Strategy for NOAA Unmanned Undersea Vehicle Systems & Operations

Ocean Exploration Advisory Board Recommendations

In response to a request from the Deputy NOAA Administrator

13 August 2019

At a recent meeting of the NOAA Ocean Exploration Advisory Board (OEAB) on 31 July 2019, the Deputy NOAA Administrator requested advice and recommendations from the OEAB on a Strategy for NOAA Unmanned Undersea Vehicles Systems and Operations. This white paper responds to that request.

Executive Summary

Unmanned Undersea Vehicles (UUVs) and autonomous underwater systems (AUVs) will create fundamental changes in the way NOAA conducts ocean exploration. Effective integration of UUVs will increase efficiencies, reduce risk and cost, and serve as a force multiplier for existing infrastructure. An integrated human-machine approach will transform our understanding of the oceans in the coming decade. Committing to and leading a sustained UUV program is absolutely essential for NOAA to be a leader in ocean exploration.

The strategic importance of UUVs was recognized by Congress in its "Commercial Engagement through Ocean Technology" (CENOTE) Act of 2018. NOAA and Administration goals to map and characterize the U.S. EEZ by 2030 require new operational and broadly applied UUV capabilities. Now is the time for NOAA to develop a world-class UUV Program.

For effective leadership in this area, and in keeping with the CENOTE Act of 2018, Administration goals, and NOAA priorities, the OEAB recommends:

1. ***NOAA should actively engage industry and entrepreneurs to develop and operate UUV systems in ocean exploration. Benefits to NOAA include:***
    a. *Effective and time-efficient strategy to achieve NOAA objectives*
    The UUV industry is immature and complex with rapidly changing technology. As a result, NOAA is best served by an adaptable, resilient strategy. Partnering with the private sector provides a robust strategy, while enabling NOAA to take advantage of industry experience with the U.S. Navy and commercial offshore operations to accelerate successful UUV operations for ocean exploration.
    b. *Unique opportunity to partner with industry and entrepreneurs*
    UUV systems and operations offer NOAA a unique opportunity to establish a meaningful partnership with the private sector as a result of program size and longevity.

2. ***NOAA OER should take the lead in coordinating a NOAA Strategic Roadmap for UUVs.***

3. ***NOAA OER should establish and maintain close ties with the U.S. Navy to coordinate NOAA activities with ongoing Navy UUV Programs.***

4. ***NOAA OER should evaluate alternatives and recommend to NOAA leadership go-forward approaches for a structured partnership with the private sector, which includes experienced industrial and engineering firms as well as start-ups and entrepreneurs.***

Introduction – Why UUVs Are Critical for Ocean Exploration Leadership

Today, we face massive unexplored areas of our oceans. In the future, UUVs and AUVs will transform the way we explore, characterize, and discover the oceans. They will play a fundamental role in advancing the "Second Bold Era of Innovation" proposed by OSTP.

UUVs offer numerous advantages over traditional approaches to ocean exploration:

- Reduced manpower to achieve ocean characterization
- Reduced risk to personnel by reducing exposure at sea and reducing the need to put humans in submersibles
- Reduced operating costs by magnifying the capability of a ship at sea
- Greater persistence and range to characterize the ocean
- Improved efficiency of data acquisition and processing to accelerate mapping and characterization of the deep ocean by employing artificial intelligence and greater processing capability in UUVs

NOAA OER has stated a primary goal of mapping the US EEZ by 2030. The *Okeanos Explorer* reaches end of life in approximately 2024. UUVs and AUVs are critical for OER, NOAA, and a national ocean exploration program to achieve this ambitious and important goal. NOAA must act now, with urgency, to enact and lead a sustained UUV strategy which will enable by 2025 effective, routine mapping/characterization deployments using UUVs.

Effectively teaming humans with UUVs will create a powerful force multiplier for collecting ocean data. Mastering proficient UUV operations is essential for leadership in ocean exploration. As technology for homing and docking advances, it is expected that UUV systems may be operated from subsea bases. Such systems could provide high persistence observations from a subsea base providing power and immediate data communication via subsea cables to an offshore platform or land. Buoys and satellite links will afford command and control from anywhere in the world, including ships at sea. Developing this proficiency has implications for national security, environmental security, and economic security of our nation.

NOAA leadership has recognized the significance of UUVs by identifying UUVs as one of four key Science & Technology Focus Areas for NOAA. The OEAB supports this recognition of UUVs as an essential NOAA S&T Focus Area.

Congress recognized the strategic importance of UUVs in its CENOTE Act of 2018, which addresses coordination of NOAA's research, assessment, and acquisition of unmanned maritime systems. OEAB recommendations here are consistent with provisions of this Act. In addition, OEAB recommendations are consistent with recommendations provided earlier this year on a National Ocean Exploration Act.[1]

[1] https://oeab.noaa.gov/sites/oeab/Documents/2019-04-07-OEAB-Recommendations-for-National-OE-Program.pdf

The OEAB has also discussed use of the term "Unmanned Undersea Vehicles." While the term is both correct and ubiquitous in use, the OEAB recommends use of an alternative term, such as "Unpopulated Undersea Vehicles" to make a conscientious statement on diversity and to recognize the many meaningful contributions of women in this field. In the Board's opinion, the abbreviation UUV should be retained due to its broad recognition and its correct inclusiveness (i.e., "autonomous" is not a correct replacement for "unmanned" since many systems are unpopulated by humans but not autonomous).

In summary, stepping up to claim ocean exploration leadership demands world-class expertise in employing UUVs at sea. The confluence of technologies available today means the time is right to exploit UUVs in practical, cost-effective applications to explore the oceans. Now is the time for NOAA to act with urgency to accelerate UUV expertise in at-sea applications of UUVs.

1. NOAA should actively engage industry and entrepreneurs to develop and operate UUV systems in ocean exploration

a. Effective and Time-Efficient Strategy to Achieve NOAA Objectives

Since UUVs are critically important to NOAA if it is to achieve its goals in ocean exploration and other ocean-related missions, including mapping and characterizing the U.S. EEZ by 2030, NOAA should implement an effective strategy to employ UUVs in its programs.

An effective strategy involves satisfying numerous needs – safety, quality, cost-effectiveness of assets and operations, reliability, sustainability, and maintainability. An understanding of how people work with robotics is essential in order to develop a successful Concept of Operations (CONOPS).

NOAA can select from a variety of approaches. The U.S. Navy has chosen to partner with industry as well as to stand up a dedicated UUV Command (UUVRON-1). Establishing a dedicated command in the Navy at least partly results from the fact that the Navy is a military organization. UUV operators could be placed in harm's way. In addition, command authority may be critical for achieving military objectives and protecting other Navy assets. In the opinion of the OEAB, the drivers to establish a NOAA cadre within the Office of Marine and Aviation Operations (OMAO) are significantly less compelling at this time due to a difference in missions and the immaturity of UUV application.

Effectively achieving NOAA's goals with UUVs demands much more than just technology. Developing a world-class program requires three key components: Technology, Processes, and Culture. Exploring these components:

- ***Technology***

  The UUV industry is still relatively immature. The technology and capabilities change rapidly. Both hardware and software are constantly changing. It is a complex environment, in which it is difficult to predict which companies and which technologies will ultimately prove most successful. As a result, it is essential that NOAA's strategy be adaptive. It should not result in being pigeonholed with significant fixed assets, which are outdated on or shortly after delivery. Procurement cycles must be short and focused. In this regard, procuring UUV hardware and services is very different from procuring ships or airplanes, assets which require long delivery times of years, and which are expected to provide decades of use.

A successful UUV program will integrate UUVs from multiple providers. Different companies provide UUVs with different attributes of cost, capability, and reliability. Some combination of gliders, ROVs, autonomous vehicles, hybrid ROV/AUVs, and autonomous surface vessels (ASVs) will best serve NOAA needs. Again, an adaptable program is necessary to map a productive UUV strategy and take advantage of the rapidly changing technology for these systems.

In summary, NOAA's UUV strategy should implement an approach to technology which is adaptable and resilient in both procurement and execution.

- ***Processes***

Successfully employing UUVs involves a broad range of expertise from establishing CONOPS and requirements, to executing efficient operations, to providing lifecycle support to maintain and upgrade systems. The OEAB believes the private sector, not OMAO or academic institutions, is currently most experienced in these capabilities, as for years the private sector has been developing and operating UUVs for commercial offshore applications and for the U.S. Navy.

Processes required include system engineering (requirements definition and verification); project management; system integration; interfacing with other assets; comprehensive analytics for troubleshooting, life cycle support, and data consolidation; and integrating teams of engineers and technicians to ensure robust, maintainable systems. Processes which have been tested and iterated in at-sea operations are incredibly valuable. NOAA should take advantage of the existing industry expertise in our nation to avoid the costly, time-consuming, and risky approach of "re-inventing the wheel."

At the same time, at-sea application of UUV and AUV technology for ocean exploration is at a relatively early stage, so innovation for new CONOPS and quickly adapting processes are vital skills for success. NOAA OER's active engagement with the private sector to define CONOPS for new technologies (or new applications of proven technologies) is critical for success.

- ***Culture***

The third key component for success is culture. The UUV service provider(s) must be customer-focused. They should understand customer needs and goals and be incentivized to provide a responsive service to all NOAA users. The provider must be able to communicate effectively and in a transparent manner. The provider must demonstrate accountability and also be adaptable to change. As discussed previously, technology is evolving and changing rapidly. As a result, the culture of the provider must be able to focus forward and adapt rapidly. Finally, the service provider must demonstrate a commitment to excellence. They should have a demonstrable track record of providing effective and efficient service: demonstrated high availability (uptime of asset operation), cost-effective operations, superior logistics support, and retention of experienced operators. The OEAB believes NOAA can benefit from competition in the private sector to ensure these attributes for UUV systems and operations.

In summary, the OEAB recommends partnerships with the private sector as the best way to take advantage of lessons learned with UUVs. Partnerships will provide the right combination of technology, processes, and culture to ensure a successful, sustained NOAA UUV Systems and Operations Program.

b. Unique Opportunity to Partner with Industry and Entrepreneurs

UUV systems and operations offer a unique opportunity for NOAA to establish a partnership with the private sector. The OEAB has discussed multiple times the need to improve NOAA's relationship with the private sector. We have identified three primary aspects to create a successful long-term partnership: 1) the program must of sufficient size to attract industry partners; 2) the program should afford the potential for a sustained, multi-year program; and 3) the program should provide regular opportunities for entrepreneurs to develop and test new technologies in operational environments. A NOAA UUV Systems and Operations Program affords a unique opportunity to fulfill all three requirements.

Establishing a partnership between NOAA and the private sector provides multiple advantages. As described previously, NOAA would get a head start in its UUV program by making effective use of industry expertise, as opposed to relying on in-house personnel, for which initial groundwork would be costly in both time and resources. Partnering with the private sector also affords the opportunity for NOAA to send personnel to selected companies to build bridges to the future. Finally, these partnerships allow NOAA to build on concepts of operation and approaches with experienced partners, which benefit the ocean exploration community, NOAA, and the national economy.

Since UUVs are broadly expected to play a significant role in future ocean operations, partnerships provide long-term stability for both NOAA and the private sector. As both partners learn more about ocean exploration applications, innovative approaches and new opportunities will arise. With opportunities, the private sector will invest its own capital and resources in R&D. NOAA investment will be greatly leveraged. In effect, NOAA will gain the benefit of shared development risk. This will also accelerate innovation and implementation of UUV systems for NOAA missions.

It is important to note that "industry" is not a monolithic enterprise. It consists of very large companies, mid-size companies, and small start-ups. Each of these types of companies have different interests, capabilities, and expertise. Some companies are focused on providing hardware systems, some on hardware components and sensors, some on software (e.g., command & control, navigation, data processing and/or visualization, and artificial intelligence), and some on providing service (at-sea operations and logistics support). These diverse capabilities offer NOAA significant opportunities if they can correctly match their needs with skills of individual companies and teams of companies.

In any true partnership, both the customer (NOAA) and the provider (private sector) must share risk and reward. Numerous contractual arrangements exist to achieve this objective. Cost savings/overruns can be shared. Performance criteria, such as target uptime/availability, can be identified with rewards/penalties for exceeding/not achieving. Successfully integrating NOAA's expertise in ocean science and exploration with private sector expertise in UUV technology and operation while properly incentivizing both partners will significantly accelerate successful UUV application in ocean exploration.

These partnerships will also build public awareness of ocean exploration and result in more STEM talent being attracted to the ocean industry. Increased job opportunities at multiple levels will result in benefits to the blue economy.

The OEAB recommends NOAA OER, with support of OMAO, other NOAA stakeholders, and the National Center for Environmental Information (NCEI), take the lead in developing this private sector partnership for the following reasons:

- OER needs UUVs as a core competence to meet its primary goal of mapping the US EEZ by 2030 – they have much at stake
- OER has demonstrated a commitment to excellence in both executing work at sea and in developing private sector partnerships
- Developing new technology is part of OER's charter ("support innovations in exploration tools and capabilities")
- OER has successfully demonstrated responsiveness to other parts of the NOAA organization and the ability to work successfully with peers
- OER has proven the skill set to operationalize new concepts, develop innovative processes, and quickly adapt them based on lessons learned – given the early stages of employing UUVs, this skillset is more important than that of refining and enforcing standard policies
- OMAO support is key to establishing a solid foundation for the future and to bring lessons learned from managing other fleet assets
- NCEI is key because of their responsibility to steward, archive, and make ocean exploration data available and easily accessible to those who need it.

2. <u>NOAA OER should take the lead in coordinating a NOAA Strategic Roadmap for UUVs</u>

An essential element for a successful NOAA UUV program is to develop a Strategic Roadmap outlining strategic goals, requirements, capabilities, and plans to fill gaps. A Strategic Roadmap is essential to align NOAA stakeholders. OEAB believes OER is uniquely qualified to lead and coordinate this Strategic Roadmap.

A strategic roadmap delivers a time-based plan, which defines where the organization is, where it wants to go, and how to get there. It provides a clear, visual representation that organizes and presents critical information related to future plans and intermediate milestones. An essential component of the Roadmap is defining clear roles and responsibilities to align all parties.

Such a product will provide the framework for proceeding. Identification of intermediate milestones and decision points is key. In addition, it provides metrics to measure future program success, which are essential in order to ensure accountability. Finally, it will communicate to the private sector NOAA's intent and multi-year commitment to a UUV Program. The OEAB encourages OER to avail itself of the capability and expertise in the Ocean Exploration Cooperative Institute (OECI) to assist in preparing the Strategic Roadmap.

3. **NOAA OER should establish and maintain close ties with the U.S. Navy to coordinate NOAA activities with ongoing Navy UUV Programs**

The US Navy has increased its focus on UUV programs within the past few years and has made progress in several areas. As a result, the OEAB recommends that NOAA should establish and maintain close ties with the US Navy to monitor progress and coordinate activities. OER is ideally suited to spearhead this coordination.

Several aspects of Navy activities can benefit NOAA in developing and implementing a UUV Strategy. First, the Navy has already developed a Strategic Roadmap for UUVs. While the Navy has different priorities and missions, the Navy Roadmap will certainly benefit NOAA in developing their own Roadmap.

Second, the Navy established Unmanned Undersea Vehicle Squadron One (UUVRON-1) as its first dedicated UUV command in September 2017. UUVRON-1 works with a wide variety of UUVs ranging in size from 10 inches to over 80 inches in diameter. The command is driving advancements in homing and docking technology, submarine launch, sensor employment, maintenance software and hardware, and energy sources. In addition, they have established a UUV operations center and watch floor to conduct command and control operations and to provide global oversight to UUV supporting operations. This experience is a great opportunity for lessons learned as NOAA proceeds.

Finally, the Navy has engaged industry partners to develop improved UUV technology and operations. In 2018, the Navy made awards to 23 companies to develop Unmanned Undersea Vehicles Family of Systems. The award for approximately $560 million could grow to about $800 million with options, and it covers work through 2023. The program is intended to develop core technologies in UUV launch, communications, command and control, navigation, endurance, recovery, payload feasibility, and mission planning. The awardees will compete for task orders to procure materials and services.

Developing close ties to the Navy programs will enable NOAA to take advantage of lessons learned and also conduct joint projects as mutually beneficial. For example, joint testing of UUVs to advance technology and prove systems at-sea is clearly in the best interest of both agencies. In addition, establishing exchange programs for NOAA/Navy employees would stimulate learning, innovation, and mutual trust.

4. **NOAA OER should evaluate alternatives and recommend to NOAA leadership go-forward approaches for a structured partnership with the private sector, which includes experienced industrial and engineering firms as well as start-ups and entrepreneurs**

Multiple alternatives exist for structuring a NOAA – Private Sector Partnership. Many of these have been used successfully by government agencies. The OEAB recommends OER take the lead in analyzing alternatives and recommending approaches to NOAA leadership.

One type of contracting mechanism used extensively in the past is a Government Owned Contractor Operated (GOCO) approach, where the government owns the asset and a contractor operates and maintains the asset. There are many examples of this type of arrangement, including support of aerial drones for the USAF and ROVs for the US Navy. It is typically used when assets involved are expensive and/or unique. Primary advantages include avoiding contractual issues over lost assets, greater control by the government agency, and easier operation of the assets by government employees when required. Downsides include significant up-front capital investment by the government to procure the assets and being "locked in" once the assets are acquired. This type of arrangement may not be as relevant at this time for UUVs given the considerations outlined above. However, there is a class of very large UUVs under development for which this model could apply.

A Contractor Owned Contractor Operated (COCO) approach affords more flexibility to the government. An example of this type of approach is the lease of industry offshore supply vessels (OSVs) for government applications. The contractor provides both the asset and the operating crews. As conditions change, the government is able to adapt and lease different assets. Another type of COCO approach is for the government to pay for data collected by contractor-owned and -operated assets, which collect data certified to meet NOAA requirements. This approach can be effective where mapping surveys or other routine operations do not require OER's direct involvement in operations – NOAA provides performance specifications and the contractor collects the data. COCO contracts in general afford a greater opportunity for the private sector, thus attracting more interest and potential partners.

NAVSEA utilizes Planning Yard contracts for the purpose of providing boats and craft which meet/exceed fleet requirements, minimizing maintenance requirements, minimizing downtime, reducing ownership cost, and providing quick response to address fleet problems. Typical scope of services includes: alteration concepts, design resolution, integration, installation, test, and lifecycle and configuration control support (technical problem liaison, planning and executing overhauls, and documentation).

Another approach is to enter into an Indefinite Delivery/Indefinite Quantity (IDIQ) contract. IDIQ contracts may be single award or multi-award, as in the case of the Navy UUV Family of Systems Contract.

Finally, OER should exploit all available mechanisms at its disposal for encouraging the development of promising new UUV and AUV technologies, particularly those developed by small companies. OER can, and does, provide ship time for at-sea testing of new technologies. CRADAs, grants, Small Business Innovation Research opportunities, support for technology incubators, engagement with the Department of Commerce small business programs, and other mechanisms can all help OER and NOAA encourage development, testing, and operationalization of technologies with the potential to advance ocean exploration operations.