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The aquanaut: still a tool for ocean science

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Introduction

Millions of people young and old were inspired by the images of The Undersea World of Jacques Cousteau (Cousteau, 1953), and the words of Rachel Carson (Carson, 1950). These influences were stunning and brought the public along on the journey of exploration, discovery, and ultimately conservation of the ocean. The experiences of *Calypso's* explorers were carefully presented in a poetic narration by Cousteau in a language not his own yet served as an irresistible draw for many who began to care for what was seen and described. Some chose their careers from these exposures to the ocean. Oceanographers and aquanauts were born. As technology has outpaced the supporting public budgets, the use of divers and aquanauts has been diminished and replaced by automated devices. Some work still requires the aquanaut, including the careful excavation of historic shipwrecks and delicate cultural resources, biological exploration of complex layered substrates, collection of sub-centimeter benthic organisms, and transplanting corals. Overall, however, most of the undersea scientific work formerly done by divers is being accomplished remotely, autonomously, or by human occupied submersibles. The value of the aquanaut in sustaining public interest and mission performance may be overlooked.

The aquanauts

The revolution in undersea exploration and placing a human in the sea was led by the US Navy with the Man in the Sea program with SEALAB I, II, and III, and through physiological experimentation, computations, and contributions now represented in the US Navy Diving Manual. Cousteau's earlier efforts beyond SCUBA including his diving saucer submersible and the ConShelf habitats demonstrated many possibilities. Other habitats followed and, for a period, proliferated (Miller and Koblick, 1995). These advances gave rise to a generation of science, commercial diving supporting the ocean oil fields, and military applications.

The critical component of these ambitions was to place a human, the adventurous diver, the aquanaut, in the sea and remaining there to do work for extended periods of time. There followed expansions of the use of underwater breathing apparatus (Bozanic, 2002), the development of a submersible industry (Interagency Committee on Oceanography of the Federal Council for Science and Technology, Undersea Vehicles for Oceanography, 1965), and even to experiments in human physiology to condition the human body to breathe a treated saline solution directly—an evolutionary phylogenetic regression to let humans breathe water (Klystra, 1974).

National ocean policies and living underwater

These influences led to enriching and adventurous careers. For a nation, these influences led to the creation of a national ocean agency, the National Oceanic and Atmospheric Administration (NOAA), in an age of environmentalism pronounced by the passage of strong laws to protect the environment: Clean Air Act; Clean Water Act; and Marine Protection, Research and Sanctuaries Act. In the course of developing NOAA, the Commission on Marine Science, Engineering and Resources, chaired by Julius Stratton, (the Stratton Commission), recognized the importance of the human relationship with the ocean, for food security and economic security. To achieve this, marine research was deemed vital to understanding the global oceans and predicting its behavior. Among many recommendations, the Stratton Commission envisaged a national program of continental shelf laboratories, some fixed in place and others portable with capabilities to mate with submersibles and endowed with complex systems for sustained *in situ* research for up to 150 divers and non-divers living under the sea (Stratton et al., 1969, pp. 162-164). While the Stratton Commission recognized the harms of ocean pollution, a focus was on advancing knowledge for resource exploitation. Later, the U.S. Ocean Commission on Ocean Policy, Chaired by Admiral James D. Watkins, USN (Ret.) (Watkins et al., 2004), was created to develop a comprehensive national ocean policy, including an assessment of technology, facilities, available natural resources, and ocean governance. Addressing the task of assessing ocean facilities, the importance of diving and humans in the sea was diminished to only a mention of the Aquarius Undersea Habitat in an inventory of laboratory assets but held none of the visions of Stratton. Instead, the vision was enthusiastically toward human-occupied and remotely operated vehicles (Our Nation and the Sea, 428-419; Appendix 5, p. 114). Addressing the vital role of human-occupied vehicles, the Commission saw value in the human presence under the sea. The U.S. Ocean Action Plan, the Response to the U.S. Commission on Ocean Policy, included the reference to extending the depth capability of the human-occupied submersible *Alvin*, and in advancing remotely operated vehicles. The status of balance between HOV and ROV was established, and the aquanaut and habitats had disappeared from U.S. ocean policy and national budgets. In 2012, the undersea habitat, *Aquarius*, was retired from NOAA's inventory and transferred to the Florida International University. The challenges of budget, maintenance, and competing science priorities and methods led NOAA to retire the facility, no longer a federal priority.

One can question the imagination or vision of federal ocean managers for winding up the last remaining undersea habitat, and this author is responsible for that decision. The reality was that given the amount of funding that NOAA had available, the habitat was underfunded, which limited its production and research value. Aquarius, as in HOVs, provides the unique human access and experience to the underwater environment that cannot easily be rivaled by remote and autonomous vehicles or devices, but at times those remote devices can bring in more data per dollar. That is an unfortunate reality.

Funding for ocean science

Another unfortunate reality is that ocean science is woefully short of funding in the United States. Had funds been available, the Aquarius Undersea Habitat may have continued as a federal asset. The US National Ocean Commission took notice in 2004 of the U.S. falling behind in funding and technological leadership, noting that "[i]f not remedied, a decline in U.S. leadership in marine technology development will result in increasing reliance on foreign capabilities" and that "Japan, the European Community, India and China are all making great strides in marine technology development and have the potential to outcompete the United States in the near future." (U.S. Commission on Ocean Policy, 2004). Today, that challenge is apparent as the U.S. has only one operational polar icebreaker and chose not to renew the contract for the nation's only deepsea drillship.

Private funding

Enter the private sector and philanthropic community. Where governments have struggled, ambitious and visionary private programs have emerged. Both James Cameron and Victor Vescovo funded their own separate vehicles to visit great ocean depths including returns to the Mariana Trench. Proteus Ocean Group[1] conceived by Fabien Cousteau sees their habitat design as an international space station of the sea and seeks to become a modular laboratory under the sea, moveable, expandable, and replicable. Also, DEEP[2] exists to "radically advance how humankind can access, explore and inhabit underwater environments" and to foster "a renaissance in ocean exploration and research." DEEP endeavors to make humans aquatic and is currently building an undersea habitat called the Sentinel System to further human ocean exploration. DEEP sees human participation as essential to understanding the ocean environment and conservation. All are putting the human back in the sea.

OceanX[3] has appeared on the National Geographic screen with a *Calypso*-like recipe engineered by James Cameron, funded by Ray Dalio, delivering a familiar character to the host ship, the *OCEANXPLORER*, as well as a cast of relatively young personable and qualified scientists to explain the work to the public. Plain language and enthusiasm cut through the techno-chatter of traditional scientific presentations. The ship is described by the host organization as the "most advanced exploration, research, and media vessel ever built." And it is.

The private sector has reached beyond what government is now willing to spend on oceans and has self-funded space-scaled answers to the vision pronounced in 2001 by the Report of the President's Panel

1 Proteus Ocean Group. https://www.proteusoceangroup.com/.

2 DEEP. https://www.deep.com/.

3 OceanX. https://oceanx.org/oceanxplorer.

on Ocean Exploration[4] to return to finish exploring the ocean with new technology and bring the public along. NOAA has steadfastly operated the Ocean Exploration and Research program since 2001[5], starting with only a $4M budget, hardly a statement of commitment to the mission. Fortitude and results have earned the federal program a current budget hovering near $50M plus one dedicated ship, although even its replacement now under construction will be eclipsed by the capabilities of the private *OCEANXPLORER*.

A comparison with space

The nation's federal ocean exploration program is funded just below $50,000,000, and the nation's federal space exploration program is funded at a multiple 166 times larger at $7,666,000,000 (Congressional Record, Senate, March 5, 2024, S. 1400-1303). That bold dichotomy reflects the cost of rockets versus ships and habitats but also the level of public support for space and for oceans. One can query the number of bioactive compounds and medicines found in the sea (Malve, 2016) and compare that with the scientific achievements from space (Dick and Launius, 2007). In one case, science is saving lives, ensuring food security, foretelling the economic and health consequences of a changing climate, and defining the health of the planet's integrated systems that give humans a habitable planet. In the other, compelling questions of the universe are being addressed. Both are deserving, exciting, and important to a progressive and curious society, but while the amount of space science and exploration investment may be deemed appropriate, it is unclear how the amount of ocean science and exploration investment may be objectively concluded to adequately serve the public and remain at such a disproportionately low level. Do not degrade space; increase oceans.

Need for social science

The ocean science community can gain footing by caring about how well the work accomplished is understood and appreciated by the public. Science should not advertise, but results should be conveyed by more than the publication of a highly technical scientific paper. Understanding public reaction to the work will enhance the success of the field. When the NOAA Ocean Exploration program was established, this author convened a gathering in 2004 of the most notable minds in ocean exploration including Sylvia Earle, Jean Michel Cousteau, and Robert Ballard. The question presented was "How to make America care about oceans?" The omission in the design of the workshop was social scientists and psychologists. The NOAA program learned from these explorers what they had done to find success, but their successes were surgical, personal, and narrow compared with the breadth of support for exploring space.

Addressing this question more appropriately, Jamieson et al. (2020) reviewed the psychological engagement of humans and the ocean, ranging from comfort and contentment to the fear of the ocean, and how the oceanographic community chooses to communicate scientific results. This relationship is quite complex. Unwittingly, scientists invite fear of the ocean in how the ocean depths and strangely appearing creatures are presented. Societal responses range from fear through ambivalence to passion among components of society, but ocean scientists press on without sufficiently measuring or contemplating the reaction of the public to the reported work. The space community is constantly advocating the importance of their work and effectively sells the sense of importance to the public. The oceanographic community may not fully understand this, or worse, care about it. This has contributed to a lack of ocean funding based on public comprehension of the importance and the presumed satisfaction with the status quo. If a person were to put a GoPro camera in a lagoon in Key Largo for 100 days and broadcast that on the internet, few would care. However, when Dr. Joseph Dituri, CDR USN (Ret.), decided to submerge for 100 days[6] in the shallow water habitat operated by the Marine Resources Development Foundation, many people cared, including 5,500 students from 15 countries with whom he engaged during his mission. Few people would be riveted to a data stream of zeros and ones. However, citizens all are interested in their fellow human's experience, either through vicarious or substantive interest. The personal, human experience matters to other humans.

The space community understands this. While there are brilliant missions into deep space that are not human occupied, the Space Station continues to hold a fascination because people are there, where most cannot be. Astronauts can explain their experiences in addition to their work. They are trained to communicate well. So too can undersea aquanauts and underwater habitat residents. The space community has built a program including human space flight, principally to further understand human space flight in the quest for longer missions and to distant planets. Robotic exploration has brought much new information about Mars, but the ambition proudly remains, to put humans on the planet. Much of ocean science is increasingly conducted by autonomous methods out of financial and practical necessity. Humans are migrating out of the loop in oceans, and humans are very much in the loop in space. The origins and strengths of the space program are rooted in garnering broad public support in science reputation, geographic breadth of manufacturing, and nearly corporate-like advertising of its value. It is brilliant and has sustained the space program since its inception (Brinkley, 2019).

Putting humans back in the sea will bring humanity along for the dive, the experience, and enhance the cultural connection and ultimately support. Long-term monitoring by mobile and fixed autonomous systems is not alone exciting. The UN Decade of Ocean Science for Sustainable Development has 10 desired outcomes, one being to restore society's relationship with the ocean (Glithero et al., 2024). This effort delivers the purposeful engagement of the social sciences to understand cultural motivation

4 President's Panel on Ocean Exploration. (2004). https://oceanexplorer.noaa.gov/about/what-we-do/program-review/presidents-panel-on-ocean-exploration-report.pdf.

5 NOAA Ocean Exploration Program (2024). https://oceanexplorer.noaa.gov.

6 Project Neptune 100. https://www.mrdf.org/project-neptune.

and how to present the importance of a healthy ocean, and ocean science, to the public. This is overdue.

A comparison between public support for oceans and space may be found in the law. Policy is generated by words, and by money. In the case of recognizing the NASA mission in education and outreach[7] and the NOAA mission in education and outreach[8], Congress has declared in parallel that both have the responsibility to conduct formal and informal education at all levels, to enhance public awareness of the missions, to address underrepresented groups, to support science careers, to increase Science, Technology, Engineering and Math (STEM) literacy, and to provide curriculum support materials, and professional development materials and opportunities for teachers. Congress agrees that both oceans and space are the inspiring tools to strengthen the nation in the recruitment of STEM students. The only difference between the vacuum of space and the pressures of the ocean depth is that Congress has provided $144,000,000 in 2024 for space education, and $35,500,00 for ocean education, four times as much for the same cause and outcome, and neither has to build a rocket, or a ship.

Conclusion

The journey of man into the sea has been long and productive. The current levels of technology have made some of the traditional functions of divers and aquanauts obsolete, but in the process, the ocean science community has left much of the public interest and curiosity behind. While governments are concentrating their slim and declining resources on the most streamlined and efficient means of attaining the information necessary for science to support policy, the private sector seems ready, visionary, and dedicated to bringing humankind back into the sea. May the aquanaut swim again and tell her stories many times to many audiences.

7 America Competes Act Reauthorization of 2010. Pub. L. No. 111-358, §202, 124 Stat. 3993-3994.

8 America Competes Act Reauthorization of 2010. Pub. L. No. 111-358, §302, 124 Stat. 3997.

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