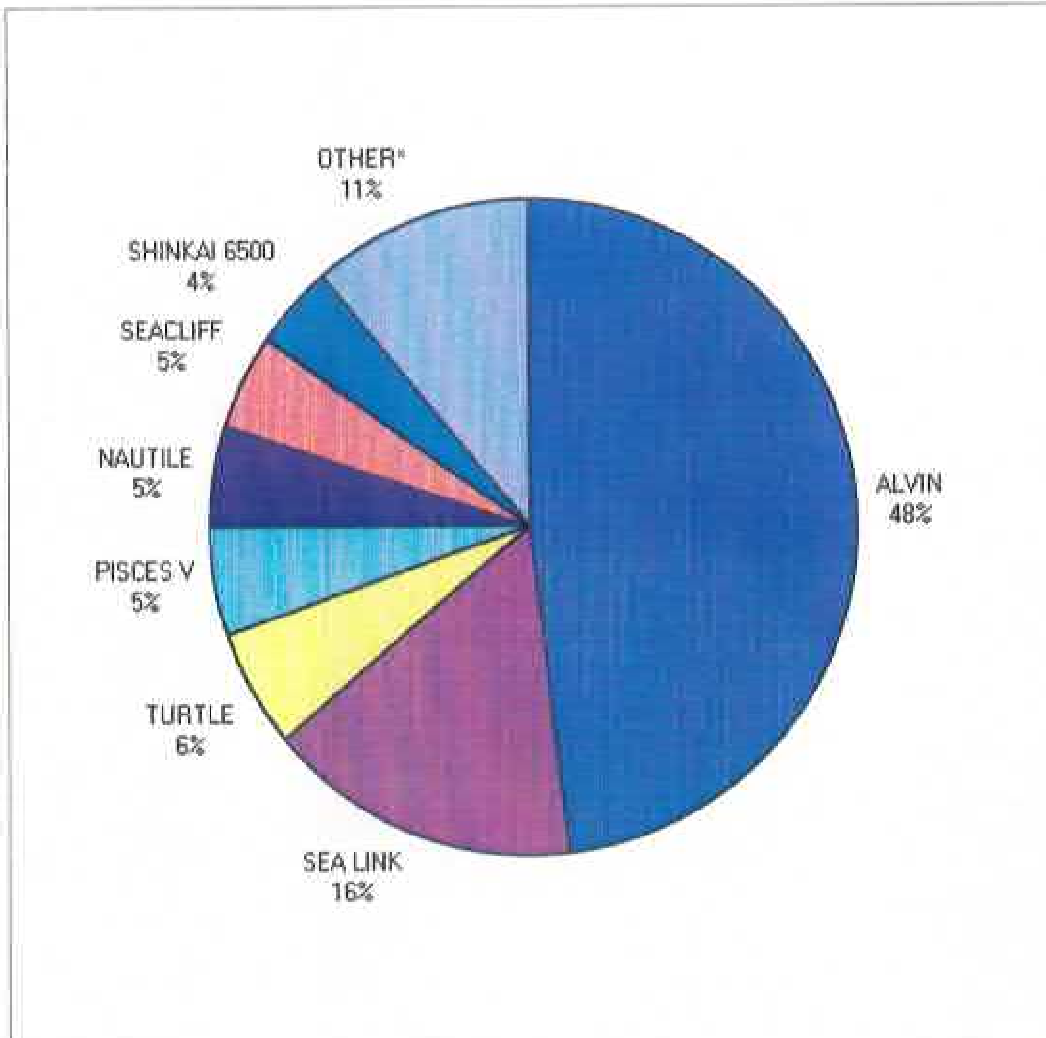


FIGURE 4

MAXIMUM DEPTH RANGE THAT DEEP SUBMERSIBLE VEHICLES SHOULD HAVE IN TERMS OF FUTURE SCIENCE REQUIREMENTS

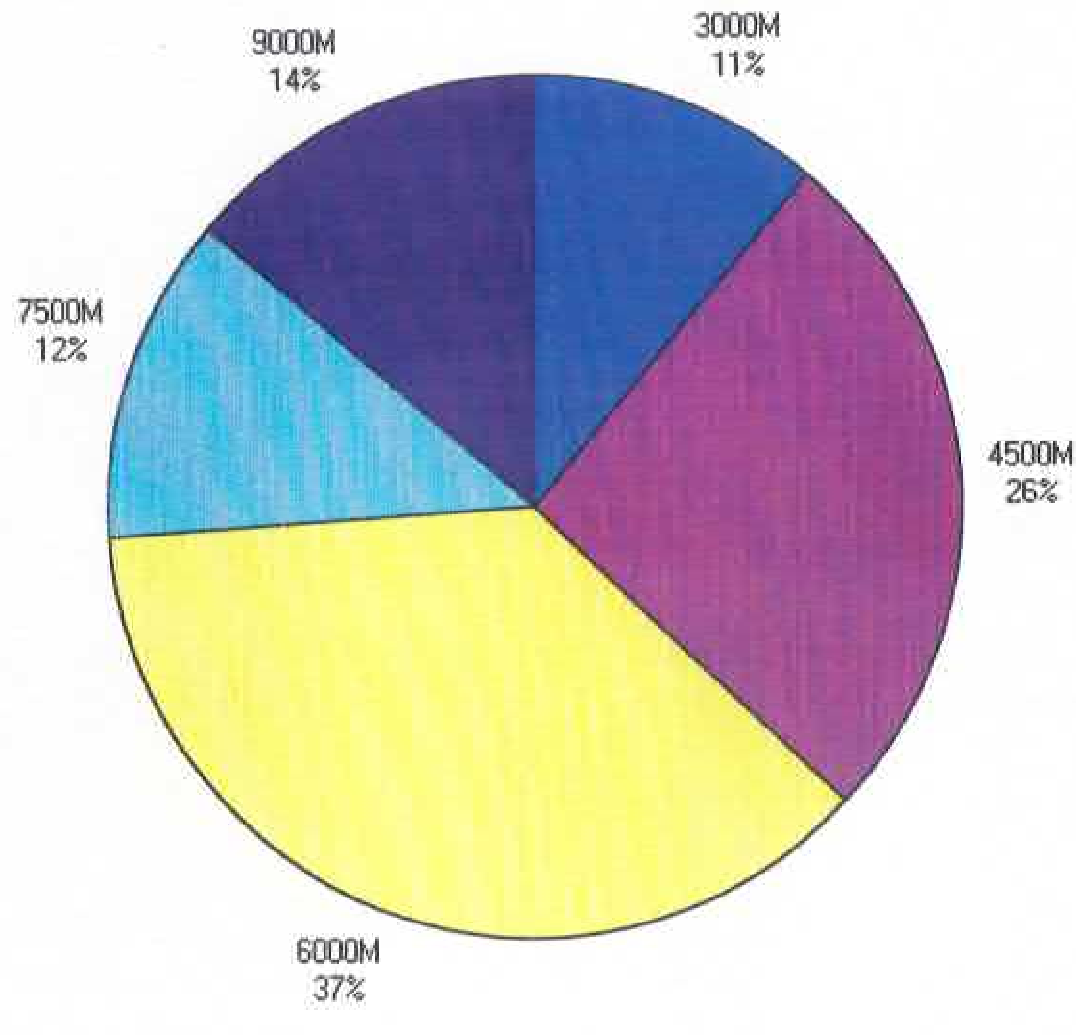


FIGURE 5

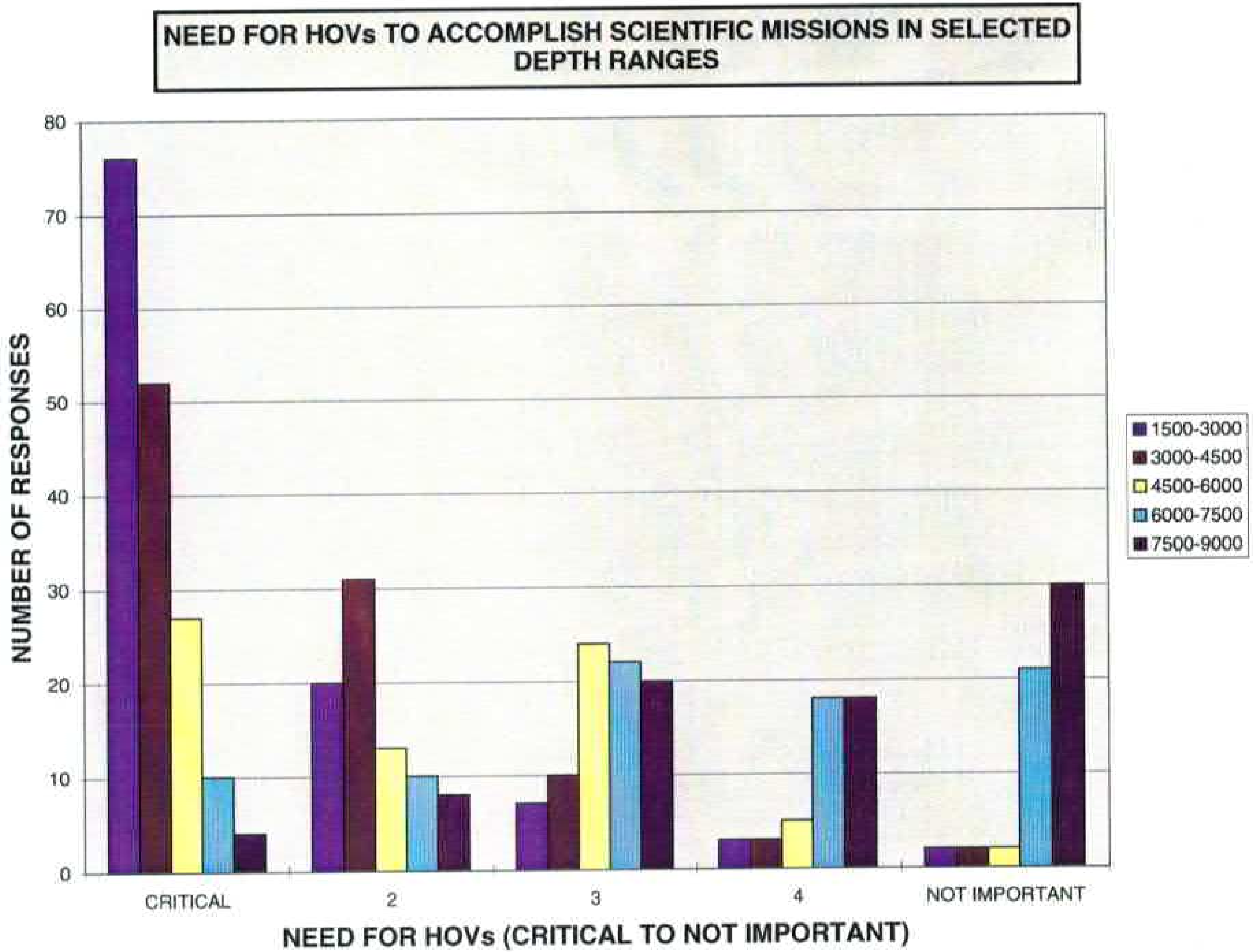

NEED FOR HOVs TO ACCOMPLISH SCIENTIFIC MISSIONS IN SELECTED DEPTH RANGES
NUMBER OF RESPONSES
80
70
60
50
40
30
20
10
0
CRITICAL
2
3
4
NOT IMPORTANT
NEED FOR HOVs (CRITICAL TO NOT IMPORTANT)
1500-3000
3000-4500
4500-6000
6000-7500
7500-9000

FIGURE 6

DEGREE OF IMPORTANCE TO HAVE AN HOV CAPABLE OF WORKING BETWEEN THE DEPTHS OF 4500 AND 6000(+)m (CRITICAL TO NOT IMPORTANT)

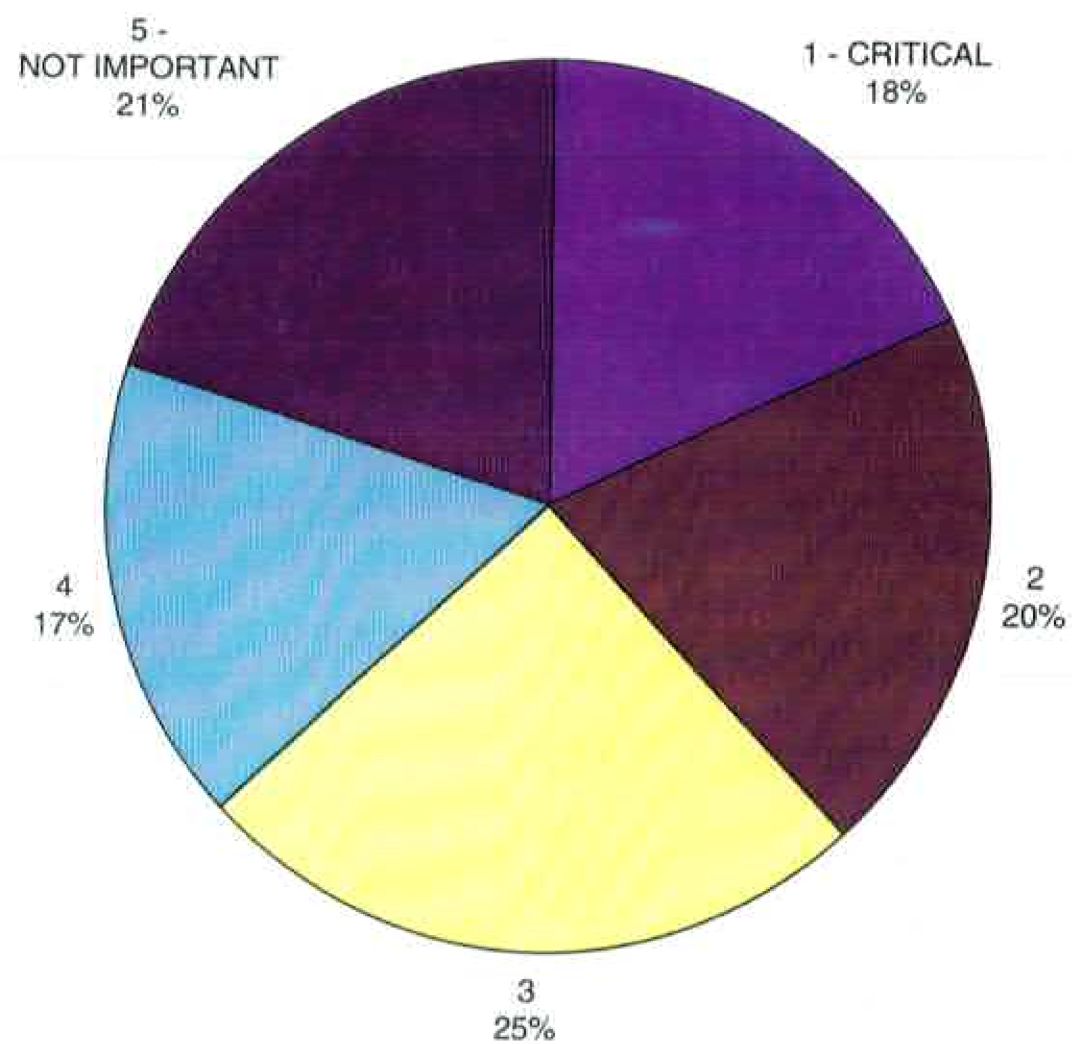


FIGURE 7

SCIENCE OBJECTIVES ACCOMPLISHED AT DEPTHS >4500M BY HOVs, ROVs OR AUVS

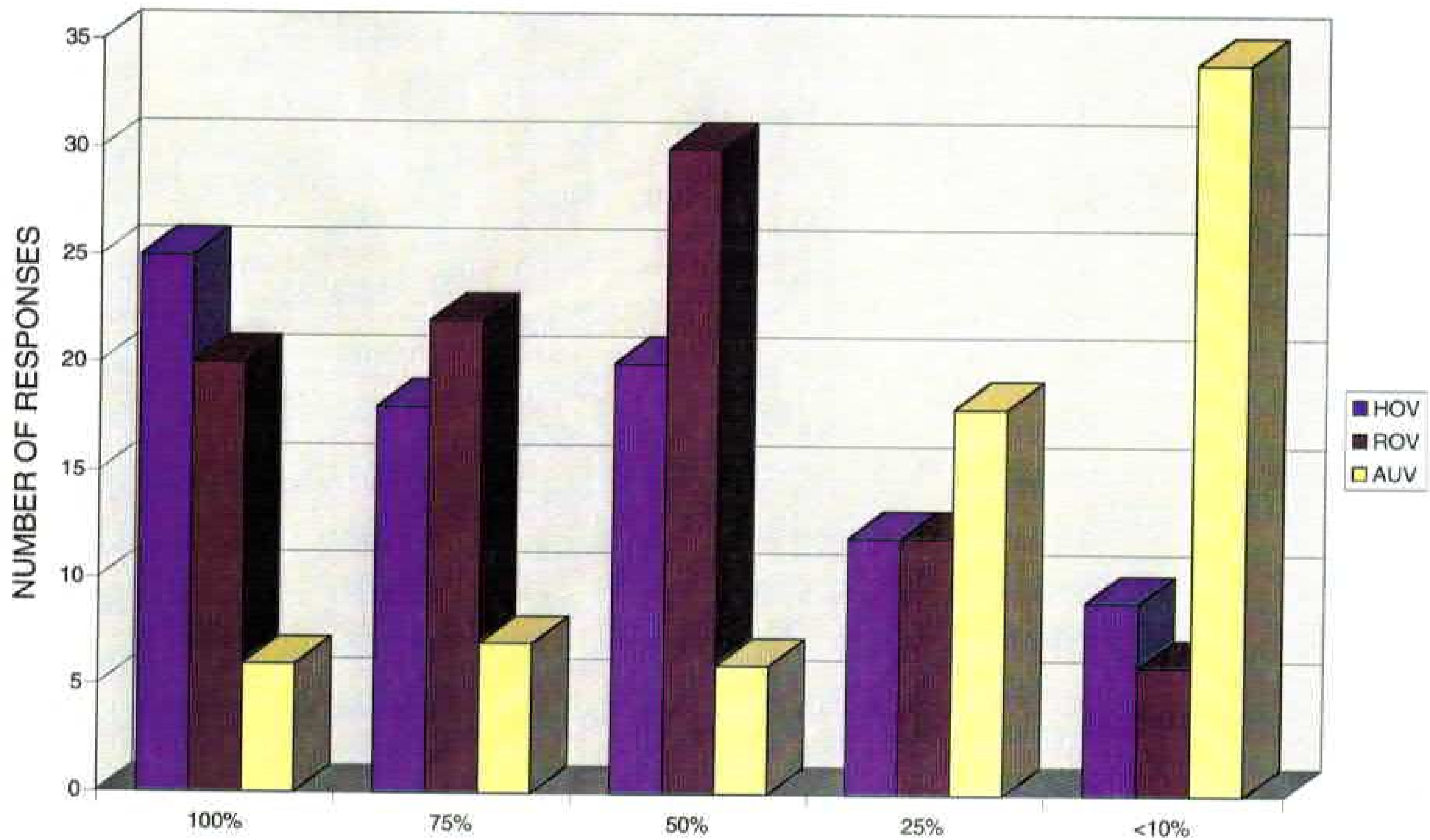


FIGURE 8

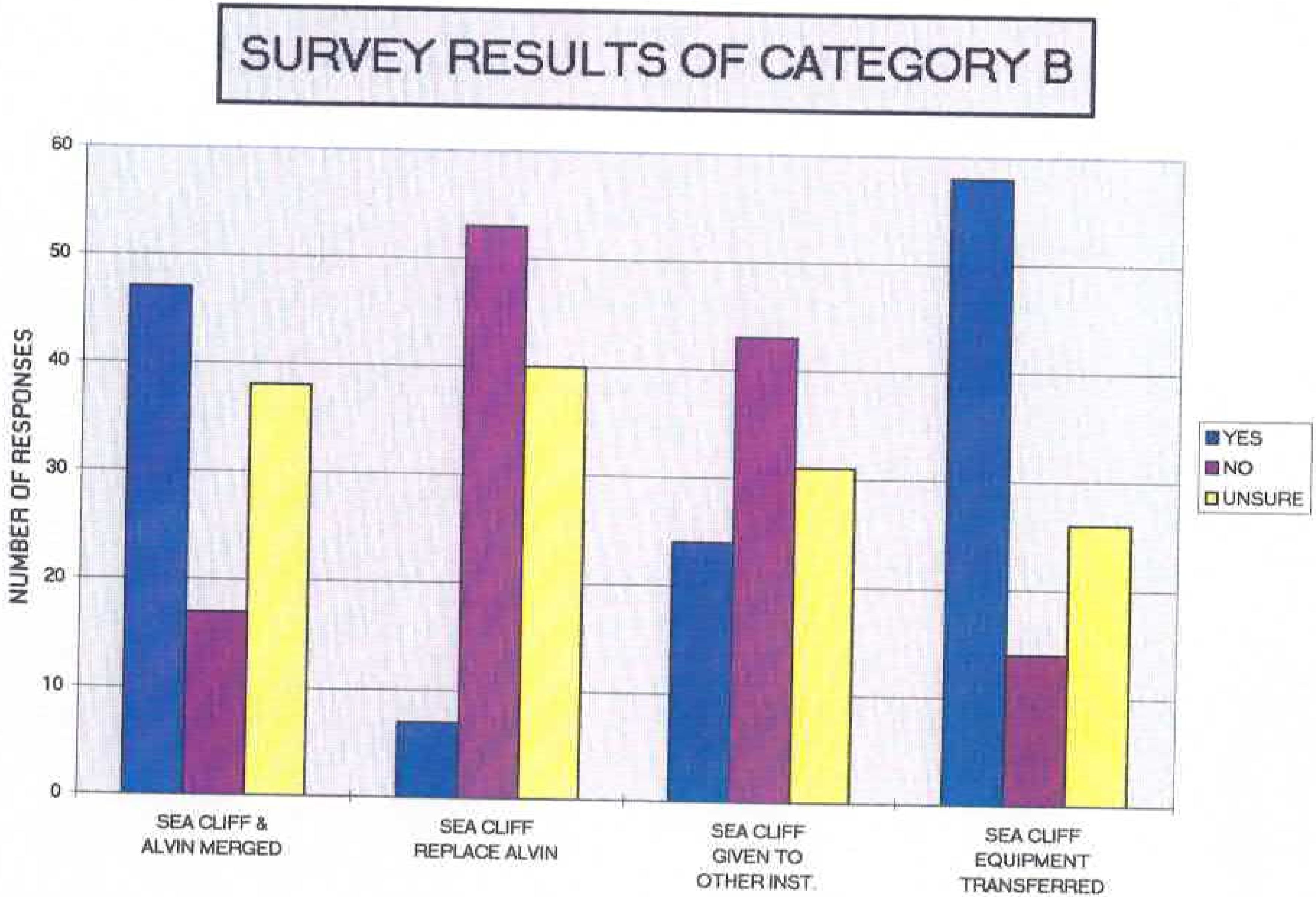

SURVEY RESULTS OF CATEGORY B
NUMBER OF RESPONSES
0
10
20
30
40
50
60
SEA CLIFF & ALVIN MERGED
SEA CLIFF REPLACE ALVIN
SEA CLIFF GIVEN TO OTHER INST.
SEA CLIFF EQUIPMENT TRANSFERRED
YES
NO
UNSURE

FIGURE 9