Being There -

The Continuing Need for Human Presence in the Deep Ocean for Scientific Research and Discovery

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We see with our mind's eye. This poetic phrase attempts to describe a complex set of human interactions by which we take in and process information about the physical world around us. For millennia, scientists and philosophers have relied on our ability to apply the uniquely human traits of perception, cognition, memory and motor action to scientific observations and experiments. *"There is no authority higher than the human eye,"* observed Leonardo DaVinci, and his prescient statement still holds true; as the majority of field biologists, geologists and other physical scientists will attest, there is no substitute for direct observations.

The submersible *Alvin* is the vehicle that has taken more scientific "eyes and brains" to the deep seafloor than any other research submersible, or human occupied vehicle (HOV), in the world. Since the early 1970s, the unique and groundbreaking accomplishments of biologists, chemists and geologists working in *Alvin* have been often cited, and *Alvin's* capabilities and reliability continue to be the standard by which other HOVs are measured. The accomplishments include: most dives by any deep-diving research submersible (>3,830); most people transported to the seafloor (>11,300); highest overall reliability (~98% of dives made vs. dives scheduled), and most cost-effective operations of any deep-diving HOV ($9,400/day - calculated over the past

16 years). *Alvin*’s ability to give scientists direct access to seafloor field areas has led to important discoveries (e.g., the first detailed sampling of hydrothermal vent fluids and biology, and observations of a seafloor volcanic eruption), and the greatest number of refereed scientific publications (>1,600) related to operations of any deep submergence vehicle.

We highlight *Alvin’s* significant contributions to encourage public discussion on the continuing importance of HOV capability within the US oceanographic community. There is an immediate need for individuals to contribute their experience and opinions on this topic to US funding agency representatives. This dialogue will assure that required submergence vehicle facilities are available for the next several decades of scientific inquiry in the deep-sea. This important issue will be discussed at an all-day UNOLS DEep Submergence Science Committee (DESSC) public meeting on Dec. 5 at the fall AGU in San Francisco (meeting location and agenda will be posted at <http://www.unols.org>).

The advent of increasingly capable remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) has led to the notion that *all* science at or near the deep seafloor can now be conducted with ROVs (and possibly AUVs in the future). We believe this vision is shortsighted. It ignores an axiomatic scientific principal—that multiple, complementary instruments or facilities are often required to solve basic scientific problems. For instance, no one would argue with the need for a diverse fleet of oceanographic research ships that include coastal vessels, intermediate range ships for regional studies, drilling vessels or platforms, ocean class vessels that can circumnavigate the globe, and ice-strengthened vessels capable of polar investigations. One cannot understand all aspects of a research problem, or specific multidisciplinary dynamic interactions and their manifestations within earth or ocean processes by using only one instrument. The same is true for deep submergence vehicles systems. The multidisciplinary problems that are now, and will continue to be, studied for decades to come in the deep ocean require an array of complementary vehicle systems – HOVs, ROVs, tethered systems and AUVs.

For the past decade the broad community of scientists exploring the deep ocean and seafloor have worked closely with the relevant federal agencies (NSF, NOAA and ONR) and the National Deep Submergence Facility (NDSF) operator at Woods Hole Oceanographic Institution (WHOI) to improve vehicle systems that permit observations, sampling and comprehensive data collection at or near the seafloor. Three specific meetings (Global Abyss Workshop, Oct. 1992, DESCEND Workshop, Oct. 1999, and the NOAA-sponsored

LINK Symposium, May 2002), and several *ad hoc* and formal committees have been convened to solicit community input on deep submergence facility needs. These deliberations have considered various improvements to US deep submergence vehicle facilities, the priorities of the required upgrades, and the methods for implementing them.

A key result of this decade-long, focused community action has been the expansion of the NDSF to include highly capable fiber-optic based ROV and towed mapping vehicles, in addition to *Alvin* (see <http://www.whoi.edu/marops/vehicles/index.html> for detailed information on all NDSF vehicle systems and links to other deep submergence vehicles within UNOLS). The expanded vehicle suite was required to provide the capability to collect high-resolution data to optimize HOV and ROV observations and sampling through better characterization of seafloor environments. Community input and NDSF implementation has resulted in vast improvements to imaging and data sensors and vehicle attitude/navigation systems on all NDSF vehicles. At the same time, the US community identified the urgent need to develop a more capable ROV to replace *Jason*, providing the catalyst for the NDSF to propose and construct a new ROV using NSF and private funding. The new *Jason*, conceived just over three years ago, is now successfully operating for UNOLS scheduled science programs with a full complement of programs planned for CY2003.

Another result of this decade-long assessment was a request—by DESSC, the majority of the US deep submergence community, and the funding agencies—that the NDSF undertake a study to identify key issues regarding the replacement of *Alvin* with a new HOV that would regain a 6,500 meter capability for US scientists and national strategic interests (Figure 1, Table 1). This year, the NSF and NOAA funded the concept development phase for a replacement 6,500 m HOV. This ongoing work will produce detailed engineering specifications for design and construction of a new HOV. As part of this phase, the New Alvin Design Advisory Committee (NADAC) was constituted through discussions between NDSF, DESSC and UNOLS. The committee was charged with providing community input in developing mission requirements and functional specifications for science-related features of the new HOV and its operational characteristics. This phase will be completed in the summer of 2003. Construction of a new 6,500 m *Alvin* is estimated to take 3-4 years and could start as soon as fall 2003 if funding is available. NADAC is actively seeking community input and support for this initiative either by direct contact with funding agency program managers and/or participation in the discussions at the DESSC meeting on Dec. 5.

The vast majority of the scientific community views building a new 6500 m *Alvin* as a critical need for the next several decades, to provide improved capabilities for both science and operations and an increased depth range to 99% of the ocean floor. This consensus has been well documented in the minutes and reports of various meetings and is overwhelmingly supported by users who submitted responses during the recent request for input on the design of a new 6,500 m *Alvin*. As Table 1 suggests, *Alvin's* operational and science capabilities will be significantly improved by building a new HOV. Still, the question remains of whether it will be essential over the next few decades to take scientists to the seafloor to conduct research. Are ROVs like WHOI's *Jason*, Monterey Bay Aquarium Institute's (MBARI) *Tiburon*, or Canada's *ROPOS* capable of doing everything that *Alvin* can? This is an important question to address publicly so that the federal agencies funding the development of a new *Alvin*, and ultimately US taxpayers, can be confident that facilities needed to provide direct observations that further scientific knowledge in the deep ocean are well supported. A hallmark of UNOLS and US oceanographic research for many decades has been the deliberative and open nature of dialogue on important scientific facility issues. This includes coordinated actions among funding agencies, the research community, and operators concerning improvements to the oceanographic fleet. Decisions that affect the entire oceanographic community should continue to reflect a community consensus.

The current debate over the importance of human access to the deep ocean is not new. It started at the two-day symposium in 1956 (attended by 103 ocean scientists, including Bob Dietz, Jacques Piccard, Willard Bascom, and Maurice Ewing among other notables) at which the oceanographic community first went on record "… *as favoring the immediate initiation of a national program aimed at obtaining for the United States undersea vehicles capable of transporting men and their instruments to the great depths of the ocean*." This view was hotly contested amid discussions of limited resources to be devoted to future deep-sea oceanographic assets. But the view of Allyn Vine, one of the engineers responsible for the creation of *Alvin*, prevailed. "*I believe firmly that a good instrument can measure almost anything better than a person can if you know what you want to measure,"* Vine said at the meeting. *"... but people are so versatile, they can sense things to be done and can instigate problems. I find it difficult to imagine what kind of instrument should have been put on the Beagle instead of Charles Darwin*."

We believe there are several critical areas in which HOVs will continue to provide important capabilities for deep ocean research for at least the next ~20 years. The following discussion underscores the need for the US deep-sea research community to speak out forcefully so that their facility needs are met.

3-D Visibility and Engagement of the Operator- Scientists working in *Alvin* consistently describe themselves as focused and conscious of every sensation throughout their dives. To engage the human consciousness at this level requires nothing short of complete physical presence. ROVs strive to achieve this, but the reality is that no ROV currently operating anywhere in the world provides human-like virtual presence. To be sure, extensive research programs in the medical and robotics sciences, and offshore oil/gas industry also seek virtual presence as their goal. The infrastructure required to provide this capability is significant and 100% virtual reality in an ROV system does not exist. Indeed the whole idea behind achieving virtual reality is to simulate the human presence to gain the level of engagement one gets from actually being there. Science time at sea is expensive and a fully engaged researcher making observations and sampling on the seafloor using an HOV is more effective and accomplishes much more than the equivalent hours spent observing and sampling using current ROVs.

Scientists who have used a range of deep submergence vehicles attest to this. Among the comments in the minutes and summaries of workshops discussing future vehicle facility requirements are these:

"On-site human vision and computation will never be surpassed and is still needed in many cases."

"No. 1 thru 10 for me is the potential to have human eyes viewing the sea floor directly. NO imaging system can provide the spatial information that a direct view can give, at least not yet. AUVs and ROVs are great for some purposes, but direct views by experienced observers can not be replaced."

Contextual Observations- The perspective gained by looking directly out of *Alvin's* view port at the three-dimensional seafloor environment—versus looking at video monitors in an ROV control van thousands of meters above the seafloor—is both unsurpassed and essential. The difference can be replicated by comparing your direct view of the room you are reading this in to your view if you looked at the room with only one eye through a rectangular hole cut in the end of a black box. The comparison is even less favorable when one considers that scientists exploring the deep sea often encounter completely unfamiliar environments, complex features, and dynamic physical and biological processes—and are seeking to put all these in context. The human sight-balance system allows *in situ* observers to place objects in a spatial realm almost automatically; this does not happen when looking at a video screen. Observers using ROVs must rely solely on the changing numbers in the digital compass on the pilot's screen to get a sense of directionality.

"Being in the environment is a tremendously important experience for a deep-sea benthic ecologist," said one scientist in submitted testimony. *"My intuitions about the environment are improved with each dive. No amount of video trains the imagination as well as being there."*

Observation of complex biosystems is far better performed by human observers *in situ*, particularly for perturbation experiments. Observers at a site in an HOV often report that they catch something critical happening beyond the field of view of ROV cameras. The same is true for some geological applications. The most effective way to perform detailed geological mapping is to have skilled persons *in situ* looking at the structural relationships in 3-D - integrating direct visual information with the cognitive ability of the human brain and tracing formation contacts. These are the hallmarks of field geology. HOVs permit geologists to "walk the outcrop" - thousands of meters beneath the ocean waves.

In some instances shimmering water from gently effusive warm springs, which may be critical for identifying sampling sites, simply can't be seen with an ROV because of the optical interference from video transmissions. As a user of both ROV and HOV systems wrote, the advantage of working from an HOV is:

"…although hard to explain - 'being there.' After two years of work at small sites on Endeavour (Ridge) with ROPOS (and hundreds of virtual hours on the bottom), I got a better feeling for my study sites in one Alvin dive than I had in the previous two years. …After a dive, I know where everything was, how big it was, what the real shapes were, etc."

Sampling by an HOV pilot directed by an observer typically takes one-half or a third less time than the equivalent operation from an ROV. Some of this difference is due to HOVs' greater maneuverability. Without an ROV's constraining tether, HOVs can move more quickly over a wider seafloor area, with the observers and pilot interacting to fully characterize the terrain or observe and sample subtle biological, chemical or geological features. One investigator with extensive HOV and ROV expressed it this way:

"Alvin can explore a new site rapidly, with maximum observational coverage and the new bottom-lock Doppler navigation is exceptional. The lack of a tether provides uninhibited freedom to traverse the seafloor at

maximum speed (up to ~2 knots) with three sets of the best imaging system known, the human eye. Observers at the seafloor in Alvin maximize the probability of discovery. An HOV can also quickly stop to make observations and sample unusual biology or geology or a new hydrothermal vent, whereas the movements of a tethered ROV have to be closely coordinated with the surface vessel.”

Capacity for Education, Outreach and Recruitment- The deep ocean remains a great frontier for science and exploration. The mystery of what lies beneath more than half our planet’s surface area continues to capture the hearts and minds of people of all ages. Over the past forty years modern explorers, like Jacques Cousteau and Bob Ballard, have engaged the public in the wonders of the ocean’s depths, thus ushering in an era in which humans more keenly appreciate the critical role of the oceans and the seafloor to life on Earth. One of the primary ways that the public and several generations of students and scientists have gained this appreciation is being there - the human presence in submersibles, directly observing and recording the extraordinary terrains, animals and processes in the ocean depths.

A new *Alvin* with improved capabilities is an essential strategic asset for our nation. It will allow rapid advances in deep-sea exploration, ensure continued US leadership in deep ocean research and technology, and continue to educate students and the public about the deep-ocean and seafloor. In the same way that we provide new ships to access and study the ocean and seafloor, building a new *Alvin* should be viewed as an investment in the future of oceanographic science. It will continue to pay significant dividends for current and future generations of scientists that require direct observations of the deep seafloor and interaction with the physical and biological processes occurring there.

References

Listing of reports of previous workshops and meetings that relate to the need for submersible facilities to support US oceanographic science:

- DESCEND Workshop: <http://www.gso.uri.edu/unols/descend/descend.htm>

- The Global Abyss: An assessment of deep submergence science in the United States, UNOLS Office, Univ. of Rhode Island, Narragansett, RI, 1994

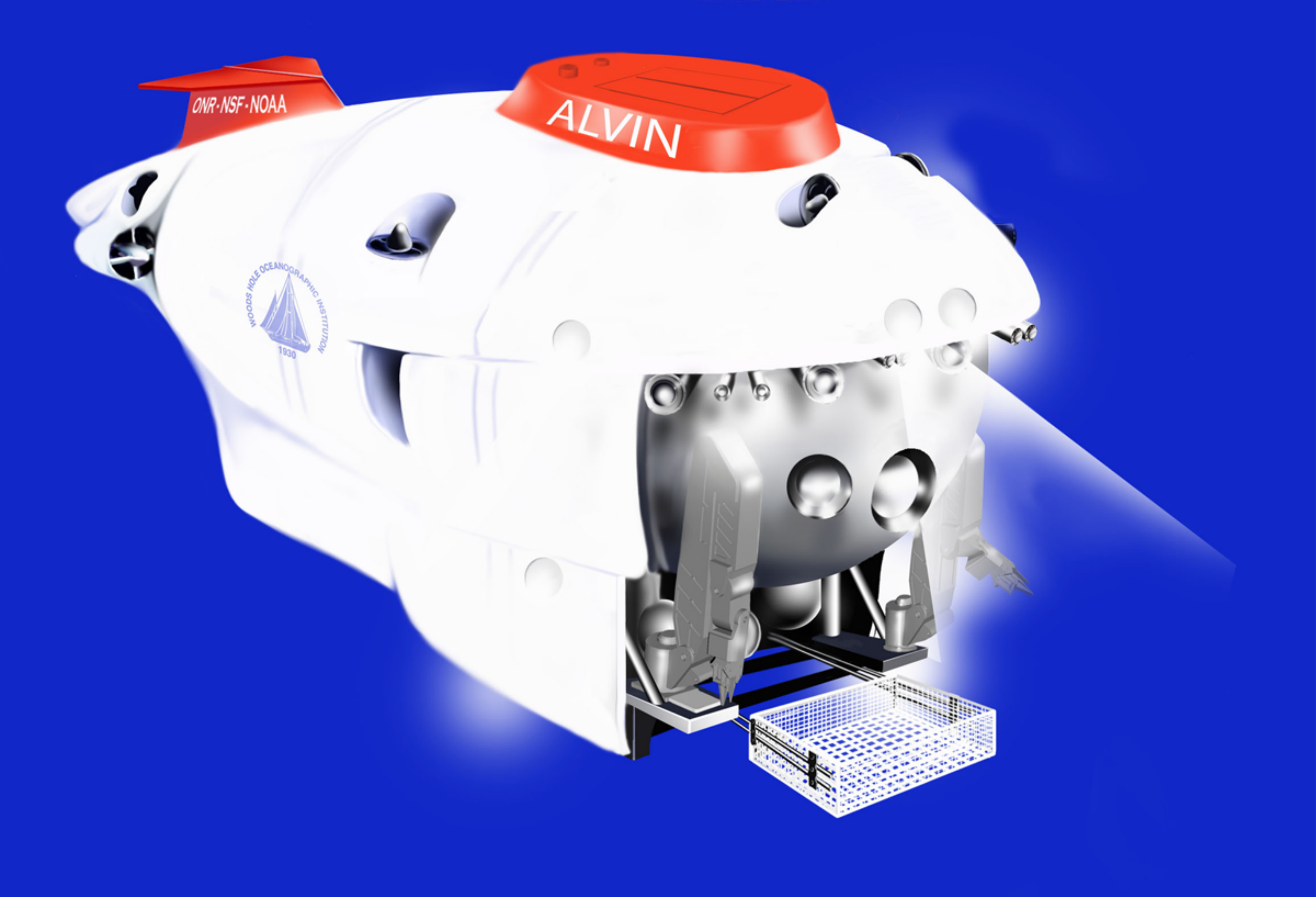
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Table 1. Design criteria for a new 6500 m *Alvin* based on community responses to planning documents, workshops and committee meetings.

•Greater speed
•Improved science sensors and tools
•Improved maneuverability
•Increased power for propulsion and payload
•Greater endurance and improved ergonomics
    (longer dive time, especially when being used to maximum depth capability)
•Better visibility and lighting
•Improved navigation
•Improved safety systems
•Improved manipulation ability
•Greater external sample storage and increased science payload
•Better communications
•Improved data collection, logging and interface capability to science instruments
•Comprehensive engineering, operational, and science-utilization documentation
•Depth capability to 6500-7000m
    (depending on technical feasibility and cost-benefit analysis)

The new submersible, with its improved systems and greater depth capability will access >99% of the ocean's depths. The new design will continue to permit operation of the new Alvin submersible by a single pilot on a routine (daily) basis, with two science observers on each dive. All the above improvements would be possible while maintaining deployment capability from the existing support ship with no major modifications to the ship design, or submersible launch-recovery system.