Testimony of

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Chairman Ezell, Ranking Member Carbajal, and Members of the Subcommittee, I appreciate the opportunity to appear before you today to testify about the National Academy of Sciences, Engineering, and Medicine's (NASEM) consensus study report on "Leveraging Unmanned Systems for Coast Guard Missions: A Strategic Imperative" (2020)[1] and to comment on subsequent advances technologies that are potentially relevant to U.S. Coast Guard missions and maritime domain awareness.

While I chaired the study committee that developed the NASEM report, I was also invited by this Subcommittee to offer my own views on relevant technological developments since the report's publication based on my expertise in guidance, navigation, and control systems; autonomous systems; communication systems; and modeling and simulation. By way of additional background, I hold the position of Chief Technology Officer at the MIT Lincoln Laboratory, after having previously served as assistant head of the Laboratory's Air, Missile, and Maritime Defense Technology Division. However, my testimony today is offered on behalf of the study committee that produced the 2020 NASEM report and in my personal capacity, and thus any views and opinions expressed are my own and not intended to represent the views and positions of the MIT Lincoln Laboratory.

Because the Subcommittee has previously heard testimony on the recommendations in the 2020 NASEM study,[2] I will only recap that advice and spend more time on the report's depiction of how uncrewed systems (UxS) and their capabilities could be leveraged to benefit Coast Guard mission execution. The report documented that all Coast Guard missions provide multiple potential uses for UxS capabilities and that, as a result, UxS will be shared across missions in the same manner that Coast Guard personnel and assets are shared to perform multiple missions. I will then summarize what the report says about the implications of this finding on the ability to trace budgetary savings to UxS investments and the need for the Coast Guard to find the right balance of UxS and crewed systems. This is in the context of the Coast Guard's full array of missions and in consideration of different concepts of operations (CONOPS).

The NASEM study committee saw the magnitude and breadth of opportunity for the Coast Guard to pursue UxS in its multiple domains and across its many missions. Five years after the NASEM report's publication, uncrewed systems are being used today with high utility in the public and private sectors, buffeted by the rapid pace of development and integration of artificial intelligence (AI), sensors, automation, and computing. Informed by the study committee's work—but in speaking for myself—I conclude my testimony with discussion on how the Coast Guard may be able to leverage and exploit new and emerging UxS technologies for maritime domain awareness.

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[1] National Academies of Sciences, Engineering, and Medicine. 2020. *Leveraging Unmanned Systems for Coast Guard Missions*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25987.

[2] Testimony of Sean T. Pribyl, member of the NASEM Committee for "Leveraging Unmanned Systems for Coast Guard Missions: A Strategic Imperative," before the Subcommittee on Coast Subcommittee on Coast Guard and Maritime Transportation, Committee on Transportation and Infrastructure, U.S. House of Representatives, September 19, 2023.

Recap of Conclusions and Recommendations from the 2020 NASEM Report

Section 812 of the Frank LoBiondo Coast Guard Authorization Act of 2018 called on NASEM to convene an expert committee to "prepare an assessment of available unmanned, autonomous, or remotely controlled maritime domain awareness technologies for use by the U.S. Coast Guard." The Act called for a study of the Coast Guard's existing and prospective use of UxS to fulfill its many critical and often unique missions. The legislative request further called for a review of the then current and emerging capabilities of these systems; their affordability, reliability, and versatility; and any realignments in Coast Guard policies, procedures, and protocols that may be necessary to exploit them more fully and effectively.

During its review, the study committee found that the Coast Guard was sponsoring multiple initiatives to assess the applicability of UxS to its missions, fleet, and force structure. To that point, however, the initiatives were characterized by limited funding spread over many years and the absence of a formal means, or a pacing mechanism, for proactively identifying, investigating, and integrating promising systems. In the meantime, technological advancements in UxS continued to accelerate, driven by commercial and military demands and interests.

In its report, the committee documented a compelling need for the Coast Guard to proceed more aggressively, albeit strategically and deliberately, in leveraging UxS advancements. Indeed, the study committee concluded that to remain responsive and fully relevant to its many missions, it was imperative for the Coast Guard to take a more strategic and accelerated approach to exploit the capabilities of existing and future unmanned systems. To this end, the committee recommended that the Coast Guard do the following:

1. **Issue a high-level UxS strategy** that articulates a compelling rationale for UxS, sets forth agency-critical goals these systems should further, and outlines the Coast Guard's approach for achieving them.
2. **Designate a senior official to advocate for the UxS strategy.**
3. **Establish a UxS program office** that will work with the top official charged with advancing the service's UxS strategy to plan out, coordinate, assess, and promote UxS activities across the Coast Guard and to leverage relevant activities and capabilities from outside the service.
4. **Expand and normalize UxS experimentation** to ensure ample and systematic operations-related experimentation with low-cost technologies, including potentially designating field units specifically for experimentation and rapid transitioning of systems into operations.
5. **Commission an internal study of needed funding** for research, assets, integration, personnel, and the like that will enable full and sustained implementation of a UxS strategy.

While I am not in a position to identify all actions that have been taken or that are planned in response to these recommendations, I understand that in 2023 the Coast Guard issued an "Unmanned Systems Strategic Plan," which establishes strategic goals for UxS, outlines challenges and opportunities for UxS, describes current UxS capabilities and projects, and lays out a desired future state of Coast Guard UxS applications, including operational scenarios and use cases. I also understand that in August of this year, the Coast Guard stood up a Robotics and Autonomous Systems Program Executive Office (RAS PEO).

I welcome these developments, which the study committee characterizes as essential steps toward a future Coast Guard that fully embraces and delivers on the promise of UxS.

Vision and Framework for Exploiting Unmanned Systems

The NASEM report identified a wide range of UxS capabilities that could benefit Coast Guard missions. Not intended to be exhaustive, the list in Table A-1 (see Appendix A) suggests tremendous potential, with all mission areas having multiple potential uses for the capabilities.[3] In particular, the list reveals the following interesting points:

- Persistent surveillance would be the most widely useful capability, applicable to most missions;
- Advanced tracking capability would support select missions in which detection, identification, and tracking of unique signatures are critical to mission success; and,
- Survey and inspection tasks enabled by UxS, can potentially allow more Coast Guard resources to be devoted to missions requiring direct human intervention such as rescues and drug interdictions.

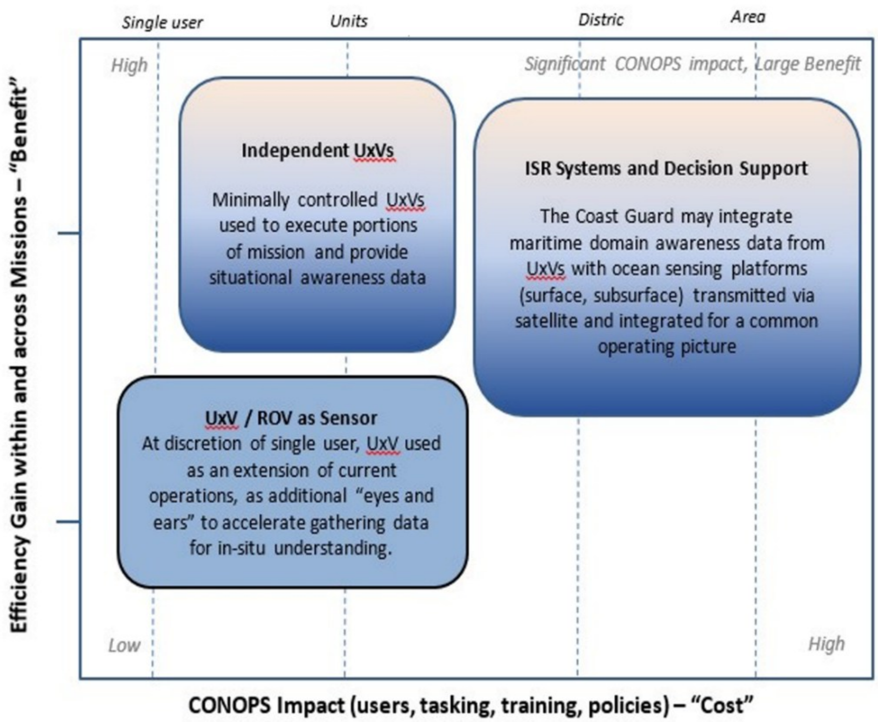
The report points out, however, that assessments of the cost-effectiveness—or the "business case"—of individual investments in UxS technologies may be impractical given the shared nature of both the new UxS investments and existing personnel and assets. For example, a UAV deployed on a National Security Cutter may enhance persistent surveillance in support of search and rescue (SAR) or the interdiction of vessels moving illicit drugs, the cutter's crew as well as uncrewed helicopters will still be necessary for rescuing survivors, boarding vessels, and apprehending suspects.

The Coast Guard will need to find the right balance of UxS and crewed systems in the context of its full set of missions and considering different CONOPs. It is reasonable to expect that over time this balance will be achieved and the Coast Guard's investments in UxS will yield budgetary savings; for instance, by deploying uncrewed assets and personnel more efficiently in accordance with the new CONOPS made possible by the UxS investments.

Another important point emphasized in the report is that decisions about where, when, and at what scale (e.g., unit, district, area) to implement UxS systems will confer different benefits and have different implications on CONOPS and other system-level considerations. Figure 1 shows how scaling UxS from single user applications to area-level implementations for multiple missions in new operational concepts can expand the efficiency benefits but also require investments in personnel training, logistics, support infrastructure, and the like.

[3] Table 5-2, *Leveraging Unmanned Systems for Coast Guard Missions*, pp. 92-93.

FIGURE 1 Coast Guard UxS Concept Trade Space[4]



ISR=Intelligence, Surveillance, and Reconnaissance

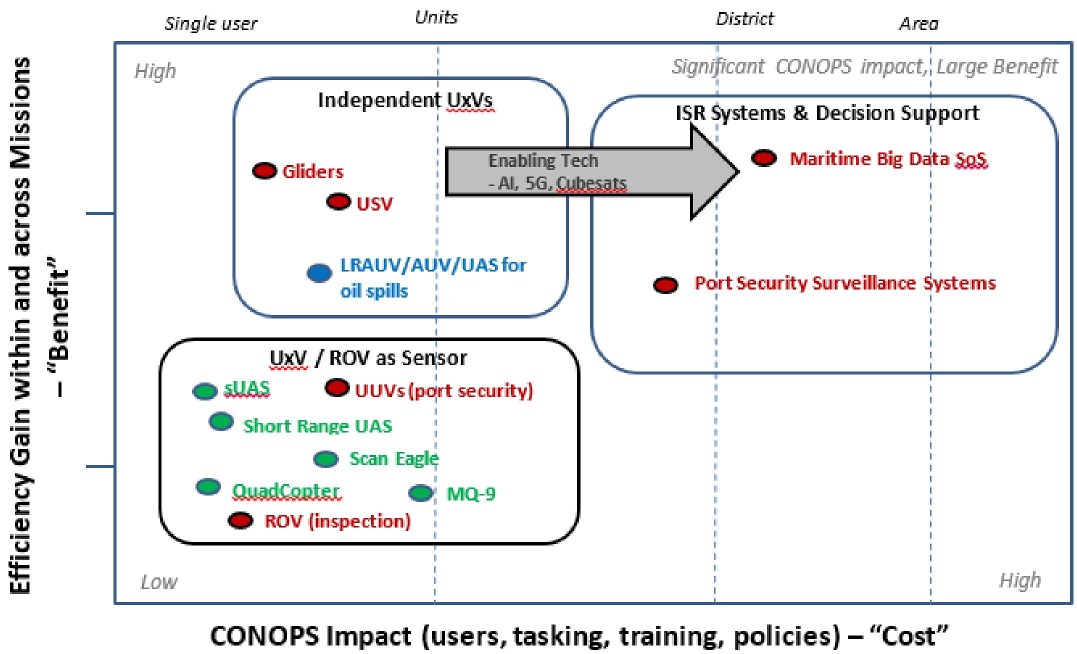
By way of example, a small uncrewed air vehicle (UAV), or drone, that increases the efficiency of current field unit operations through expanded surveillance capability could have minimal development and operational cost implications if the system is widely available through commercial industry providers and operated by contractors.

Advancing the capabilities of UxS to the point where they can be used by field units to execute partial missions with autonomy could substantially increase operational benefits. This expansion would likely increase costs for personnel training but potentially not in proportion to the added benefits because of the systems' capacity to act independently. A UxS that is implemented at larger scale to potentially benefit multiple missions performed by units across a Coast Guard district or area could confer even larger efficiency benefits but also larger cost impacts associated with new operational concepts and an increasingly complex operating environment.

This trade space framework, which is depicted in Figure 2 with several more examples, offers a way for the Coast Guard to begin to assess leveraging different types of UxS at different scales.

[4] Figure 5-2, *Leveraging Unmanned Systems for Coast Guard Missions*, p. 94

FIGURE 2 System Considerations for Persistent Surveillance Capabilities Using Unmanned Systems[5]



Looking to the Future: New and Emerging UxS Opportunities for the Coast Guard

The report outlined three key areas where autonomous systems technology could be leveraged at varying scales to augment Coast Guard capabilities and, in some cases, transform how the Service executes certain missions should uncrewed vehicles and AI-driven analytics be broadly adopted. Since the report's publication in 2020, the states of the art in autonomy, robotics, and artificial intelligence have evolved from limited application to widespread commercial deployment, and (in some mission areas) mainstream military use. Enabled by likewise improvements in sensing, data fusion, generative AI, edge computing, and communication capabilities, autonomous systems in all three areas of Coast Guard use now hold even more potential to transform maritime operations in air, surface, and subsurface domains.

1. UxVs or ROVs as a Sensor

Originally used primarily in military contexts for surveillance activities, uncrewed vehicles (UxVs) or remotely operated vehicles (ROVs) are now considered mature technical products widely available in the commercial market. As a data point, consider that in the past 5 years, over 2,500 privately held companies have made a deal in the area of uncrewed vehicles for air, land and maritime environments (per AUVSI market trends, industry/ecosystem overview).

[5] Figure 5-3, *Leveraging Unmanned Systems for Coast Guard Missions*, p. 97

Applications include real-time traffic management, remote sensing, wireless communications coverage, goods delivery, search and rescue, precision agriculture, security, surveillance, and infrastructure inspection.

A UxS (or ROV) can be deployed as a sensor to collect imagery or video in short range of a crewed platform, thereby extending situation awareness for the platform. Many UxVs now support multimodal sensors for perception (i.e., LiDAR, radar, optical or acoustic sensors for situational awareness/obstacle avoidance), and mission data collection (i.e., visible light for inspection, thermal sensors to detect heat signatures or multispectral/hyperspectral cameras for detailed image analysis across many light bands). The widespread availability of these UxVs presents an opportunity for the Coast Guard to leverage commercial innovation to improve small-unit operations within close range of crewed or land-based assets.

2. Independent UxVs

Advances in independent UxVs present the greatest opportunity for the Coast Guard in leveraging maturing technology for operational use. Technical developments are driving new capabilities in air with UAVs, on the surface with uncrewed surface vehicles (USVs), and undersea with uncrewed underwater vehicles (UUVs), often replacing risky or routine human-operated missions.

<u>UAVs</u>

Rapid advancement of drone technology has fueled the use of UAVs across a broad range of application areas. These advancements enable drones to process data more intelligently to allow for improved autonomous flight capabilities, complex decision-making, and adaptive responses to dynamic environments. AI-powered drones can avoid obstacles more efficiently, optimize flight paths, and perform tasks with minimal or no human intervention, broadening their usefulness.

Battery life and energy efficiency are also set to improve significantly. Current limitations on drone flight durations often hinder operational scope, but innovations in battery chemistry, wireless charging and power management have the potential to increase drone endurance and enhance sensor and payload capabilities.

<u>USVs</u>

USVs have emerged as key enablers in the maritime domain, augmenting crewed operations across multiple industries including defense, oceanography, offshore energy, and logistics. Advancements in AI, autonomy technology and communication networks have furthered maritime capability in threat detection, maritime and port surveillance, environmental awareness, and decision making with significant potential to enhance efficiency, safety, and cost-effectiveness.

Recognizing this potential and the global shift towards robotic warfare, the US Navy, for example, has established several USVRON squadrons to push autonomous sea power. USVRON-1 (established in May 2022) focuses on medium/large USVs such as the Sea Hunter; USVRON-3 (May 2024) operates smaller USVs; and USVRON-7 (April 2025) focuses on creating a hybrid fleet of crewed and uncrewed systems.

It should be noted that while USVs do offer significant advantages, difficulties persist in the development of fully automated systems. To fully realize the benefits of USVs in operations, advances are still needed in computer vision, such as in trustworthy sensing, perception and scene understanding, and in multi-modal data fusion technology. In addition, AI-enabled autonomy is still an area of active research, given limitations in robust decision-making under unpredictable environmental conditions where data are sparse for training of machine learning algorithms. Heterogeneous teams of collaborative vehicles also require further development, as does cybersecurity which presents challenges where USVs leverage potentially vulnerable networks.

<u>UUVs</u>

Advances in UUVs are on an inherently slower timeline due to the unique operational challenges posed by the undersea environment. While progress has been made on vehicle component technologies (i.e., AI-enabled mission planning, advanced sonar and acoustic processing technologies), fundamental challenges still exist in undersea communication, navigation, and energy systems. Certainly, machine learning technologies would enhance UUV autonomy and the ability to perform complex tasks, if sufficient data can be made available for training the AI models. This is often not the case in undersea scenarios, and more work is needed in AI training for sparse data conditions.

That said, the application of UUVs in certain Coast Guard mission areas is still a valid option, keeping in mind where UUVs provide unique value and where situation awareness can be obtained through other sensing means. The US Navy has invested significant funding in the development and maturation of UUV technology for mine countermeasures, anti-submarine warfare, and intelligence gathering. In select areas, the USCG could benefit from similar technology.

3. ISR Systems and Decision Support

Advances in Intelligence, Surveillance, and Reconnaissance (ISR) capabilities will reap the benefits of a number of breakthroughs in enabling technical capability.

<u>Proliferated Satellite Constellations</u>: Future space capability will be provided by hundreds or even thousands of small, low-cost satellites in low-earth orbit. Enabled by AI, advances in edge computing, focal plane arrays and on-chip image processing, these satellites have the potential to improve space-based surveillance rates at several orders of magnitude. Satellite-based communication networks could also support swarm USV and UAV capability. Synthetic aperture radar satellite systems could provide persistent detection, classification, and tracking of vessel traffic and icebergs in the Arctic region, improving situation awareness and therefore the safety of all vessels and commercial activities in these areas.

<u>Advanced Sensors</u>: Next generation ground-based and mobile radar systems, as well as novel small form-factor optical and infrared sensors will push state of the art in surveillance capability.

<u>Generative AI</u>: Advanced AI models trained on massive data sets can revolutionize ISR by automating data processing (video, image, text) and analysis, identifying patterns, anomalies and threats, and highlighting features for analysts to further review. By reducing human overload in

complex operations, AI can serve as a force multiplier enabling decision makers to more rapidly act as necessary, or assist in complex workflows. AI may also generate synthetic data, creating realistic simulations and virtual environments to evaluate strategies and train other AI models to handle unique or rare mission scenarios.

Mission Applications

Given these advances in technology in the last 5 years, it is pertinent to revisit the 2020 report's mapping of uncrewed system capabilities that could benefit Coast Guard Missions, as shown in Table A-1 below. New and emerging technologies would certainly advance the capabilities across several mission areas. While further analysis on mission needs and technology readiness would need to be performed, a first order review suggests significant opportunity in persistent surveillance, search, presence, or tracking capabilities. Uncrewed vehicles would be even more reliable, intelligent, and generally capable today for functions such as the delivery of equipment and supplies, post-storm surveys, and hazard mapping. Integrated AI-enabled, distributed sensing systems would accelerate situation awareness, mission planning, and execution. Some areas still require further technological development, such as Counter-UAS or Disabling Capability.

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In conclusion, I wish to thank you—Chairman Ezell, Ranking Member Carbajal, and Members of the Subcommittee—for the opportunity to testify before you about the NASEM committee report, "Leveraging Unmanned Systems for Coast Guard Missions: A Strategic Imperative." The Coast Guard undertakes a broad and diverse array of vital missions that present many opportunities for the effective use of uncrewed systems. The Coast Guard no doubt appreciates your recognition of these opportunities and interest in exploiting them.

TABLE A-1 Uncrewed Systems Capabilities that Could Benefit Coast Guard Missions

Capabilities	**Statutory Missions**											**Totals** (how many missions would benefit from this capability)
	Ports & Waterways Security	Drug Interdiction	Aids to Navigation	Search & Rescue	Living Marine Resources	Marine Safety	Defense Readiness	Migrant Interdiction	Marine Environmental Protection	Ice Operations	Other Law Enforcement	
Persistent surveillance	x	x			x		x	x			x	**6**
Persistent search				x								1
Expansion of search area				x								1
Persistent presence (for deterrence or other)	x							x		x	x	**4**
Persistent tracking					x					x		2
Semi-submersible tracking		x										1
Tracking (fish populations, whales, etc.)					x							1
Counter Unmanned Air Systems (C-UAS)	x						x					2
Detection	x							x		x		**3**
Identify targets of interest		x										1
Search and locate ATON			x									1
Disabling capability -- non-lethal		x										1
Delivery of equipment or supplies				x				x				2
LIDAR to make 3D images of target (mapping interior/exterior of ships)		x										1

TABLE A-1 (CONT) Uncrewed Systems Capabilities that Could Benefit Coast Guard Missions

Capabilities	Statutory Missions											**Totals** (how many missions would benefit from this capability)
	Ports & Waterways Security	Drug Interdiction	Aids to Navigation	Search & Rescue	Living Marine Resources	Marine Safety	Defense Readiness	Migrant Interdiction	Marine Environmental Protection	Ice Operations	Other Law Enforcement	
ATON Survey			x									1
Post storm survey			x									1
Ice survey										x		1
Annual-required inspections (hull, buoy chafe)			x									1
Inspections: vessels (tank bottoms, shell plating thickness, confined spaces)						x						1
Inspections: Stack gas emissions						x						1
Visual pre-screen prior boarding						x						1
Boom deployment									x			1
Fishing gear inspection while deployed					x						x	2
Fishing vessel speed tracking capability					x						x	2
Mapping oil/hazardous substances above and below surface									x			1
Sample collection									x			1
Dispersant delivery									x			1
Directional electromagnetic pulse (EMP)							x					1