Manned Submersibles
Translating the ocean sciences for a global audience

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Abstract—Research and exploration guided by the scientific community define the nature of our vibrant, complex and sensitive planet. Translating this research into awareness and concern necessitates bridging the gap between pure science and the compelling story it tells. Decades of work by influential underwater explorers—including Jacques-Yves Cousteau and Sylvia Earle—have brought advanced marine technologies to the forefront of underwater story telling. One of the most powerful technologies is the use of manned submersibles. These small research submarines are uniquely adapted platforms for researchers to not only collect data, but to interact with the environment in a way which captures the hearts and minds of humanity. The first hand experience of physically diving into the sea is inspiring and unique. Through interviews, interactions and recounted experiences this paper explores the benefits which manned submersibles provide the underwater storyteller.

Index Terms—Manned Submersibles, Science Communication, Exploration, Storytelling, Oceanography

I. INTRODUCTION

As we emerge into an age of growing global awareness of the oceans, enthusiasm for research is needed to bring oceanography the credit it merits. The oceans mediate many critical earth processes yet they are lacking the attention they deserve. To bring the significance of ocean processes into the limelight, researchers in the fields of chemical, physical, and biological oceanography, as well as marine geology, share their findings with a diverse audience. This is not done without difficulty. Engaging a public audience in the sciences involves tapping into an interest shared by a great number of people—an innate desire to experience. Utilizing this nearly universal interest will increase the level of excitement for oceanography. While there are many avenues for researchers to utilize deep sea robots and make discoveries remotely, there is no substitute for sending individuals into the deep.

In the mid 1960s and 1970s a push towards deep-sea exploration made way for the commissioning of the first deep submergence vehicles. These submersibles faced a number of technological hurdles that prevented them from being mass-produced. These included (a) the low ratio of battery capacity to their weight and volume; (b) the tendency of electrical cables and connectors to take on water over repeated dives; (c) the limited visibility which turbid water and small, poorly located ports provided [1]. New innovations in the fields of sonar technology, deep-sea electrical systems, and material sciences are a few of the key adaptations that have addressed these issues and modernized submersible designs. These innovations allow researchers to carry out their work with greater efficiency and comfort [2].

Manned submersibles, additionally, provide something beyond the advanced use of technology. They add value to scientific methods through an engaging experience that is exclusive to observing phenomena first hand. Direct observation enhances exploration because it takes advantage of the physical senses. The human ability to create mental maps, perceive sounds, feel acceleration, and simply look around allows us to define the conditions of the surrounding environment. These perceptions provide oceanographers information through which they can engage a broad audience.

It is crucial that oceanographers bring awareness about the state of our oceans to the greater community. Reaching out and communicating the value of deep-sea research to a global audience paves the way for humanity to understand and protect the oceans that have sustained us for so many centuries. A leading figure in science communication is Dr. Sylvia Earle, whose unstinting commitment to ocean outreach has inspired a generation. She uses her extensive experience diving submersibles to narrate the attractions of the deep-sea to nonscientists the world over.

Oceanographic instruments, including remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), gliders, buoys, sub-sea stations, and manned submersibles are impressive pieces of equipment which are designed, built, and operated by people. In the global scheme of understanding our planet there is one advantage manned submersibles exclusively provide, the ability to protect and deliver, directly into the sea, the most adaptable and complex computer ever known, the human brain. Advances in manned submersible technology and the potential for the individuals onboard to impact science communication will provide one incredibly influential tool to impact a global community which is ready to listen.

II. THE PRESENT STATE OF SUBMERSIBLES

In increasing use today are a number of submersible vehicles, most of which are unmanned, though many have pilots who operate them remotely from the surface. ROVs have been heavily utilized as the workhorses of the sea. With highly
trained pilots controlling them, ROVs are capable of carrying out an extensive range of scientific and industrial tasks at depth. These vehicles are powered and controlled through tethers sometimes thousands of meters long. While they operate regularly in the deep sea, delving into the deepest points is prohibitively expensive and technologically complex due to the tether management they require.

Autonomous underwater vehicles as well as benthic and moored instrumentation provide continuous streams of data to the researchers who build and maintain them. In an environment that never stands still, these devices study changes and patterns in the ocean over time. At regular intervals these devices stream the data they have collected to the labs where it will be analyzed and interpreted by experts.

Modern manned submersibles were developed through government projects or by the privately funded endeavors of wealthy individuals. Among these are five currently or recently operating deep submersion vehicles each owned by national governments and used mainly for research. They are the American sub Alvin, capable of reaching 4500 meters, the Chinese built Jiaolong, rated for 7000 meters, the two Russian vehicles Mir 1 and Mir 2 which dive to 6000 meters, the Japanese submersible Shinkai 6500, and the French sub Nautilus, rated for 6000 meters [3] (Fig. 1.)

Most modern deep submersion vehicles, both manned and unmanned, dive to just over half of the full ocean depth. The main driver in designing subs for deep-water capabilities is that at near 1,000 meters, only a small fraction of the seafloor is accessible to researchers. At 7000 meters, however, nearly 98 percent of the ocean floor is accessible (Fig. 2). The remaining 2 percent of the sea floor are the trenches that are more than 10,000 meters deep.

Only four dives have ever been made to these deep and unknown parts of the ocean. In 1960 the bathyscaphe Trieste took two men, Don Walsh and Jacques Piccard, to the bottom of Challenger Deep in the Mariana Trench, 10,911 meters below the surface of the ocean. The deep was untouched again until two ROVs rated for 11,000 meters Kaiko and Nereus touched down in 1995 and 2009 respectively. Recently, in March 2012, a single man vehicle called the Deepsea Challenger carried the third human, filmmaker and explorer James Cameron, to the bottom of the ocean.

III. BENEFITS OF DIRECT OBSERVATION

Researchers utilize multiple tools to make observations in everyday field research. What allows the harmonious and synchronized use of these tools is the human eye. It takes time, and several observant individuals working together, to process all of the data from pelagic and benthic communities. Of all the tasks manned submersibles are capable of, their true value lies in the ability to provide a platform for researchers to make personal observations. The ability to directly observe the environment can be a benefit to each of the four disciplines of oceanography.

Chemical and physical oceanographers can observe and feel the movement of water due to physical and chemical processes. For example, ocean mixing is a common topic in the study of physical oceanography. Mixing occurs when water bodies separated by temperature and density gradients are forced together by intense tidal pumping, ocean circulation currents, and wind-driven waves [4]. Human beings would arguably never have imagined the mirage of heat shimmering on the roadway or over hot desert sands without ever having seen it. The same shimmering occurs when water bodies mix across the pycnocline creating a stunning display of mixing water clarities that fill the entire field of view. This layer, where the density gradient between shallow and deep waters is the greatest, is found in all of the world’s oceans, but is rarely observed directly. First-hand experience of this type of occurrence adds a depth of understanding and context within the greater study of oceanography.
Biological oceanographers diving in submersibles are in a position to observe the natural state of benthic biota. Species identification and behavioral analysis performed from an unobtrusive submersible yields results available only through this unique capability. The extensive range of human vision expands our field of view beyond that of unmanned vehicles and instrument packages. This was evident to Matt Tretter during a dive on the shelf of the Monterey canyon in California. Onboard the submersible Antipodes, a 305-meter capable vehicle with twin 58” viewing domes, Tretter had the opportunity to observe without an explicit objective. He mentioned it wasn’t until the sub had been sitting stationary and he had been examining the entire surroundings for nearly an hour before he discovered an enormous sun star in the left field of view [5]. The seafloor was littered with so much life it took an hour to identify even the macro organisms. These observations remind the surface and sub-sea crews how much visual data must be collected to define any sector of the seafloor.

While pilots of remotely operated equipment must practice identifying and compensating for the movement of water, sub crews can feel when they are being swept along regardless of previous experience. In this way the pilot and crew are bonded in their experience of the deep and agree more intuitively on how best to approach a task. Geologist Mark Legg, PhD, while studying an escarpment off the coastline of Catalina Island, CA noted that his theories about the bathymetry were affirmed when he not only saw the evidence in the terrain but felt the currents he had expected [6]. By working with the pilot and moving across the landscape with the flow of water he not only studied the geology of the seafloor but joined the process that created it.

Crewmembers onboard submersibles have the ability to adapt their observational patterns based on what they are discovering. Instruments are efficient at data collection when oceanographers know the exact type of data they aim to collect, but as Allyn Vine, the father of Alvin, eloquently said, finding an instrument that could replace Charles Darwin on the Beagle is difficult to imagine [7].

IV. MANNED SUBMERSIBLE CAPABILITIES

Improved technology on manned submersibles brought them into the modern age of deep ocean exploration. Among the most valuable features of submersibles are the flexibility of their mounted systems and the ability to quickly refit for missions. Instruments such as sonar, electronic sensors and human observations are regularly combined on manned submersible dives, creating a powerful and extremely capable machine for studying the deep ocean.

A. Advanced Sonar Imagery

Sonars use high frequency sound to measure the detailed echo characteristics of the landscape before them. Sonar technologies employed by submersibles accomplish two things: (1) real-time sonar capabilities address the visibility issues which plagued early submersibles, and (2) the availability of many types of sonars increases the number of tasks for which they can be utilized [3].

Visibility issues due to poor water clarity and dim light are overcome when sonar and personal observation are used in conjunction. Observation gives researchers the opportunity to use their knowledge or familiarity with an area, event, or object to identify processes taking place. Using sonar at the same time will allow a researcher to identify dimensions and material characteristics (Fig. 3.) The detailed view of a target provided by 2 dimensional (2D) sonar, when paired with video and observational data, allows flexibility in how oceanographers study and share their discoveries.

A submersible outfitted with multiple sonars (Fig. 4) gives researchers the ability to choose the particular tool best suited for a given job. This ability to make a decision in real time maximizes the effectiveness of sonar use. Sub crews can choose 2D sonars to safely navigate themselves through terrain and do reconnaissance passes to determine the length and breadth of a target and then decide to use a different, more advanced 3D sonar to collect multiple sets of point-cloud data to map the target they are exploring.

![Figure 3. The still image of a steel structure (Left) shows the life and condition of the structure while the sonar image (Right) displays detailed spatial dimensions.](image1)

![Figure 4. Pan and Tilt system with dual sonar heads mounted on a submersible Antipodes.](image2)

B. The individual as a scientific instrument

Humans possess many characteristics that make us well-adapted instruments to collect data. Using nothing more than our own perceptions we can describe our surroundings in detail. This is the kind of data collection which will bring science into the language of the nonscientist. To a layman, a complex figure describing water salinity variations over depth (Fig. 6) becomes tangible when the researcher displaying it...
can also describe the change in buoyancy experienced physically during a descent through a fresh water lens into the saline layer below.

On a dive conducted in the Puget Sound, WA, an instrument mounted on the sub that measures conductivity (linked directly to salinity), temperature and density (CTD), collected data on characteristics of the water as it descended through the water column. Later analysis of the data indicated that the conductivity was 2.0 Siemens/meter (S/m) on the surface of the dive site increasing to 3.0 S/m within the first 10 meters of the dive and remained constant throughout the following 70 meters to the bottom. To a seasoned oceanographer this describes a freshwater lens likely due to heavy rainfall and river runoff. To a layman, however, only a personal experience could fully describe what that meant.

A submarine must be at a very calculated weight to dive. If it is too light it will not submerge, and if it is too heavy it will not surface by normal procedures. Before every dive a weight capacity is calculated based upon the density of the water in the dive zone. On the Puget Sound dive, previous experience indicated that the water was brackish, a mix between the saline waters of the Pacific Ocean and freshwater draining from rivers and rainfall. According to these conditions the submersible carried bags of lead as ballast to be properly weighted for brackish water. Unbeknownst to the crew, the first 10 meters would be through the very low density layer of fresh water. As soon as the sub began venting air, it sank rapidly, cruising through the freshwater layer in a comparatively heavy sub. At 10 meters, where the freshwater lens ended, the sub slowed rapidly. The difference between the fresh and the saltwater densities made a barrier so dramatic the entire crew felt the sudden shift in acceleration. The physical experience in the sub provided a valuable data point that was corroborated by CTD data after the dive. While instruments provide oceanographers the data required to carry out their research, a physical experience in a submarine will give them a valuable data point that was corroborated by CTD data after the dive.

At the western edge of the Gulf Stream, 4-15 nautical miles off the Florida coastline, rough choppy water transitions into a smooth flat surface in a zone as little as one meter across. For those with an oceanography background, “Sverdrup’s” becomes more than a unit of measure describing the volume of water moving through an area at a given moment, it becomes a tangible physicality. There is a sudden understanding of the shear force of ocean circulation where the difference between normal water movement and the power of the Gulf Stream can be felt and seen. Sitting in a small submersible experiencing the gravity of the powerful ocean, renders the word and its description in textbooks simply insufficient.

People respond positively to a few universal themes and exploration is one of them. In an environment such as deep space or the deep sea, the dissimilarity to our own terrestrial habitat prevents a broad audience from becoming emotionally involved. Sending a human being into a strange and often dangerous new environment makes inner and outer space relatable. No matter how valuable the work of NASA scientists, audiences tend to lack interest in hearing from them. At the same time astronauts are treated as heroes [8]. Give scientists the opportunity to be both researchers and first-hand explorers and they become powerful tools for ocean outreach. It is the direct observations and experiences of astronauts which bring widespread awareness to space exploration. Likewise, it is the first-hand experience of aquanauts that will make the oceans a central topic of public understanding and concern.

V. SUMMARY

As humanity advances closer to the sustainability limits of the earth, looking beyond our horizons is vital to the state of our world. Encouraging widespread consciousness will improve the communal level of knowledge about our ocean planet and validate an increase in oceanographic research. Sculpting research into inspiration by sharing results in a meaningful and exciting way is crucial to opening the collective eyes of humanity to the deep sea. The access that manned submersibles provide oceanographers is unparalleled. By simultaneously providing a platform for extensive research and stories of first hand experience, manned submersibles provide an exciting nearness to the mysteries of the deep.

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