# Appendix X

## DESSC Input to Future Deep Submergence Science Issues

**DESSC White Paper**
**6/15/98**

**Request from Mike Perfit:**

In preparation for the meeting, I would like all of us to think about the future of deep submergence science in order to produce a DESSC White Paper that addresses future deep submergence science facility needs. In my recent discussions with the Federal agency reps., it has become clear that they want the deep submergence community to join together to "decide" what the important aspects of deep submergence science will be in the next decade and what tools we will need to accomplish our research. These "decisions" will have to be made by meetings open to the general science community in the next year or so. The first meeting will probably be held at the beginning of 1999 and may be run by some combination of RIDGE, UNOLS and/or NOAA. I believe it is important for DESSC to present our view of the future of deep submergence science in order to guide the community and facilitate the planning. Consequently, I would like each committee member to prepare two to three pages of material addressing the following questions with regard to your own specialties and general beliefs.

1. What are the current important deep submergence science research interests in your field of research?
2. What do you see as your important future deep submergence research directions in the next five to ten years?
3. What deep submergence vehicles will be needed to accomplish your research objectives?

Please submit your response to these three questions no later than 10 June to the UNOLS Office <unols@gso.uri.edu>. We will compile the responses for review at the DESSC meeting.

**1) WHAT ARE THE CURRENT IMPORTANT DEEP SUBMERGENCE SCIENCE RESEARCH INTERESTS IN YOUR FIELD OF RESEARCH?**

**(P.F.)** I and several colleagues are currently work in nonaccretionary convergent margins. Our interests encompass geologic processes active in three principal tectonic environments: forearcs (between the trench axis and the volcanic arc), the volcanic arc, and backarc basins.

The deep submergence aspects of the forearc studies include exploration of processes active on the inner slope of the trench. The inner trench slope processes under investigation are tectonic erosion, transport of sediments across the deeper parts of the forearc toe, seismic activity associated with faulting on the inner slope of the trench and processes of mud volcanism and fluid venting on the seafloor along the deep inner slope. Understanding these processes benefit from various types of surveys that require submersible tools and from in situ experimentation and deployment of long-term monitoring systems. The use of ROVs is preferred for these environments because of the lengthy descent and ascent times that would be required to accomplish work at depths in excess of 6500 m. The outer forearc, in depths between the break in slope at the edge of the inner trench slope and the forearc basin regions, includes fault-bounded horst blocks and grabens, mud volcanism and sites of fluid venting. These sites are of interest for detailed studies and will require deep-towed surveying tools of several types (see below) and geologic sampling (with HOVs or ROVs) that includes collecting rocks, coring sediments, drilling into deposits, slurping up biota, sampling vent fluids, taking vent temperature, taking heatflow measurements in vent sites and surrounding regions, and deploying various short- and long-term monitoring devices.

Arc and backarc basin volcanism and tectonic deformation are associated with extension in the backarc regime. I am interested in the tectonic control over distribution of volcanic centers, in the interrelationship between stresses and faulting, and in variations in the composition of the lavas. Studies will include surveying faults and volcanic features with both shallow and deep-towed systems for imagery, magnetics and detailed bottom photography and sampling.

**(HM)** VENTS/RIDGE related research - primarily in the JDFR: Vent chemistry, geology, geophysics, etc.

**(DO)**

- fluid flow
- geodetics
- seafloor mapping
- long term monitoring of ODP drillholes
- gas hydrates

**(CW)** Following are some comments requested regarding my own area of research in relation to present and future deep submergence needs. I am keeping it brief. I do not think things have changed too much from what went into the Global Abyss Report of 1994. I should say that while "our area" is microbiology I will mention as best as I can the needs of large organism biology , based on my knowledge of the work of others.

There exists for our field of research the need to image, place and retrieve experiments and in particular sample (both generally and on fine scale) in the following areas accessible by deep submergence vehicles:

1. mid and deep water column
2. soft bottom - deep sea benthos and petroleum seep sites (also Guaymas Basin)
3. hard bottom - cold and hot vent sites

The current research interests, for a majority of involved scientists in the area of microbiology (and to a large part also biologists), center around hydrothermal vent areas followed by cold or petroleum seep sites. These microbiological interests ask questions of "who's there", "how many are there", and "what are they doing". The path taken of late seems to be a marriage between classical cultural microbiology and newer molecular biology approaches. Aspects of sulfur and nitrogen metabolism involved in both free living organisms as well as in symbiotic associations receives a lot of attention. The whole field of high temperature microbiology, concentrating on the hyperthermophilic archaea, is of great interest from both ecological as well as biotechnological directions. Research into energy fluxes as well as spatial and temporal variation are ongoing or new ones envisioned.

## 2) WHAT DO YOU SEE AS YOUR IMPORTANT FUTURE DEEP SUBMERGENCE RESEARCH DIRECTIONS IN THE NEXT FIVE TO TEN YEARS?

**(P.F.)** The focus of my marine research and that of my collaborators will be on developing a comprehensive view of the processes involved in recycling of lithospheric constituents within subduction regimes. This will require detailed investigation of the geology of mud volcanoes and fault-controlled fluid venting in forearc regions and the study of variability of arc and backarc basin volcanism. The study of the mud volcanism phenomenon will entail instrumentation of the edifices including reentry drill holes, CORKed and instrumented in order to monitor long-term changes in fluid flux, chemistry, heat flow, seismicity and stress regime. Also I am in the process of developing coring techniques from standard research vessels that will permit deployment of ancillary monitoring devices near drill holes or as arrays around mud volcanoes and fault systems in the forearc environment. These cores will produce shallow cased holes that will be appropriate for instrumentation. The instruments will need to be deployed and data recovered from them by submersible tools, ROVs or HOVs would be appropriate. It may even be possible to deploy AUVs to so the data collection. The study of arc and backarc volcanism and tectonics.

**(HM)** Continued effort on the JDFR with additional work on the EPR with similar science goals. However, we envision an increasing interest in microbiology, rapid response, and long term observatories driving the field effort.

**(CW)** With respect to important directions in the future I think what I just referred to (energy flux determinations and more detailed spatial and temporal variation studies) will be directions for major work in the future. Sampling requirements, more so than imaging and mapping, will continue to be paramount in our areas of research. More fine scale sampling, combined with physical parameter measurements, will be important in vent research and to some degree in the other oceanic areas employing deep submergence vehicles. Instrumentation development, apart from submersible improvements, will proceed as funding allows and will depend on the skill and capacity of deep submergence assets for accurate deployment and recovery. It would be my hope that more involvement of soft bottom and water column researchers would take place over the next decade, especially if opportunities to visit new areas heretofore uninvestigated by submersible operations happen.

**(CVD)** Current and future important deep submergence science research interests:

General:

Fisheries/habitat research for stock assessment and management and basic fisheries research. This work begins in shallow water (100 m and greater) but extend into deeper waters (>1000 m) where developing fisheries are becoming important. There is increasing interest in a variety of aspects of fish biology in populations that exploit seamount hydrographies and habitat.

Pollution assessment and remediation. This work again is often, but not always, in relatively shallow waters (100-1000 m), below SCUBA depths and "out-of-sight, out-of-mind". Military disposal of chemical and other wastes is often to blame. Other pollution hazards include sunken ships with full fuel tanks or cargoes of toxic material.

Clathrate deposits. As our appreciation for the size of clathrate deposits in the oceans grows, there is gathering interest in understanding the global flux of methane from the seabed into the ocean. These deposits also can support biota (both microbial and macrobiota) of interest for their existence in an extreme environment.

Tectonic hazards. Active plate margins on coasts are targets for efforts to determine mechanisms and dates of activity and their seabed and coastal consequences. These also include a component related to flux of porewater fluids expelled along fault lines and the biota that exploit these fluxes.

Sub-ice processes. Primary production beneath ice and coupling of this production to the benthos are dynamic processes that are high priorities for Arctic and Antarctic research.

Arctic ecosystems, climate oscillations and global warming. Productive coastal waters of the Arctic are targets of increasing study due to the perception that these will be among the most sensitive systems to changes in surface ocean temperatures.

Diversity: Diversity in the deep sea can be extremely high. There is a push to understand patterns of diversity at much greater resolution and with more systematic sampling than ever before. This does kind of sampling does not usually require submersibles or other deep-water assets.

RIDGE CREST BIOLOGY

Biogeography: Priorities include Arctic Ocean Ridges, Bransfield Straits, Scotia Ridge, Cayman Trough, Andaman Ridge, Southern Atlantic and any active deep-water seamounts. Other targets for comparative studies include seep sites in remote locations and whale skeletons wherever encountered.

Time-series studies: Wherever eruptions take place to study succession rates, patterns, especially the microbiology immediately post-eruption and greater emphasis on larval and recruitment studies at appropriate temporal and spatial scales (especially weekly, bimonthly sampling or instrumentation maintenance or maybe even daily). This is probably also true of other aspects of time-series processes following eruptions, especially in the critical first 6 months or so.

Reproductive Biology: Replicated short-term experiments needed to study settlement cues and frequent sample intervals to study gametogenesis especially in species shown to be synchronous. Reproductive synchrony implies the presence of an exogenous cue. Right now this is guessed to be tidal but no one has been able to demonstrate this link.

Diversity: Quantitative replicated sampling of microhabitats to study relationship between, for example, diversity and species composition vs age of a vent, areal extent of a vent, spreading rate and/or geographic location, distance between vent sites, depth etc.

Physiology: Continuing interest in physiological adaptations of a variety of vent species.

Phototrophs/Extremophiles/Suburface Biosphere: Search for...

NASA interests: NASA is developing plans to focus on remote, sub-ice ocean hydrothermal systems (and perhaps other systems) to assist in developing operational capabilities for exploration of Lake Vostok in Antarctica and the Europan Ocean. For obvious reasons, they are likely to be especially interested in autonomous vehicles with sophisticated sensor and navigational packages. They are also interested in sampling extreme environments in their continuing studies of the origin of life on earth.

**(RC)** Deep Submergence Science Research - Chemical Oceanography (CO)

Much of the emphasis in CO research over the past decade has been on upper ocean/atmosphere chemical cycles - especially the biogeochemistry related to the carbon cycle. The recent "FOCUS" workshop products reinforce that this is likely to continue. This community has not been very active in using deep submergence assets.

However, Marine Geochemistry (sitting between Chem and Geol) deals with the inventories and processes controling elements in the oceans and particularly identifying the "Oceanic Sources and Sinks" responsible for net fluxes. These studies explicitly focus on the interfaces. In this domain rest the most powerful applications of deep submergence technology. There are probably at least three classes of natural environments that will require insitu manipulative capabilities and, most likely, human presence on the seafloor. These include: seafloor hydrothermal systems (low and high temp.), ocean margin subduction zones, and the benthic environments under highly productive upper ocean environments. This list is not unique to chemistry - in fact MG&G, through the RIDGE initiative and core programs, has been the primary funder of these efforts.

Seafloor Hydrothermal Systems were first sampled by ALVIN over a decade ago. Continued effort on these system will expand to include more low temp focus, work on a variety of time series experiments and observatories, and continued work on the unique biochemistry the vent system community.

The Margins Initiative reflects a new interdisciplinary focus on active continental margins environments. Large-scale fluid circulation is the most important chemical transport mechanism through margins. Geochemical processes such as diagenesis and metamorphism, and deformation processes such as stick-slip faulting versus creep, are strongly controlled by the rate of fluid flow, fluid composition and the rate of rock-fluid interactions. Fluid flow and diagenetic processes represent important contributions to the global geochemical inventory.

The study of Paleoenvironments and Sedimentary Process will continue to be a major focus of the marine geochemical community. In particular, submergence assets will support insitu studies of modern biogeochemical processes so that they can be used to interpret the sediment record.

**(DO)**

- determining the role of gas in fluid expulsion, seafloor geomorphology, reflectivity, and shallow hazards
- long term monitoring of fluid flow/physical properties at the seafloor as well as at drillholes
- examining the relationship between physical properties, fluid flow and seismicity

**3) WHAT DEEP SUBMERGENCE VEHICLES WILL BE NEEDED TO ACCOMPLISH YOUR RESEARCH OBJECTIVES?**

**(P.F.)** The forearc studies I envision will require surveys with side-scan sonar (both regional initially and then followed by deep-towed high-resolution systems - e.g., DSL120). I expect that some surveys will require bottom photography (digital systems would be preferable). The break-away coring system and mini-CORKs that I am developing will produce shallow, cased, holes with appropriately-sized CORKs for instrumentation of various sorts. Emplacement of these shallow, cased holes will require precision coring of a type only attainable if the corer is instrumented with real-time video and may require some level of propulsion. These mini-CORKed holes will have to be serviced by HOVs, ROVs, or possibly AUVs in order to function as long-term monitoring sites.

The sorts of features I have been working with require very detailed and precise sampling. We may need to develop rock drilling capability for HOVs in order to do some of the work. Bottom drilling with a tethered drilling device that has some maneuverability would be useful, but for detailed, precision sampling, for instance, sampling within crevices or into the sides of vent structures, a rock drill mounted on an HOV or dedicated ROV may be required.

Our particular need will be to attain a deep presence (deeper than 6500 m) and I will be very interested in development of deep ROVs or development of collaborative programs with facilities that have them.

**(HM)** An ROV with larger payload capacity that JASON (something closer to ROPOS) but with good mapping, manipulative, and sampling tools would best serve the deep submergence needs of this Laboratory. A vehicle that could be used on any of the new AGOR class vessels would give the scheduling flexibility needed, and with the increased bottom time and other attributes, the sampling and monitoring programs would grow. There should be little need for a manned submersible for these tasks. Additionally, AUVs should be used for event response, as proposed for ABE and others.

**(CW)** The answer to the third question regarding what vehicle needs is a simple one. Both are needed, but will depend on the specific mission of the research. For our area, microbiology and biology, sampling needs on a daily basis is most often the case. Sometimes these needs can be accomplished by a JASON type ROV if they are not too great. Other times the need for a much heavier lift capability is required, and this can be served by the vehicle itself or possibly by an elevator system. In any case, the vehicles needed to accomplish the goals of our research include both manned and unmanned vehicles, perhaps with an emphasis on the manned submersible.

**(CVD)** Deep-Submergence Vehicle Requirement for Vent Biology Research:

ROV Specs:

- 6000 m or greater depth capability
- precision sampling capability for biota
- system for returning macrobiota at ambient pressures and temperatures
- system for drilling sulfides for study of microbial/geochemical gradients
- > 150 lb payload routinely (either associated with the vehicle itself or
- through a sophisticated elevator system)
- precision navigation
- high def, reliable, flexible imaging platforms
- maneuverability (100 m scope on the seafloor without moving the ship;
- stability during sampling)
- endurance (48 hour deployments or longer)
- standard and flexible plug-ins for ancillary instruments/sensors

- data management

Probably the greatest limitations to my research right now are NOT the quality of the vehicles per se, but science funding and vehicle availability, especially for time-series studies or replicated sampling.

**(RC)** Both margins and ridgecrest research communities have identified insitu laboratories and observatories as critical new tools to establish time-series studies of chemical processes. On going efforts to develop/improve insitu sensors will broaden the need and uses of deep submergence assets.

If we are going to “entrain” new users onto the submergence platforms, we need to bring in some "new customers" - people that have been using other tools but may be ready for the vehicles. The midwater range between 200m depth and 1000m depth represents a habitat that is chemically important yet difficult to sample for important particulate matter processes.

**(DO)**

- ROVs, preferably heavy duty, hydraulic equipped.
- AUVs for retrieving data?
- seafloor observatories.

**VEHICLE TECHNOLOGY - Jim Bellingham**

**Q: What is the state of AUV technology?**

A: AUVs are operated fairly routinely by a number of groups. In particular, in the US there is a large focus on small, high performance AUVs. These systems are presently limited by available sensors and by ranges/endurances well below those theoretically achievable. The research focus is no longer on getting the systems working, rather it is on more advanced issues like developing docking capabilities and/or extending range. Navigation remains a problem, although the limitations here are conceptually not much different from those with which ROVs and crewed vehicles have to deal.

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**Q: Are AUVs going to make it into the field?**

A: There are a number of AUV efforts emerging which support significant field programs. In the US those are: the MIT/WHOI/other ODYSSEY (Bellingham et al.), WHOI ABE (Yoerger, Bradley), WHOI REMUS effort (von Alt), and FAU Ocean Explorer/Voyager (Smith). There are other groups working on AUV technology, but the central players are listed above. The ODYSSEY effort has fielded 18 cruises/ice camps over the last several years, and the balance of operations is steadily moving from engineering proof of concept to science driven data gathering. ABE had what I would call an extremely successful science cruise last summer.

Most of the AUV operations to date have been one-time events, demonstrating some new sensor or operational capability. However, as feasibility is proven by ground breaking efforts, other more focused teams are being to coalesce to design systems for specific projects and applications.

My experience is that there has been an enormous amount of excitement over AUV operations. I get far more calls for field operations than I can support with my present infrastructure. Many of these requests are from scientists who have been involved with previous AUV operations.

I would not be surprised if in five-ten years, most of the large ship time is consumed with AUV operations of one type or another.

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**Q: Who is funding this work?**

A: With the exception of ABE, which was developed with NSF $ and does not have core funding, virtually all the money in this arena comes from ONR.

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**Q: Are these deepwater science vehicles?**

A: In terms of user communities, the deep science community is very conservative re technology adoption, heavily committed to existing assets, and weak from a technology development funding perspective. Despite the fact that the strongest economic arguments for use of AUVs are for deepwater applications, it seems likely that deep submergence science will lag behind other AUVs users in adopting the technology. Most of the AUV activity addresses shallow water applications (< 200 m). Both ODYSSEY and ABE are deepwater systems, although most Odyssey operations have been <500 m.

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**Q: What is a likely model for adoption of deep AUVs by the scientific community as operational assets?**

A: I thought about this a great deal, and don't have a firm grasp on all the dimensions of the problem. Maybe a well outfitted deep sonar platform might be 400-800 K a few years down the road (the present shallow Hugin is a 2.5 M system). Most of the cost, or at least a large portion, is the sensor. These vehicles will be out of reach of the typical laboratory, but probably not so expensive as to be limited to a single national facility. It is worth noting that there are much greater costs associated with the support equipment and personnel for operations. One option I looked at a while ago was to view AUVs as part of a ship's compliment of equipment. One could imagine mature systems being supported by one expert and the ship's SSG. In any case, the data processing capability will become an extremely important part of any such capability - sending the scientist home with raw data will not work!

One interesting question is the role AUVs will play in deep sea observatories. This is an area in which a national facility could play an important role.

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**Q: What is going on in industry?**

A: The oil industry is moving into deep water (3000 m) and is finding it does not have the tools to work there. There is great interest in AUVs, and indeed one of the most successful AUV programs around is the Norwegian

Hugin effort, which is entirely focused on oil/gas commercial applications. One of my lab members has spent several weeks in the last year visiting oil companies and has found a great deal of (active) interest in AUVs. The threshold to entry here is very high, but one commercial system already exists (Hugin). In my discussion with industry, I've noticed a very different change in attitude with respect to AUVs. It used to be that the question was whether AUVs were useful for anything, now the question is what is the successful business model. The economic arguments are clear, and the technology required appears very achievable. It is interesting to note that virtually all the commercial focused activity is overseas - most US activities are focusing on the military sector, as usual. An exception is the Bluefin spinoff from my lab.

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**Q: What is the international scene?**

A: There are some very active programs in Europe. The Autosub project in the UK has been revitalized in recent years, and is racking up a reasonable number of successful field deployments. While the present Autosub is not full ocean rated, the objective of this effort is to develop deep vehicles, and they seems to be making good progress. The Danish Martin program is developing AUVs for commercial applications, and seems to be well funded from private coffers. The Norwegian Hugin program (mentioned above) is a consortium of government, oil company, equipment/sonar company and operations company. It has taken a very focused approach to developing AUVs for deep surveys (their present vehicle is shallow, but their next vehicle will be 2000 m rated and with and endurance of multiple days). I am not that familiar with the Japanese efforts - they have achieved very little return for their large AUV investment in the last decade - however I hear 2nd hand that they might be refocusing their efforts. The Russians developed a very credible operational AUV capability in the last days of the cold war, and over the last several years apparently have built vehicles for the Chinese and the Koreans (deep rated systems) if I understand correctly. Other countries, such as Australia and Singapore have both been making the rounds building up critical mass to launch significant AUV projects, primarily focused on Navy applications. The Singapore effort has been particularly high level.

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**Q: What about ROVs in industry?**

A: There have been a number of changes in ROV manufacturer/user communities. First, commercially available ROVs with deep ratings are becoming more common as many companies anticipated the oil industry shift to deep water (there have been extremely capable deep systems for a while). Second, ROV operators have started building their own vehicles, to the dismay of the commercial manufacturers. Indeed, most of the deep ROV manufactured are built inside the large operators (Oceaneering, Racal, etc.). These vehicles tend to be work vehicles, not mapping vehicles. For mapping, industry is still using towed systems, and is beginning to look to AUVs.

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**Q: What about manned vehicles in industry?**

A: Very minimal role.

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DESSC 6/4/98

# Deep Submergence Tasks

- Image
- Survey — HOV
- Sample — ROV
- Manipulate — AUV
- Sensor

Science Feedback

Bigger, Faster, More, Cheaper, Reliable

Industry perspective

ROVs (and AUVs)

built for customers - and not all alike!

[ROV = vehicle with propulsion and manipulation]

DO Favors (next 5 years)

HOV for cognitive presence

AUVs for data interrogation

survey

(esp. Mid-water)(observatory)

ROVs → torque (hydraulic-electric)

(wish list?)

strong manipulators

payload

hydraulic tool chest

↑ HP (min. power limitations)

on the fly course, sample flexibility

lights, video, bandwith