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Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress

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SUMMARY

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Ronald O'Rourke
Specialist in Naval Affairs

Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress

The Navy wants to develop and procure three types of large unmanned vehicles (UVs) called Large Unmanned Surface Vehicles (LUSVs), Medium Unmanned Surface Vehicles (MUSVs), and Extra-Large Unmanned Undersea Vehicles (XLUUVs). The Navy's proposed FY2022 budget requests $434.1 million in research and development funding for these large UVs and their enabling technologies.

The Navy wants to acquire these large UVs as part of an effort to shift the Navy to a more distributed fleet architecture. Compared to the current fleet architecture, this more distributed architecture is to include a smaller proportion of larger ships (such as large-deck aircraft carriers, cruisers, destroyers, large amphibious ships, and large resupply ships), a larger proportion of smaller ships (such as frigates, corvettes, smaller amphibious ships, and smaller resupply ships), and a new third tier of large UVs.

The Navy envisions LUSVs as being 200 feet to 300 feet in length and having full load displacements of 1,000 tons to 2,000 tons, which would make them the size of a corvette. (i.e., a ship larger than a patrol craft and smaller than a frigate). The Navy wants LUSVs to be low-cost, high-endurance, reconfigurable ships based on commercial ship designs, with ample capacity for carrying various modular payloads—particularly anti-surface warfare (ASuW) and strike payloads, meaning principally anti-ship and land-attack missiles. Although referred to as UVs, LUSVs might be more accurately described as optionally or lightly manned ships, because they might sometimes have a few onboard crew members, particularly in the nearer term as the Navy works out LUSV enabling technologies and operational concepts.

The Navy defines MUSVs as being 45 feet to 190 feet long, with displacements of roughly 500 tons, which would make them the size of a patrol craft. The Navy wants MUSVs, like LUSVs, to be low-cost, high-endurance, reconfigurable ships that can accommodate various payloads. Initial payloads for MUSVs are to be intelligence, surveillance and reconnaissance (ISR) payloads and electronic warfare (EW) systems.

The first five XLUUVs were funded in FY2019; they are being built by Boeing and are roughly the size of a subway car. The Navy wants procure additional XLUUVs starting in FY2024. The Navy wants to use XLUUVs to, among other things, covertly deploy the Hammerhead mine, a planned mine that would be tethered to the seabed and armed with an antisubmarine torpedo, broadly similar to the Navy's Cold War-era CAPTOR (encapsulated torpedo) mine.

The Navy's large UV programs pose a number of oversight issues for Congress, including issues relating to the analytical basis for the more distributed fleet architecture; the Navy's acquisition strategies for these programs; technical, schedule, and cost risk in the programs; the proposed annual procurement rates for the programs; the industrial base implications of the programs; potential implications for miscalculation or escalation at sea; the personnel implications of the programs; and whether the Navy has accurately priced the work it is proposing to do on the programs for the fiscal year in question.

In marking up the Navy's proposed FY2020 and FY2021 budgets, the congressional defense committees expressed concerns over whether the Navy's acquisition strategies provided enough time to adequately develop concepts of operations and key technologies for these large UVs, particularly the LUSV, and included legislative provisions intended to address these concerns. In response to these markups, the Navy has restructured its acquisition strategy for the LUSV program so as to comply with these legislative provisions and provide more time for developing operational concepts and key technologies before entering into serial production of deployable units.

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Introduction

This report provides background information and potential issues for Congress for three types of large unmanned vehicles (UVs) that the Navy wants to develop and procure in FY2022 and beyond:

- Large Unmanned Surface Vehicles (LUSVs);
- Medium Unmanned Surface Vehicles (MUSVs); and
- Extra-large Unmanned Undersea Vehicles (XLUUVs).

The Navy wants to acquire these large UVs as part of an effort to shift the Navy to a new fleet architecture (i.e., a new combination of ships and other platforms) that is more widely distributed than the Navy's current fleet architecture. The Navy's proposed FY2022 budget requests $434.1 million in research and development funding for these large UVs and their enabling technologies.

The issue for Congress is whether to approve, reject, or modify the Navy's acquisition strategies and funding requests for these large UVs. The Navy's proposals for developing and procuring them pose a number of oversight issues for Congress. Congress's decisions on these issues could substantially affect Navy capabilities and funding requirements and the shipbuilding and UV industrial bases.

In addition to the large UVs covered in this report, the Navy also wants to develop and procure smaller USVs and UUVs, as well as unmanned aerial vehicles (UAVs) of various sizes. Other U.S. military services are developing, procuring, and operating their own types of UVs. Separate CRS reports address some of these efforts.[1]

Background

Navy USVs and UUVs in General

UVs in the Navy

UVs are one of several new capabilities—along with directed-energy weapons, hypersonic weapons, artificial intelligence, cyber capabilities, and quantum technologies—that the Navy and other U.S. military services are pursuing to meet emerging military challenges, particularly from China.[2] UVs can be equipped with sensors, weapons, or other payloads, and can be operated remotely, semi-autonomously, or (with technological advancements) autonomously. They can be individually less expensive to procure than manned ships and aircraft because their designs do not need to incorporate spaces and support equipment for onboard human operators. UVs can be particularly suitable for long-duration missions that might tax the physical endurance of onboard human operators, or missions that pose a high risk of injury, death, or capture of onboard human operators—so-called "three D" missions, meaning missions that are dull, dirty, or dangerous.[3]

[1] See, for example, CRS Report R45519, *The Army's Optionally Manned Fighting Vehicle (OMFV) Program: Background and Issues for Congress*, by Andrew Feickert, and CRS In Focus IF11150, *Defense Primer: U.S. Policy on Lethal Autonomous Weapon Systems*, by Kelley M. Sayler.

[2] For a CRS report on advanced military technologies, see CRS In Focus IF11105, *Defense Primer: Emerging Technologies*, by Kelley M. Sayler.

[3] See, for example, Ann Diab, "Drones Perform the Dull, Dirty, or Dangerous Work," Tech.co, November 12, 2014;

The Navy has been developing and experimenting with various types of UVs for many years, and has transitioned some of these efforts (particularly those for UAVs) into procurement programs. Even so, some observers have occasionally expressed dissatisfaction with what they view as the Navy's slow pace in transitioning UV development efforts into programs for procuring UVs in quantity and integrating them into the operational fleet.

March 2021 Campaign Framework Document for UVs

On March 16, 2021, the Department of the Navy released a "campaign framework" (i.e., overall strategy) document for developing and acquiring Navy and Marine UVs of various types and integrating them into U.S. naval operations.[4]

Navy USV and UUV Categories

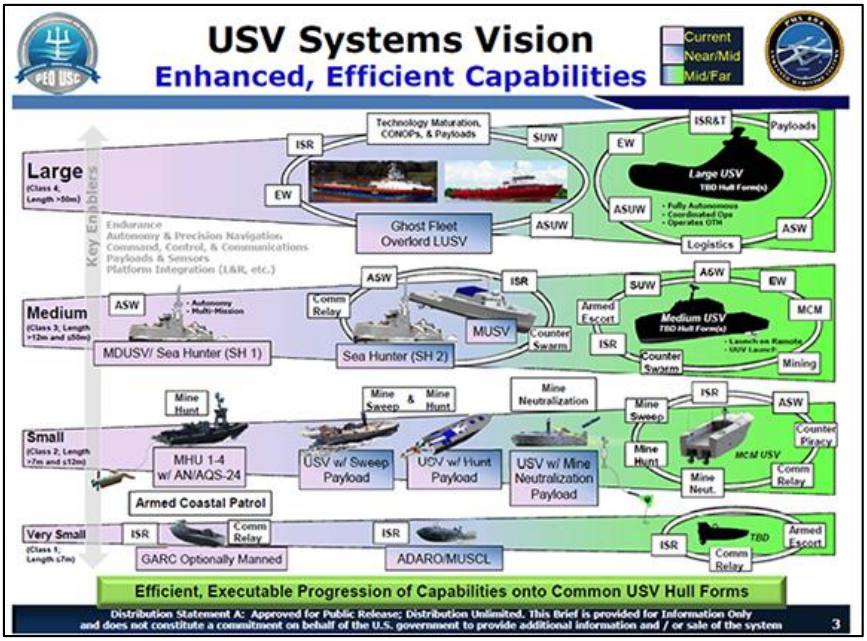
As shown in **Figure 1** and **Figure 2**, the Navy organizes its USV acquisition programs into four size-based categories that the Navy calls large, medium, small, and very small, and its UUV acquisition programs similarly into four size-based categories that the Navy calls extra-large, large, medium, and small. The large UVs discussed in this CRS report fall into the top two USV categories in **Figure 1** and the top UUV category in **Figure 2**.

The smaller UVs shown in the other categories of **Figure 1** and **Figure 2**, which are not covered in this report, can be deployed from manned Navy ships and submarines to extend the operational reach of those ships and submarines. The large UVs covered in this CRS report, in contrast, are more likely to be deployed directly from pier to perform missions that might otherwise be assigned to manned ships and submarines.

Bonnie Robinson, "Dull, Dirty, Dangerous Mission? Send in the Robot Vehicle," U.S. Army, August 20, 2015; Bernard Marr, "The 4 Ds Of Robotization: Dull, Dirty, Dangerous And Dear," *Forbes*, October 16, 2017.

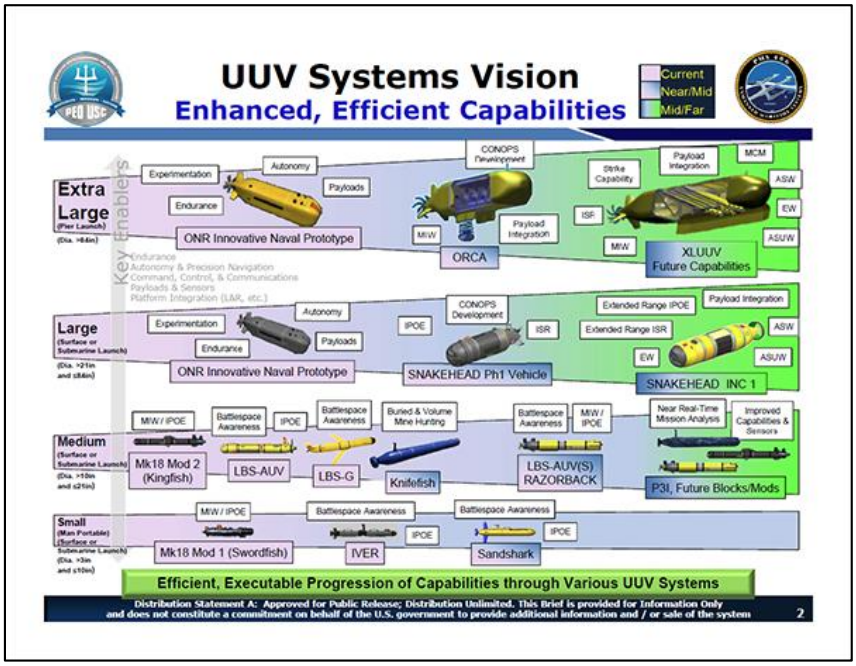
[4] Department of the Navy, *Department of the Navy Unmanned Campaign Framework*, March 16, 2021, 37 pp. See also Megan Eckstein, "Navy, Marines Unveil How They Will Buy and Operate Future Pilotless Aircraft and Crewless Ships," *USNI News*, March 16, 2021; Gina Harkins, "Why You Should Trust Drone Ships and Unmanned Tech, According to the Navy," *Military.com*, March 16, 2021; Stew Magnuson, "Just In: Navy, Marine Corps Unmanned Framework Calls For 'Capabilities' Over Platforms," *National Defense*, March 16, 2021; Seapower Staff, "Navy, Marine Corps Release Unmanned Campaign Plan," *Seapower*, March 16, 2021; Jordan Wolman, "Looking to the Future of Combat and Competition, Navy Releases Much-Anticipated Campaign Plan on Unmanned Systems," *Inside Defense*, March 16, 2021.

Figure 1. Navy USV Systems Vision



Source: Slide 3 of briefing by Captain Pete Small, Program Manager, Unmanned Maritime Systems (PMS 406), entitled "Unmanned Maritime Systems Update," January 15, 2019, accessed May 22, 2019, at https://www.navsea.navy.mil/Portals/103/Documents/Exhibits/SNA2019/UnmannedMaritimeSys-Small.pdf?ver=2019-01-15-165105-297.

Figure 2. Navy UUV Systems Vision



Source: Slide 2 of briefing by Captain Pete Small, Program Manager, Unmanned Maritime Systems (PMS 406), entitled "Unmanned Maritime Systems Update," January 15, 2019, accessed May 22, 2019, at https://www.navsea.navy.mil/Portals/103/Documents/Exhibits/SNA2019/UnmannedMaritimeSys-Small.pdf?ver=2019-01-15-165105-297.

Large UVs and Navy Ship Count

Because the large UVs covered in this report can be deployed directly from pier to perform missions that might otherwise be assigned to manned ships and submarines, some observers have raised a question as to whether the large UVs covered in this report should be included in the top-level count of the number of ships in the Navy.

Part of More Distributed Navy Fleet Architecture

The Navy and DOD have been working since 2019 to develop a new Navy force-level goal to replace the Navy's current 355-ship force-level goal. This new Navy force-level goal is expected to introduce a change in fleet architecture, meaning basic the types of ships that make up the Navy and how these ships are used in combination with one another to perform Navy missions. This new fleet architecture is expected to be more distributed than the fleet architecture reflected in the 355-ship goal or previous Navy force-level goals. In particular, the new fleet architecture is expected to feature

- a smaller proportion of larger ships (such as large-deck aircraft carriers, cruisers, destroyers, large amphibious ships, and large resupply ships),
- a larger proportion of smaller ships (such as frigates, corvettes, smaller amphibious ships, and smaller resupply ships), and
- a new third tier of large UVs.

Navy and DOD leaders believe that shifting to a more distributed fleet architecture is

- **operationally necessary**, to respond effectively to the improving maritime anti-access/area-denial (A2/AD) capabilities of other countries, particularly China;[5]
- **technically feasible** as a result of advances in technologies for UVs and for networking widely distributed maritime forces that include significant numbers of UVs; and
- **affordable**—no more expensive than the current fleet architecture for generating a given amount of naval capability.

Shifting to a more distributed force architecture, Navy and Marine Corps officials have suggested, will support the implementation of the Navy and Marine Corps' new overarching

[5] See, for example, David B. Larter, "With China Gunning for Aircraft Carriers, US Navy Says It Must Change How It Fights," *Defense News*, December 6, 2019; Arthur H. Barber, "Redesign the Fleet," *U.S. Naval Institute Proceedings*, January 2019. Some observers have long urged the Navy to shift to a more distributed fleet architecture, on the grounds that the Navy's current architecture—which concentrates much of the fleet's capability into a relatively limited number of individually larger and more expensive surface ships—is increasingly vulnerable to attack by the improving A2/AD capabilities (particularly anti-ship missiles and their supporting detection and targeting systems) of potential adversaries, particularly China. Shifting to a more distributed architecture, these observers have argued, would

- complicate an adversary's targeting challenge by presenting the adversary with a larger number of Navy units to detect, identify, and track;
- reduce the loss in aggregate Navy capability that would result from the destruction of an individual Navy platform;
- give U.S. leaders the option of deploying USVs and UUVs in wartime to sea locations that would be tactically advantageous but too risky for manned ships; and
- increase the modularity and reconfigurability of the fleet for adapting to changing mission needs.

For more on China's maritime A2/AD capabilities, see CRS Report RL33153, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, by Ronald O'Rourke.

operational concept, called Distributed Maritime Operations (DMO), and a supporting Marine Corps operational concept called Expeditionary Advanced Base Operations (EABO). While Navy officials have provided few details in public about DMO,[6] the Navy did state in its FY2021 budget submission that

> MUSV and LUSV are key enablers of the Navy's Distributed Maritime Operations (DMO) concept, which includes being able to forward deploy and team with individual manned combatants or augment battle groups. Fielding of MUSV and LUSV will provide the Navy increased capability and necessary capacity at lower procurement and sustainment costs, reduced risk to sailors and increased readiness by offloading missions from manned combatants.[7]

On December 9, 2020, the Navy released a long-range Navy shipbuilding document that presented the Trump Administration's emerging successor to the Navy's current 355-ship force-level goal, which calls for a fleet of 355 manned ships. The document called for a Navy with a more distributed fleet architecture, including 382 to 446 manned ships, 119 to 166 LUSVs and MUSVs, and 24 to 76 XLUUVs.[8]

On June 17, 2021, the Navy released a long-range Navy shipbuilding document that presents the Biden Administration's emerging successor to the Navy's current 355-ship force-level goal. The document calls for a Navy with a more distributed fleet architecture, including 321 to 372 manned ships, 59 to 89 LUSVs and MUSVs, and 24 to 76 XLUUVs.[9]

Acquisition Strategies and Enabling Technologies

The LUSV and MUSV programs are building on USV development work done by the Department of Defense's (DOD's) Strategic Capabilities Office (SCO). SCO's effort to develop USVs is called Ghost Fleet, and its LUSV development effort within Ghost Fleet is called Overlord.

As shown in **Figure 3**, Navy in 2019 identified five key enabling groups of technologies for its USV and UUV programs.[10] Given limitations on underwater communications (most radio-

[6] Then-Chief of Naval Operations Admiral John Richardson, in explaining DMO, stated in December 2018 that "Our fundamental force element right now in many instances is the [individual] carrier strike group. We're going to scale up so our fundamental force element for fighting is at the fleet[-wide] level, and the [individual] strike groups plug into those [larger] numbered fleets. And they will be, the strike groups and the fleet together, will be operating in a distributed maritime operations way." (Chief of Naval Operations Admiral John Richardson, as quoted in Megan Eckstein, "Navy Planning for Gray-Zone Conflict; Finalizing Distributed Maritime Operations for High-End Fight," *USNI News*, December 19, 2018.)

[7] Department of Defense Fiscal Year (FY) 2021 Budget Estimates, Navy Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, February 2020, PDF page 90 of 1,538. The statement also appears on PDF page 324 of 1,538. For more on the more distributed force architecture, DMO, and EABO, see CRS Report RL32665, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*, by Ronald O'Rourke. See also Kevin Eyer and Steve McJessy, "Operationalizing Distributed Maritime Operations," Center for International Maritime Security (CIMSEC), March 5, 2019; Christopher H. Popa et al., *Distributed Maritime Operations and Unmanned Systems Tactical Employment*, Naval Postgraduate School, June 2018, 171 pp. (Systems Engineering Capstone Report); Lyla Englehorn, *Distributed Maritime Operations (DMO) Warfare Innovation Continuum (WIC) Workshop September 2017 After Action Report*, Naval Postgraduate School, December 2017, 99 pp.

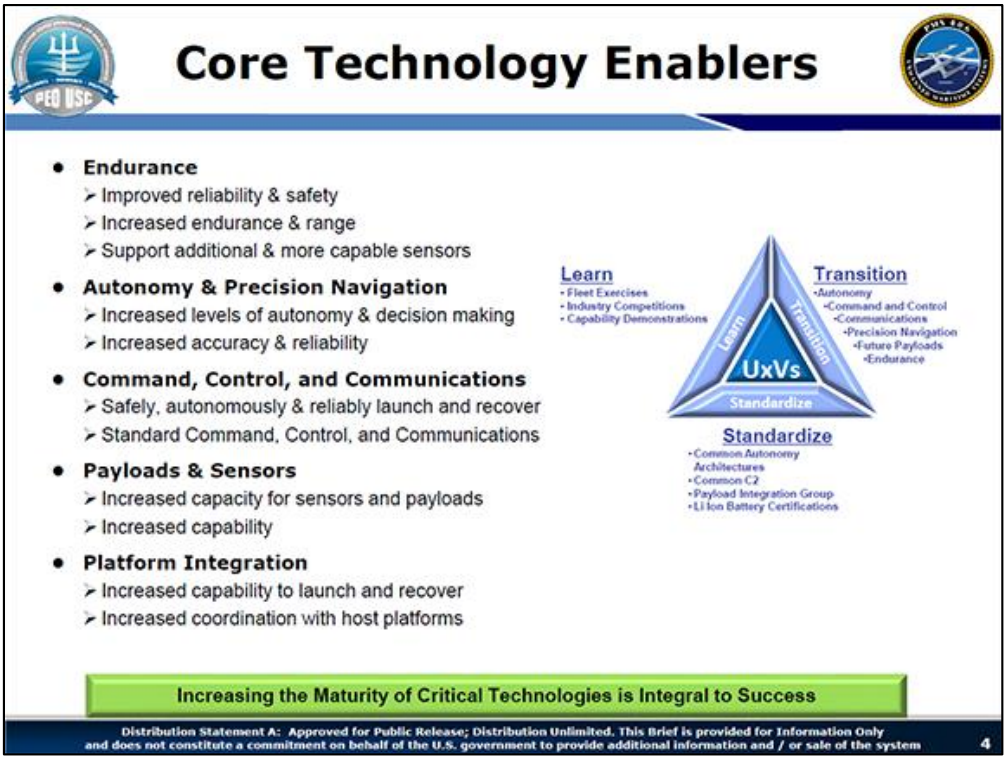
[8] U.S. Navy, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels*, December 2020, 23 pp.

[9] U.S. Navy, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2022*, June 2021, 16 pp.

[10] For additional discussion of some of the enabling technologies shown in **Figure 3**, see Pete Small, "Empowering the Unmanned Maritime Revolution," Undersea Warfare, Spring 2019: 12-13.

frequency electromagnetic waves do not travel far underwater), technologies for autonomous operations (such as artificial intelligence) will be particularly important for the XLUUV program (and other UUV programs).[11]

Figure 3. Enabling Technologies for USVs and UUVs



Source: Slide 4 of briefing by Captain Pete Small, Program Manager, Unmanned Maritime Systems (PMS 406), entitled "Unmanned Maritime Systems Update," January 15, 2019, accessed May 22, 2019, at https://www.navsea.navy.mil/Portals/103/Documents/Exhibits/SNA2019/UnmannedMaritimeSys-Small.pdf?ver=2019-01-15-165105-297.

In May 2019, the Navy established a surface development squadron to help develop operational concepts for LUSVs and MUSVs. The squadron was initially to consist of a Zumwalt (DDG-1000) class destroyer and one Sea Hunter prototype medium displacement USV (**Figure 4**). A second Sea Hunter prototype was reportedly to be added around the end of FY2020, and LUSVs and MUSVs would then be added as they become available.[12]

[11] For more on the use of artificial intelligence in defense programs, see CRS Report R45178, *Artificial Intelligence and National Security*, by Kelley M. Sayler.

[12] See, for example, Megan Eckstein, "Navy Stands Up Surface Development Squadron for DDG-1000, Unmanned Experimentation," *USNI News*, May 22, 2019; David B. Larter, "With Billions Planned in Funding, the US Navy Charts Its Unmanned Future," *Defense News*, May 6, 2019. See also Michael Fabey, "USN Seeks Path for Unmanned Systems Operational Concepts," *Jane's Navy International*, May 16, 2019.

Figure 4. Sea Hunter Prototype Medium Displacement USV

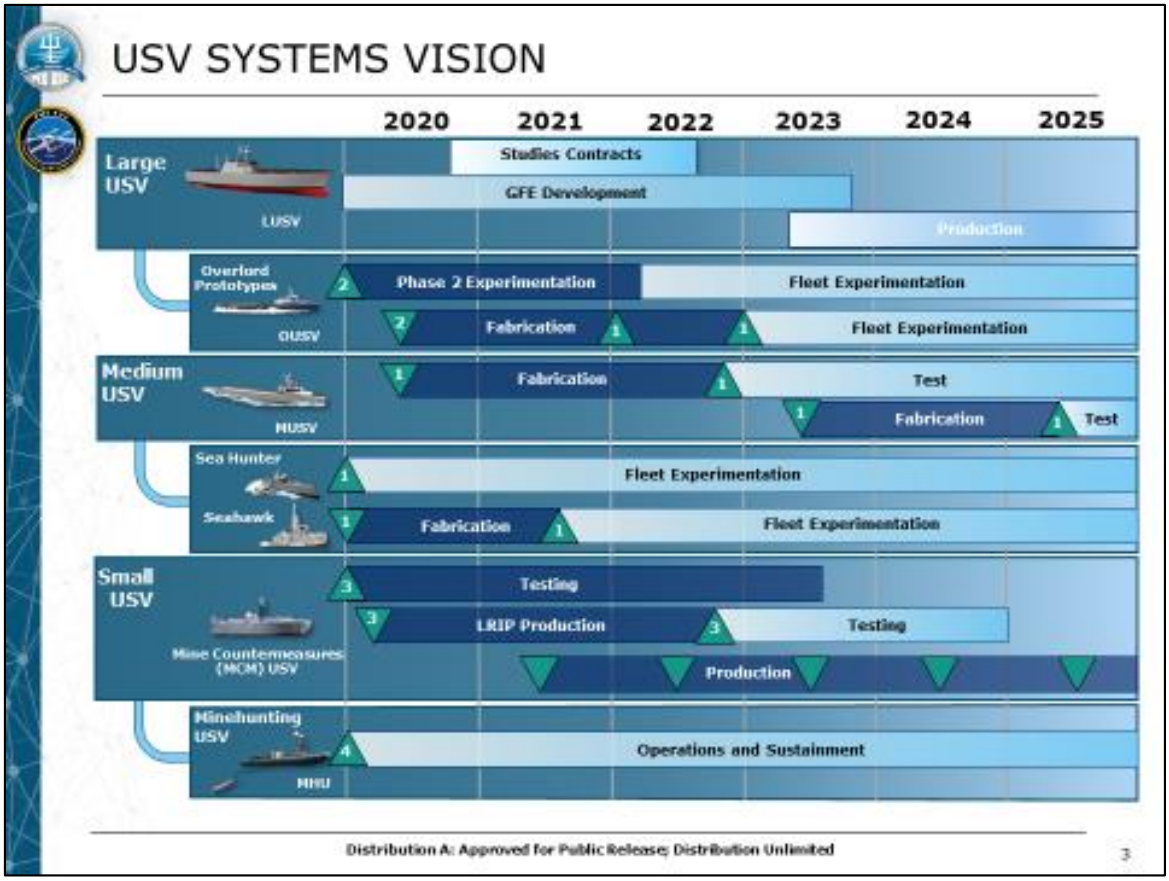
Source: Photograph credited to U.S. Navy accompanying John Grady, "Panel: Unmanned Surface Vessels Will be Significant Part of Future U.S. Fleet," *USNI News*, April 15, 2019.

LUSV, MUSV, and LXUUV Programs in Brief

Navy Vision and Schedule for USVs and UUVs

Figure 5 and **Figure 6** show the Navy's vision and schedule as of March 2021 for building, testing, and conducting fleet experiments with USVs and UUVs, including the LUSV, the MUSV, and the XLUUV, along with supporting efforts such as the Overlord and Sea Hunter prototype USVs, as well as smaller USVs and UUVs that are not covered in this report. Under the Navy's proposed FY2022 budget, the schedules shown in these two figures may have changed, particularly so as to provide more time for maturing technologies prior to initiating larger-scale procurement of USVs and UUVs.

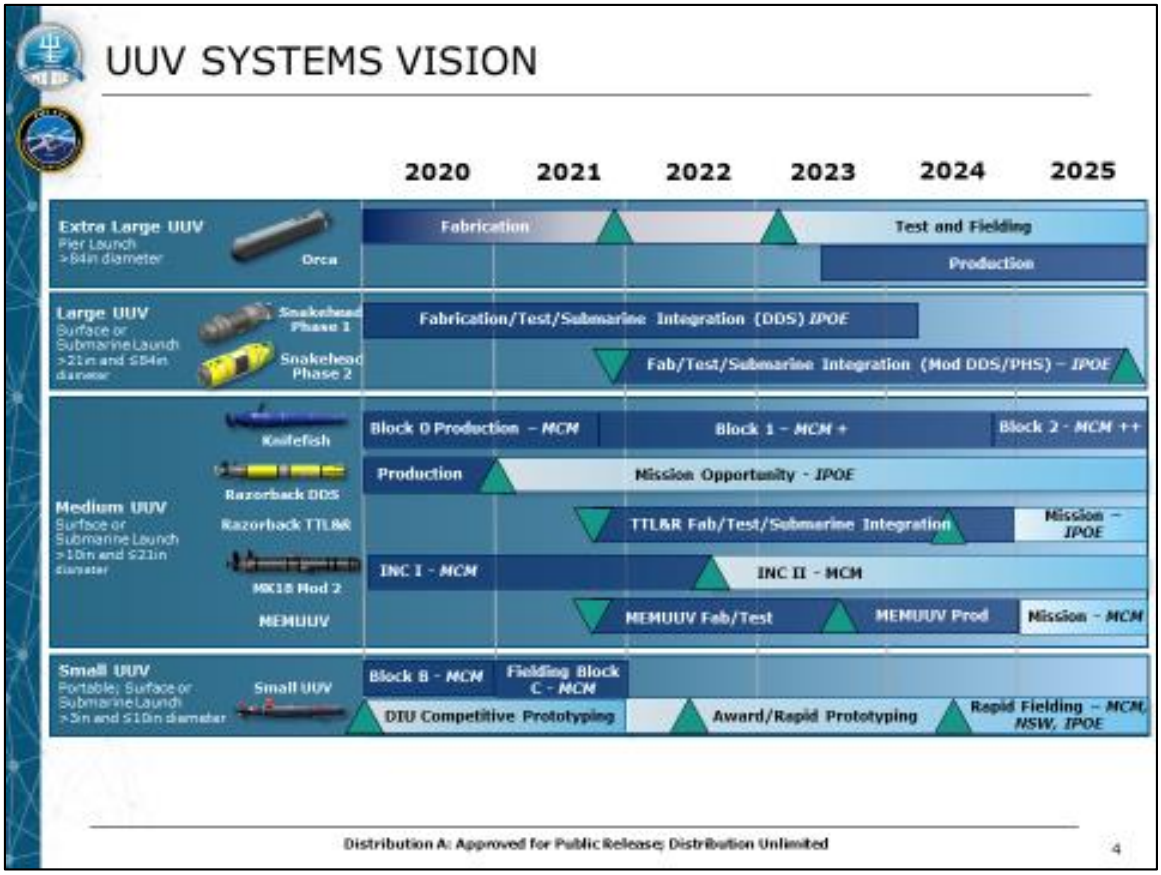
Figure 5. Navy USV Systems Vision as of March 2021



Source: Captain Pete Small, "PMS 406 Unmanned Maritime Systems," briefing at NDIA Undersea Warfare Conference, March 24, 2021, slide 3.

Notes: GFE means government-furnished equipment, meaning equipment that the government will provide to the firm that is building the USV, for incorporation into the USV.

Figure 6. Navy UUV Systems Vision as of March 2021



Source: Captain Pete Small, "PMS 406 Unmanned Maritime Systems," briefing at NDIA Undersea Warfare Conference, March 24, 2021, slide 4.

Notes: DDS is dry deck shelter, which is a module that can be attached to the top surface of a submarine for the purpose of carrying a special payload. PHS is payload handling system. IPOE is intelligence preparation of the operational environment. MCM is mine countermeasures. TTL&R is torpedo tube launch and recovery. INC is increment (i.e., version). DIU is Defense Innovation Unit, which is a DOD organization. NSW is naval special warfare.

LUSV Program

Overview

The Navy envisions LUSVs as being 200 feet to 300 feet in length and having full load displacements of 1,000 tons to 2,000 tons, which would make them the size of a corvette (i.e., a ship larger than a patrol craft and smaller than a frigate). **Figure 7** shows a detail from a Navy briefing slide showing images of prototype LUSVs and silhouettes of a notional LUSV and a notional MUSV. **Figure 8** and **Figure 9** show ships that have been used as LUSV prototypes. In unclassified presentations on the program, the Navy has used images of offshore support ships used by the oil and gas industry to illustrate the kinds of ships that might be used as the basis for LUSVs.[13]

[13] Sam LaGrone, "Navy Wants 10-Ship Unmanned 'Ghost Fleet' to Supplement Manned Force," *USNI News*, March 13, 2019.

Figure 7. Prototype and Notional LUSVs and MUSVs

Source: Detail from Navy briefing slide entitled Unmanned Maritime Systems, slide 5 in a Navy briefing entitled "Designing & Building the Surface Fleet: Unmanned and Small Combatants," by Rear Admiral Casey Moton at a June 20, 2019, conference of the American Society of Naval Engineers (ASNE).

Figure 8. LUSV Prototype

Source: Cropped version of photograph accompanying Mallory Shelbourne, "6 Companies Awarded Contracts to Start Work on Large Unmanned Surface Vehicle," *USNI News*, September 4, 2020. The caption to the photograph states in part: "A Ghost Fleet Overlord test vessel takes part in a capstone demonstration during the conclusion of Phase I of the program in September." The photo is credited to the U.S. Navy.

Figure 9. LUSV prototype

Source: Cropped version of photograph accompanying Mallory Shelbourne, "6 Companies Awarded Contracts to Start Work on Large Unmanned Surface Vehicle," *USNI News*, September 4, 2020. The caption to the photograph states in part: "A Ghost Fleet Overlord test vessel takes part in a capstone demonstration during the conclusion of Phase I of the program in September." The photo is credited to the U.S. Navy.

The Navy wants LUSVs to be low-cost, high-endurance, reconfigurable ships based on commercial ship designs, with ample capacity for carrying various modular payloads—particularly anti-surface warfare (ASuW) and strike payloads, meaning principally anti-ship and land-attack missiles.[14] Although the Navy testified in June 2021 that each LUSV is to have 64 vertical launch system (VLS) missile-launching tubes,[15] the Navy subsequently said this was a misstatement, and that the correct figure is 16 to 32 VLS cells.[16]

The Navy wants LUSVs to be capable of operating with human operators in the loop,[17] or semi-autonomously (with human operators on the loop),[18] or fully autonomously, and to be capable of operating either independently or in conjunction with manned surface combatants. Although referred to as UVs, LUSVs might be more accurately described as optionally or lightly manned ships, because they might sometimes have a few onboard crew members, particularly in the nearer term as the Navy works out LUSV enabling technologies and operational concepts.[19] LUSVs are to feature both built-in capabilities and an ability to accept modular payloads, and are to use existing Navy sensors and weapon launchers. The Navy states that

[14] The Navy states that the LUSV "provides distributed fires" and will include an "offensive missile capability." See slide 5 of briefing by Captain Pete Small, Program Manager, Unmanned Maritime Systems (PMS 406), entitled "Unmanned Maritime Systems Update," January 15, 2019, accessed May 22, 2019, at https://www.navsea.navy.mil/Portals/103/Documents/Exhibits/SNA2019/UnmannedMaritimeSys-Small.pdf?ver=2019-01-15-165105-297.

[15] See Rich Abott, "Officials Defend Cost Balancing In Cruiser Retirement Plans," *Defense Daily*, June 17, 2021; Richard R. Burgess, "Kilby: LUSV's Missile Cells Would Replace Cells Lost with Decommissioned Cruisers," *Seapower*, Jnue 17, 2021.

[16] Source: Navy FY2022 program briefing on LUSV and MUSV programs for CRS and CBO, July 14, 2021.

[17] The Navy states that having the operator in the loop can be understood as referring to continuous or near-continuous observation and/or control of the UV by the operator. (Source: Navy email to CRS dated June 4, 2019.)

[18] The Navy states that having the operator on the loop can be understood as referring to a UV that is operating semi-autonomously, with the UV controlling its own actions much of the time, but with a human operator potentially intervening from time to time in response to either a prompt from the UV or data sent from the UV or other sources. (Source: Navy email to CRS dated June 4, 2019.)

[19] See, for example, David B. Larter, "US Navy Looks to Ease into Using Unmanned Robot Ships with a Manned Crew," *Defense News*, January 29, 2019.

> The Navy's LUSV builds upon work funded by DoD's Strategic Capabilities Office (SCO) and experimentation executed by the Navy USVs in Project Overlord. LUSV will be a high-endurance vessel based on commercial specifications, capable of weeks-long deployments and trans-oceanic transits. With a large payload capacity, the LUSV will be designed to conduct a variety of warfare operations initially in conjunction with manned surface combatants while under the positive control of a man-in-the-loop for employment of weapons systems. The Navy is taking an iterative, systems engineering approach to obtaining this technology and has designed an integration and experimentation plan that will validate high reliability mechanical and electrical systems, autonomous navigation and maneuvering, integration of combat system, and platform command and control capabilities prior to employment opportunities.
>
> LUSV Design Studies contracts were awarded in September 2020 to six Industry teams to provide robust collaboration with government and industry to assist in maturation of platform specifications, and ensure achievable technical requirements are in place for a follow on development contract. Both Industry and the Navy are using these collaborative interactions to significantly advance the knowledge base that will feed into the LUSV program….
>
> The Navy has benefited through its prototyping and experimenting with Sea Hunter and Overlord unmanned surface vessel prototypes accumulating over 3,100 hours of autonomous operations to include teaming with other manned ships. The Navy will continue experimentation and reliability demonstration efforts in FY 2021 and FY 2022 on the two SCO-funded Overlord vessels as ownership shifts to the Navy. The Navy is also building two additional Overlord prototypes that will deliver in FY 2022 to support continued experimentation, and future mission CONOPS. The Navy is evaluating other DMO applications to include logistics supply and refueling, Marine Corps expeditionary options, and enhancements to other surface platform missions. As part of this evaluation, the Navy is collaborating with Military Sealift Command and the Marine Corps to modify a T-EPF [expeditionary fast transport ship] with autonomy to gain more autonomy knowledge and reliability on a class of ship equipped with V-22 [tilt-rotor aircraft] landing capability, a large logistic and personnel size, weight and power capability, and the ability to operate at high speeds.[20]

In marking up the Navy's proposed FY2020 and FY2021 budgets, the congressional defense committees expressed concerns over whether the Navy's acquisition strategies provided enough time to adequately develop concepts of operations and key technologies for these large UVs, particularly the LUSV, and included legislative provisions intended to address these concerns.[21] In response to these markups, the Navy has restructured its acquisition strategy for the LUSV program so as to comply with these legislative provisions and provide more time for developing operational concepts and key technologies before entering into serial production of deployable units.

[20] Statement of Frederick J. Stefany, Acting Assistant Secretary of the Navy for Research, Development and Acquisition (ASN (RD&A)) and Vice Admiral James W. Kilby, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities (OPNAV N9) and Lieutenant General Eric M. Smith, Deputy Commandant, Combat Development and Integration, Commanding General, Marine Corps Combat Development Command, before the Subcommittee on Seapower of the Senate Armed Services Committee on Department of the Navy Fiscal Year 2022 Budget Request for Seapower, June 8, 2021, pp. 14-15.

[21] In the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (H.R. 6395 /P.L. 116-283 of January 1, 2021), these provisions included Sections 122 and 227.

September 4, 2020 Contract Award

On September 4, 2020, DOD announced the following six contract awards for industry studies on the LUSV:

> Huntington Ingalls Inc., Pascagoula, Mississippi (N00024-20-C-6319); Lockheed Martin Corp., Baltimore, Maryland (N00024-20-C-6320); Bollinger Shipyards Lockport LLC, Lockport, Louisiana (N00024-20-C-6316); Marinette Marine Corp., Marinette, Wisconsin (N00024-20-C-6317); Gibbs & Cox Inc., Arlington, Virginia (N0002420C6318); and Austal USA LLC, Mobile, Alabama (N00024-20-C-6315), are each being awarded a firm-fixed price contract for studies of a Large Unmanned Surface Vessel with a combined value across all awards of $41,985,112.
>
> Each contract includes an option for engineering support, that if exercised, would bring the cumulative value for all awards to $59,476,146.

- The contract awarded to Huntington Ingalls Inc. is $7,000,000;
- the contract awarded to Lockheed Martin Corp. is $6,999,978;
- the contract awarded to Bollinger Shipyards Lockport LLC, is $6,996,832;
- the contract awarded to Marinette Marine Corp. is $6,999,783;
- the contract awarded to Gibbs & Cox Inc. is $6,989,499; and
- the contract awarded to Austal USA LLC is $6,999,020.

> Work will be performed in various locations in the contiguous U.S. in accordance with each contract and is expected to be complete by August 2021, and if option(s) are exercised, work is expected to be complete by May 2022.
>
> Fiscal 2020 research, development, test and evaluation (Navy) funds in the amount $41,985,112 will be obligated at time of award and will not expire at the end of the current fiscal year.
>
> These contracts were competitively procured via Federal Business Opportunities (now beta.SAM.gov) with eight offers received. The Naval Sea Systems Command, Washington, D.C., is the contracting activity.[22]

A September 4, 2020, press report about the contract awards stated

> "These contracts were established in order to refine specifications and requirements for a Large Unmanned Surface Vessel and conduct reliability studies informed by industry partners with potential solutions prior to release of a Detail Design and Construction contract," Navy spokesman Capt. Danny Hernandez told USNI News in a statement.
>
> "The studies effort is designed to provide robust collaboration with government and industry to assist in maturation of platform specifications, and ensure achievable technical requirements are in place for a separate LUSV DD&C competition."…
>
> "The LUSV studies will support efforts that facilitate requirements refinement, development of an affordable and effective platform; provide opportunities to continue maturing the performance specifications and conduct analysis of alternative design approaches; facilitate reliability improvements and plans for government-furnished equipment and mechanical and electrical systems; and support development of cost reduction and other affordability initiatives," Hernandez said.[23]

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[22] Department of Defense, "Contracts For Sept. 4, 2020," accessed September 8, 2020. The announcement is posted as a single, unbroken paragraph. In reprinting the text of the announcement, CRS broke the announcement into the smaller paragraphs shown here to make the announcement easier to read.

[23] Mallory Shelbourne, "6 Companies Awarded Contracts to Start Work on Large Unmanned Surface Vehicle," *USNI*

MUSV Program

The Navy defines MUSVs as being 45 feet to 190 feet long, with displacements of roughly 500 tons, which would make them the size of a patrol craft. The Navy wants MUSVs, like LUSVs, to be low-cost, high-endurance, reconfigurable ships that can accommodate various payloads. Initial payloads for MUSVs are to be intelligence, surveillance and reconnaissance (ISR) payloads and electronic warfare (EW) systems. The Navy is pursuing the MUSV program as a rapid prototyping effort under what is known as Section 804 middle tier acquisition authority.[24] The first MUSV prototype was funded in FY2019.

The MUSV program is building on development work by the Defense Advanced Research Projects Agency (DARPA) under its Anti-Submarine Warfare Continuous Trail Unmanned Vessel (ACTUV) effort and the Office of Naval Research (ONR) under its Medium Displacement USV effort. As shown in **Figure 1**, this work led to the design, construction, and testing of the prototype Sea Hunter medium displacement USV, which has a reported length of 132 feet (about 40.2 meters) and a displacement of about 140 tons.[25] The Navy's MUSV program is also to employ a fleet-ready command and control (C2) solution for USVs that was developed by the Strategic Capabilities Office for the LUSV program. The Navy states that

> Medium unmanned surface vehicle (MUSV) is an unmanned sensor-ship, built to carry modular payloads, and standardized for easy integration with current Navy systems. Inexpensive compared to manned combatants, MUSVs can be built in numbers, quickly adding capacity to the Fleet. MUSV delivers a distributed sensor network that can navigate and operate with man in/on the loop oversight, and will be capable of weeks-long deployments and trans-oceanic transits. The Navy awarded a design and fabrication contract to develop the first MUSV prototype which is targeted for delivery in FY 2023.[26]

On July 13, 2020, the Navy announced that it had awarded "a $34,999,948 contract to L3[Harris] Technologies, Inc. for the development of a single Medium Unmanned Surface Vehicle (MUSV) prototype, with options to procure up to eight additional MUSVs. The award follows a full and open competitive procurement process. Funding is in place on this contract for the initial prototype. With all options exercised, the contract is valued at $281,435,446 if additional funding is provided in future budget years."[27] The Navy reportedly stated that there were five competitors

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News, September 4, 2020. See also Paul McLeary, "Navy Awards Study Contracts On Large Unmanned Ship—As Congress Watches Closely," *Breaking Defense*, September 4, 2020.

[24] This is a reference to Section 804 of the FY2016 National Defense Authorization Act (S. 1356/P.L. 114-92 of November 25, 2015). The rapid prototyping authority provided by that section is now codified at 10 U.S.C. 2302 note. For more on this authority, see "Middle Tier Acquisition (Section 804)," MITRE, undated, accessed May 24, 2019, at https://aida.mitre.org/middle-tier/; and "Acquisition Process, Middle Tier Acquisition (Section 804)," AcqNotes, updated March 26, 2019, accessed May 24, 2019, at http://acqnotes.com/acqnote/acquisitions/middle-tier-acquisitions.

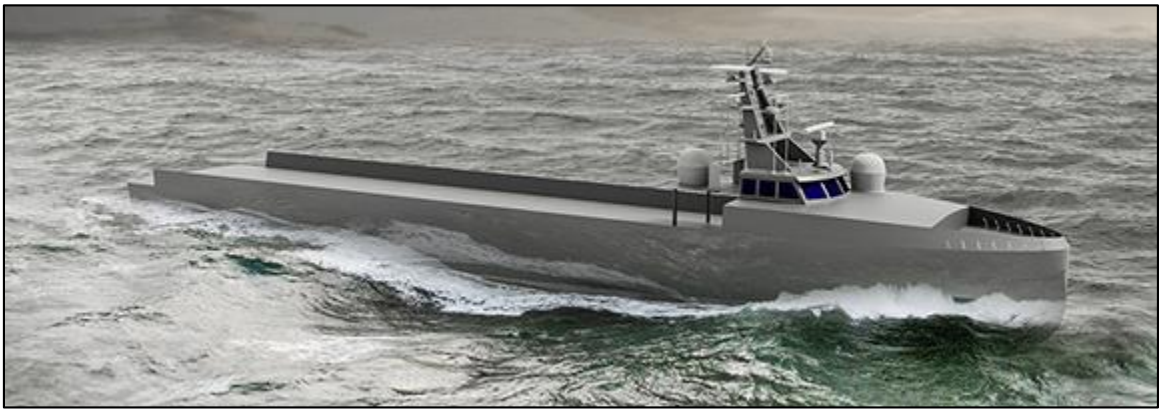
[25] See, for example, Megan Eckstein, "Sea Hunter Unmanned Ship Continues Autonomy Testing as NAVSEA Moves Forward with Draft RFP," *USNI News*, April 29, 2019; Evan Milberg, "DARPA "Sea Hunter," World's Largest Autonomous Ship, Transferred to U.S. Navy," *Composites Manufacturing Magazine*, February 12, 2018; Sydney J. Freedberg Jr., "DSD [Deputy Secretary of Defense] Work Embraces DARPA's Robot Boat, Sea Hunter," *Breaking Defense*, April 7, 2016.

[26] Statement of Frederick J. Stefany, Acting Assistant Secretary of the Navy for Research, Development and Acquisition (ASN (RD&A)) and Vice Admiral James W. Kilby, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities (OPNAV N9) and Lieutenant General Eric M. Smith, Deputy Commandant, Combat Development and Integration, Commanding General, Marine Corps Combat Development Command, before the Subcommittee on Seapower of the Senate Armed Services Committee on Department of the Navy Fiscal Year 2022 Budget Request for Seapower, June 8, 2021, pp. 14-15.

[27] PEO Unmanned and Small Combatants Public Affairs, "Navy Awards Contract for Medium Unmanned Surface Vehicle Prototype," Naval Sea Systems Command, July 13, 2020.

for the contract, but did not identify the other four.[28] **Figure 10** shows a rendering of L3Harris's design concept.

Figure 10. Rendering of L3Harris Design Concept for MUSV



Source: L3Harris Technologies, "L3Harris Technologies Awarded Medium Unmanned Surface Vehicle Program from US Navy," August 18, 2020. See also Richard R. Burgess, "Navy's Medium USV to Be Based on Commercial Vehicle," *Seapower*, August 19, 2020.

L3Harris states that

> will integrate the company's ASView™ autonomy technology into a purpose-built 195-foot commercially derived vehicle from a facility along the Gulf Coast of Louisiana. The MUSV will provide intelligence, surveillance and reconnaissance to the fleet while maneuvering autonomously and complying with international Collision Regulations, even in operational environments.…
>
> L3Harris will be the systems integrator and provide the mission autonomy and perception technology as the prime contractor on the program. The program team includes Gibbs & Cox and Incat Crowther who will provide the ship design and Swiftships will complete the construction of the vehicle.
>
> L3Harris is a world leader in actively powered Unmanned Surface Vehicle (USV) systems, with over 115 USVs delivered worldwide. L3Harris' USVs are actively serving the Navy, universities, research institutions and commercial businesses.[29]

XLUUV Program

The XLUUV program, also known as the Orca program, was established to address a Joint Emergent Operational Need (JEON). As shown in **Figure 2**, the Navy defines XLUUVs as UUVs with a diameter of more than 84 inches, meaning that XLUUVs are to be too large to be launched from a manned Navy submarine.[30] Consequently, XLUUVs instead will transported to a forward operating port and then launched from pier. The Department of the Navy's March 16, 2021, unmanned campaign framework document states that the XLUUV will be designed "to

[28] Rich Abott, "L3Harris Wins $35 Million MUSV Prototype Contract," *Defense Daily*, July 13, 2020. See also Sam LaGrone, "Navy Awards Contract for First Vessel In Its Family of Unmanned Surface Vehicles," *USNI News*, July 14 (updated July 15), 2020; Paul McLeary, "Navy Inks Deal For New Unmanned Fleet," *Breaking Defense*, July 13, 2020.

[29] L3Harris Technologies, "L3Harris Technologies Awarded Medium Unmanned Surface Vehicle Program from US Navy," August 18, 2020.

[30] Navy submarines equipped with large-diameter vertical launch tubes can launch missiles or other payloads with diameters of up to about 83 inches.

accommodate a variety of large payloads….”[31] The Navy testified on March 18, 2021, that mines will be the initial payload for XLUUVs.[32] More specifically, the Navy wants to use XLUUVs to, among other things, covertly deploy the Hammerhead mine, a planned mine that would be tethered to the seabed and armed with an antisubmarine torpedo, broadly similar to the Navy’s Cold War-era CAPTOR (encapsulated torpedo) mine.[33]

The first five XLUUVs were funded in FY2019 through the Navy’s research and development appropriation account. The Navy conducted a competition for the design of the XLUUV, and announced on February 13, 2019, that it had selected Boeing to fabricate, test, and deliver the first four Orca XLUUVs and associated support elements.[34] (The other bidder was a team led by Lockheed Martin.) On March 27, 2019, the Navy announced that the award to Boeing had been expanded to include the fifth Orca.[35] Boeing has partnered with the Technical Solutions division of Huntington Ingalls Industries (HII) to build Orca XLUUVs.[36] (A separate division of HII—Newport News Shipbuilding (NNS) of Newport News, VA—is one of the Navy’s two submarine builders.) The Navy states

> Orca XLUUV is a multi-phased accelerated acquisition effort using [Title 10] USC Sec. 2358 [acquisition] authorities [for research and development projects] to rapidly deliver capability to the Fleet.
>
> Phase 1 was a competitively sourced design effort. Two design contracts were awarded to Industry in FY 2017.
>
> Phase 2 commenced with a down select in FY 2019 to one of the Phase 1 vendors for fabrication and testing of the vehicle and support elements. Five (5) Orca XLUUV operationally relevant prototype systems (vehicles, mobile C2 equipment, and support equipment) are being fabricated for demonstration and use by the Fleet. Additional XLUUV technologies/capabilities risk reduction will occur in parallel, leveraging the competitive Industrial base.[37]
>
> Phase 3 provides the option to fabricate up to four (4) additional systems from the vendor who fabricated vehicles in Phase 2. Fabrication award of these additional Orca XLUUV systems is planned to be no earlier than FY24. Transition to an Acquisition Category (ACAT) Program and production may occur as early as FY24, pending successful completion of Government testing.[38]

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[31] Department of the Navy, *Department of the Navy Unmanned Campaign Framework*, March 16, 2021, p. 16.

[32] Richard R. Burgess, “Navy’s Orca XLUUV to Have Mine-Laying Mission, Adm. Kilby Says,” *Seapower*, March 18, 2021.

[33] For a discussion of the Hammerhead mine, see, for example, David Hambling, “With Hammerhead Mine, U.S. Navy Plots New Style Of Warfare To Tip Balance In South China Sea,” *Forbes*, October 22, 2020.

[34] Department of Defense, *Contracts for Feb. 13, 2019*.

[35] Department of Defense, *Contracts for March 27, 2019*.

[36] See, for example, Hugh Lessig, “Shipbuilder Lends a Hand with Rise of Robot Submarines,” *Defense News*, May 26, 2019.

[37] The Navy states: “Testing and delivery of the vehicles and support elements has been delayed to FY22 due to contractor challenges and supplier issues. The Navy is working with Boeing to mitigate schedule delays and execute risk reduction testing under prototyping effort.” (*Department of Defense, Fiscal Year (FY) 2022 Budget Estimates, Navy Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy*, May 2021, p. 1301.)

[38] The Navy states: “Fabrication awards of additional Orca XLUUV systems are planned for FY24 and out, gradually ramping up quantities in future fiscal years, depending on the progress from the first five systems.” (*Department of Defense, Fiscal Year (FY) 2022 Budget Estimates, Navy Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy*, May 2021, p. 1301.)

> XLUUV will have a modular payload bay, including a universal payload module, with defined interfaces that current and future payloads must adhere to for employment from the vehicle. The Hammerhead [mine] payload is the next payload for integration with Orca XLUUV. Other potential future payloads, advanced energy solutions, and enhanced autonomy and command and control will be developed and evaluated under the Core Technologies PE [program element in the Navy's research and development account] 0604029N, and/or by other Science and technology organizations, and integrated into Orca XLUUV when ready.
>
> The Navy is concurrently updating facilities at the Naval Base Ventura County site for XLUUV testing, training, and work-ups, in coordination with large unmanned surface vessel testing for cost efficiencies. In parallel, the Navy is evaluating options for future far-forward basing locations.[39]

Boeing's Orca XLUUV design will be informed by (but will differ in certain respects from) the design of Boeing's Echo Voyager UUV (**Figure 11**, **Figure 12**, and **Figure 13**).[40] Echo Voyager is roughly the size of a subway car—it is 51 feet long and has a rectangular cross section of 8.5 feet by 8.5 feet, a weight in the air of 50 tons, and a range of up to 6,500 nautical miles. It can accommodate a modular payload section up to 34 feet in length, increasing its length to as much as 85 feet. A 34-foot modular payload section provides about 2,000 cubic feet of internal payload volume; a shorter (14-foot) section provides about 900 cubic feet. Echo Voyager can also accommodate external payloads.[41] The Navy states that the XLUUV

> is based off Boeing's Echo Voyager, but incorporates significant changes to support military mission requirements. This has resulted in challenges in establishing the manufacturing process, building up the industrial base, and aligning material purchases to produce the first group of prototype vehicles. Orca represents the leading edge of autonomous maritime vehicle technology and will have extended range and a reconfigurable, modular payload bay to support multiple payloads and a variety of missions.[42]

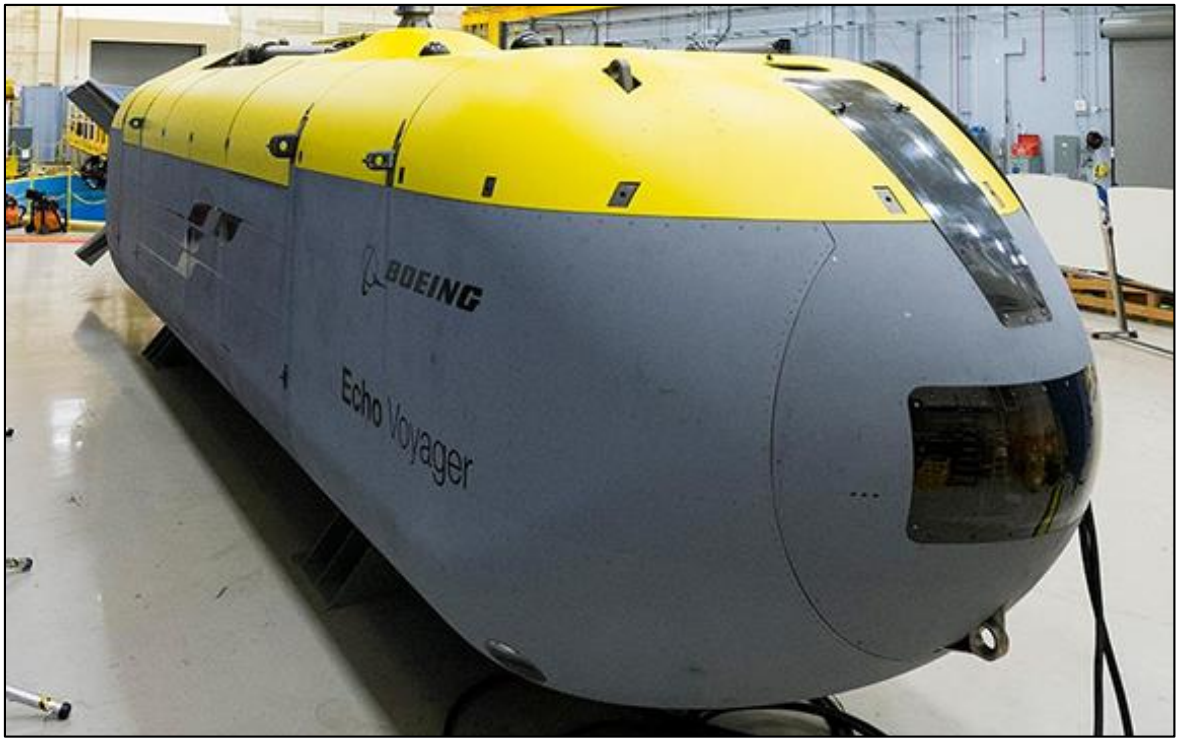
[39] *Department of Defense, Fiscal Year (FY) 2022 Budget Estimates, Navy Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy*, May 2021, p. 1306.

[40] See, for example, Hugh Lessig, "Shipbuilder Lends a Hand with Rise of Robot Submarines," *Defense News*, May 26, 2019.

[41] Source: Boeing product sheet on Echo Voyager, accessed May 31, 2019, at https://www.boeing.com/resources/boeingdotcom/defense/autonomous-systems/echo-voyager/echo_voyager_product_sheet.pdf.

[42] Statement of Fredrick J. Stefany, Acting Assistant Secretary of the Navy for Research, Development and Acquisition (ASN [RD&A]) and Vice Admiral James W. Kilby, Deputy Chief of Naval Operations for Warfare Systems and Lieutenant General Eric M. Smith, Deputy Commandant Combat Development and Integration & Commanding General, Marine Corps Combat Development Command, before the House Armed Services Committee Subcommittee on Seapower and Projection Forces, on Department of the Navy Unmanned Systems, March 18, 2021, p. 12.

Figure 11. Boeing Echo Voyager UUV



Source: Boeing photograph posted at https://www.boeing.com/defense/autonomous-systems/echo-voyager/index.page#/gallery.

Figure 12. Boeing Echo Voyager UUV

Source: Boeing photograph posted at https://www.boeing.com/defense/autonomous-systems/echo-voyager/index.page#/gallery.

Figure 13. Boeing Echo Voyager UUV

Source: Navy briefing entitled "Unmanned Maritime Systems," Howard Berkof, Deputy Program Manager, Unmanned Maritime Systems, PMS 406, Distribution A: Approved for public release; distribution unlimited, October 23, 2019, slide 5.

Issues for Congress

The Navy's proposals for developing and procuring the large UVs covered in this report pose a number of oversight issues for Congress, including those discussed below.

Analytical Basis for More Distributed Fleet Architecture

One potential oversight issue for Congress concerns the analytical basis for the Navy's desire to shift to a more distributed fleet architecture featuring a significant contribution from large UVs. Potential oversight questions for Congress include the following:

- What Navy analyses led to the Navy's decision to shift toward a more distributed architecture?
- What did these analyses show regarding the relative costs, capabilities, and risks of the Navy's current architecture and the more distributed architecture?
- How well developed, and how well tested, are the operational concepts associated with the more distributed architecture?

The Navy states

> As directed in the FY 2021 National Defense Authorization Act,[43] the Navy is conducting a Distributed Offensive Surface Fires AoA [analysis of alternatives] to compare the currently planned large unmanned surface vessel (LUSV) with an integrated missile launcher payload against a broad range of alternative surface platforms and capabilities to determine the most appropriate vessel to deliver additional missile capability and capacity to the surface force. We expect to complete this analysis and report our findings to Congress before the end of this calendar year.[44]

[43] Section 227(e) of H.R. 6395/P.L. 116-283 of January 1, 2021.

[44] Statement of Frederick J. Stefany, Acting Assistant Secretary of the Navy for Research, Development and

Concept of Operations (CONOPS)

Another potential oversight issue for Congress concerns the Navy's concept of operations (CONOPS) for these large UVs, meaning the Navy's understanding at a detailed level of how it will operate these UVs in conjunction with manned Navy ships in various operational scenarios, and consequently how, exactly, these UVs will fit into the Navy's overall force structure and operations. Potential oversight questions for Congress include the following:

- How fully has the Navy developed its CONOPS for these large UVs? What activities is the Navy undertaking to develop its CONOPS for them?
- What is the Navy's CONOPS for using these large UVs in day-to-day, noncombat operations?
- How sensitive are the performance requirements that the Navy has established for these large UVs to potential changes in their CONOPS that may occur as the Navy continues to develop the CONOPS? How likely is it, if at all, that the Navy will have to change the performance requirements for these large UVs as a consequence of more fully developing their CONOPS?

As mentioned earlier, in May 2019, the Navy established a surface development squadron to help develop operational concepts for LUSVs and MUSVs. The squadron was initially to consist of a Zumwalt (DDG-1000) class destroyer and one Sea Hunter prototype medium displacement USV (**Figure 4**). A second Sea Hunter prototype reportedly was to be added around the end of FY2020, and LUSVs and MUSVs would then be added as they become available.[45] A September 9, 2020, press report states

> Development squadrons working with unmanned underwater and surface vehicles are moving out quickly to develop concepts of operations and human-machine interfaces, even as they're still using prototypes ahead of the delivery of fleet USVs and UUVs, officials said this week.
>
> Capt. Hank Adams, the commodore of Surface Development Squadron One (SURFDEVRON), is planning an upcoming weeks-long experiment with sailors in an unmanned operations center (UOC) ashore commanding and controlling an Overlord USV that the Navy hasn't even taken ownership of from the Pentagon, in a bid to get a head start on figuring out what the command and control process looks like and what the supervisory control system must allow sailors to do.
>
> And Cmdr. Rob Patchin, commanding officer of Unmanned Undersea Vehicles Squadron One (UUVRON-1), is pushing the limits of his test vehicles to send the program office a list of vehicle behaviors that his operators need their UUVs to have that the commercial prototypes today don't have.

Acquisition (ASN (RD&A)) and Vice Admiral James W. Kilby, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities (OPNAV N9) and Lieutenant General Eric M. Smith, Deputy Commandant, Combat Development and Integration, Commanding General, Marine Corps Combat Development Command, before the Subcommittee on Seapower of the Senate Armed Services Committee on Department of the Navy Fiscal Year 2022 Budget Request for Seapower, June 8, 2021, p. 14. See also Jason Sherman, "Navy considering alternatives to LUSV, packing amphibs, commercial designs more with long-range missiles," *Inside Defense*, April 9, 2021.

[45] See, for example, Megan Eckstein, "Navy Stands Up Surface Development Squadron for DDG-1000, Unmanned Experimentation," *USNI News*, May 22, 2019; David B. Larter, "With Billions Planned in Funding, the US Navy Charts Its Unmanned Future," *Defense News*, May 6, 2019. See also Michael Fabey, "USN Seeks Path for Unmanned Systems Operational Concepts," *Jane's Navy International*, May 16, 2019.

> The two spoke during a panel at the Association for Unmanned Vehicle Systems International (AUVSI) annual defense conference on Tuesday, and made clear that they want to have the fleet trained and ready to start using UUVs and USVs when industry is ready to deliver them.[46]

An October 30, 2020, press report stated:

> The Navy is set to complete and release a concept of operations for the medium and large unmanned surface vehicles in "the next few months," a Navy spokesman told Inside Defense.
>
> Alan Baribeau, a spokesman for Naval Sea Systems Command, said the Navy extended the due date to allow for more flexibility during the COVID-19 pandemic and allow for sufficient time for review and staffing….
>
> The CONOPS is currently undergoing flag-level review after completing action officer-level review as well as O6-level review, Baribeau said.[47]

Acquisition Strategies and Funding Method

Another potential oversight issue for Congress concerns the acquisition strategies that the Navy wants to use for these large UV programs. Potential oversight questions for Congress include the following:

- Are the Navy's proposed changes to the LUSV's acquisition strategy appropriate and sufficient in terms of complying with Congress's legislative provisions and providing enough time to develop operational concepts and key technologies before entering into serial production of deployable units?
- To what degree, if any, can these large UV programs contribute to new approaches for defense acquisition that are intended to respond to the new international security environment?

Technical, Schedule, and Cost Risk

Another potential oversight issue for Congress concerns the amount of technical, schedule, and cost risk in these programs, particularly given that these platforms potentially are to operate at sea unmanned and semi-autonomously or autonomously for extended periods of time. Potential oversight questions for Congress include the following:

- How much risk of this kind do these programs pose, particularly given the enabling technologies that need to be developed for them?
- In addition to the Navy's proposed changes to the LUSV's acquisition strategy, what is the Navy doing to mitigate or manage cost, schedule, and technical risks while it seeks to deploy these UVs? Are these risk-mitigation and risk-management efforts appropriate and sufficient?
- At what point would technical problems, schedule delays, or cost growth in these programs require a reassessment of the Navy's plan to shift from the current fleet architecture to a more distributed architecture?

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[46] Megan Eckstein, "USV, UUV Squadrons Testing Out Concepts Ahead of Delivery of Their Vehicles," *USNI News*, September 9, 2020.

[47] Aidan Quigley, "Navy Finishing Unmanned Surface Vehicles Concept of Operations 'in Next Few Months,'" *Inside Defense*, October 30, 2020.

A June 1, 2020, press report states

> The U.S. military is banking on unmanned surface and subsurface vessels to boost its capacity in the face of a tsunami of Chinese naval spending. But before it can field the systems, it must answer some basic questions.
>
> How will these systems deploy? How will they be supported overseas? Who will support them? Can the systems be made sufficiently reliable to operate alone and unafraid on the open ocean for weeks at a time? Will the systems be able to communicate in denied environments?
>
> As the Navy goes all-in on its unmanned future, with billions of dollars of investments planed, how the service answers those questions will be crucial to the success or failure of its unmanned pivot.[48]

A June 23, 2020, press report states

> The Navy's transition from prototype to program of record for its portfolio of unmanned surface and undersea systems is being aided by industry, international partners and developmental squadrons, even as the program office seeks to ease concerns that the transition is happening too fast, the program executive officer for unmanned and small combatants said today.
>
> Rear Adm. Casey Moton said he's aware of concerns regarding how unmanned systems – particularly the Large Unmanned Surface Vessel – will be developed and used by the fleet, but he's confident in his team's path forward.
>
> "From my standpoint we are making a lot of great progress in working out the technical maturity, answering those kinds of questions (about how to employ and sustain the vessels) and getting the requirements right before we move into production," he said in a virtual event today co-hosted by the U.S. Naval Institute and the Center for Strategic and International Studies.[49]

An August 17, 2020, press report states

> As the U.S. Navy pushes forward with developing its large unmanned surface vessel, envisioned as a kind of external missile magazine that will tag along with larger manned surface combatants, a growing consensus is forming that the service needs to get its requirements and systems right before making a big investment. . . .
>
> In an exclusive July 16 interview with Defense News, Chief of Naval Operations Adm. Michael Gilday said that while the [congressional] marks [on the program] were frustrating, he agreed with Congress that requirements must be concrete right up front.
>
> "The approach has to be deliberate," Gilday said. "We have to make sure that the systems that are on those unmanned systems with respect to the [hull, mechanical and electrical system], that they are designed to requirement, and perform to requirement. And most importantly, are those requirements sound?
>
> "I go back to [a question from years ago relating to the development of the Navy's Littoral Combat Ship (LCS)]: Do I really need a littoral combat ship to go 40 knots? That's going to drive the entire design of the ship, not just the engineering plant but how it's built. That becomes a critical factor. If you take your eye off the ball with respect to requirements, you can find yourself drifting. That has to be deliberate."

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[48] David B. Larter, "US Navy Embraces Robot Ships, But Some Unresolved Issues Are Holding Them Back," *Defense News*, June 1, 2020. See also Bryan Clark, "Pentagon Needs To Go Faster—And Slower—On Unmanned Systems," *Forbes*, June 11, 2020.

[49] Megan Eckstein, "Program Office Maturing USVs, UUVs With Help From Industry, International Partners," *USNI News*, June 23, 2020.

> Gilday has called for the Navy to pursue a comprehensive "Unmanned Campaign Plan" that creates a path forward for developing and fielding unmanned systems in the air, on the sea and under the water. Right now, the effort exists in a number of different programs that may not all be pulling in the same direction, he said.
>
> "What I've found is that we didn't necessarily have the rigor that's required across a number of programs that would bring those together in a way that's driven toward objectives with milestones," Gilday told Defense News. "If you took a look at [all the programs], where are there similarities and where are there differences? Where am I making progress in meeting conditions and meeting milestones that we can leverage in other experiments?
>
> "At what point do I reach a decision point where I drop a program and double down on a program that I can accelerate?"[50]

A September 8, 2020, press report states

> Several Navy program officials and resource sponsors today outlined how they'll spend the next couple years giving Congress enough confidence in unmanned surface and underwater vehicles to allow the service to move from prototyping into programs of record.
>
> Across the entire family of USVs and UUVs, the Navy has prototypes in the water today for experimentation and in tandem is making plans to design and buy the next better vehicle or more advanced payloads, with the idea that the service will iterate its way to achieve congressional confidence and authorization to move forward on buying these unmanned systems in bulk.
>
> Rear Adm. Casey Moton, the program executive officer for unmanned and small combatants, spoke today at the Association for Unmanned Vehicle Systems International (AUVSI) annual defense conference and provided an update on the status of his portfolio of UUVs and USVs, some of which have run into trouble with lawmakers not convinced of their technical maturity and their tactical utility.
>
> Anticipating audience questions, he said in his speech, "what about Congress? What about the marks and the report language and the questions? So I'm going to put some of that into context from my perspective. I believe the discussion with Congress has not been about if unmanned vessels will be part of the Navy. 'If' has not been the focus. I don't even believe right now that 'if' is a major question. The focus has been on 'how,' with a healthy dose of 'what,' in terms of requirements and mission type. And of course, 'how many' is a question. How many, I will not focus on today. How many is dependent on Navy and [Office of the Secretary of Defense] force structure work. But for PEO USC, how many is ultimately important, but our focus now in this prototyping and experimentation and development phase is on the how, and working with our requirements sponsors and the fleet on the what."
>
> The most ambitious part of the Navy's current plan calls for the start of a Large USV program of record in Fiscal Year 2023, despite the LUSV being the piece of the family of USVs that Congress takes issue with the most. The Navy intends for these ships to be armed with vertical launch system cells to fire off defensive and offensive missiles—with sailors onboard manned ships overseeing targeting and firing decisions, since there would be no personnel on the LUSV.[51]

[50] David B. Larter, "In Developing Robot Warships, US Navy Wants to Avoid Another Littoral Combat Ship," *Defense News*, August 17, 2020. See also Loren Thompson, "U.S. Navy Mounts Campaign To Convince Congress That Unmanned Vessels Are Critical To Winning Future Wars," *Forbes*, August 17, 2020.

[51] Megan Eckstein, "Navy Pushing to Maintain 2023 USV Program of Record Timeline," *USNI News*, September 8, 2020.

A March 26, 2021, press report about a March 18, 2021, hearing on Department of the Navy unmanned vehicle programs before the Seapower and Projection Forces subcommittee of the House Armed Services Committee stated:

> On the unmanned underwater vehicle side, the Navy's largest vehicle in development is hitting some snags, though [Vice Adm. Jim Kilby, the deputy chief of naval operations for warfighting requirements and capabilities (OPNAV N9)] said it was a production issue more than a fundamental issue with the service's requirements.
>
> Kilby said the Navy wanted the Orca Extra Large UUV to lay mines in the water, among other clandestine operations. But building a UUV that can do that is more complex than it sounds, he told lawmakers.
>
> "I've got to avoid fishing nets and sea mounts and currents and all the things. I've got to be able to communicate with it, sustain it. I've got to maybe be able to tell it to abort a mission, which means it has to come up to the surface and communicate, or get communications from its current depth. Those are all complexities we've got to work through with the [concept of operations] of this vehicle," he said.
>
> "In its development, though, there have been delays with the contractor that we're working through, and we want to aggressively work with them to pursue, to get this vehicle down to Port Hueneme so we can start testing it and understand its capabilities. And to me the challenges will be all those things – the C2, the endurance, the delivery of the payload, the ability to change mission potentially – those are all things we have to deliver to meet the needs of the combatant commander."
>
> Boeing is on contract to build five XLUUVs, which were supposed to be delivered by 2022. Construction on the first vessel didn't begin until late last year, though, and Kilby categorized the program as alive but delayed.
>
> Asked by seapower subcommittee chairman Rep. Joe Courtney (D-Conn.) if Orca was proving to be a program that had failed and the Navy needed to cut its losses on, Kilby said, "I think we're going to get these first five vessels, and in the spirit of the committee, we want to make sure we've got it right before we go build something else. I think it's scoped out ideally, we've got to get through those technical and operational challenges to go deliver on the capability we're trying to close on."
>
> He said earlier in the hearing that "we are pursuing that vehicle because we have an operational need from a combatant commander to go solve this specific problem. That vessel really hasn't operated – the XLUUV is, as you know, a migration from the Echo Voyager from Boeing with a mission module placed in the middle of it to initially carry mines. We need to get that initial prototype built and start employing it start seeing if we can achieve the requirements to go do that mission set. And I think, to the point so far made several times, if we can't meet our milestones, we need to critically look at that and decide if we have to pursue another model or another methodology to get after that combatant need. But in the case of the XLUUV, we haven't even had enough run time with that vessel to make that determination yet. Certainly, there's challenges with that vehicle, though."[52]

An April 13, 2021, press report states

> The Navy is making arrangements for land-based testing of its Medium Unmanned Surface Vessel prototype and eyeing similar plans for its Large USV, as the sea service tries to get Congress on board with its plans to rapidly field unmanned vehicles in all domains to create a hybrid manned-unmanned force.
>
> Rear Adm. Casey Moton, the program executive officer for unmanned and small combatants, said today at an event hosted by AUVSI [Association for Unmanned Vehicle

[52] Megan Eckstein, "Status Report: Navy Unmanned Aerial, Subsurface Platforms," *USNI News*, March 26, 2021.

Systems International] that the Navy and Pentagon already have four medium and large USV prototypes in the water today and will have three more delivered in the next few years.

"The testing we're doing at sea on those systems is very important for [hull, mechanical and electrical systems], and we're going to continue that. Where we have definitely expanded our plans is on the land-based side," he said.

The Navy's pitch was to begin buying prototype vessels in numbers so the service could learn a lot about both HM&E [hull, mechanical, and electrical] component reliability and USV concepts of operations before beginning a program of record to buy new vessels in bulk. Lawmakers had concerns that the Navy wouldn't be able to collect enough data before beginning the programs of record and have insisted the Navy invest in land-based testing to wring out components that will have to be able to operate for weeks or months at sea without sailors around to perform routine maintenance or to take corrective action if something fails.

Moton said during the event that he appreciates that leadership, including House Armed Services seapower and projection forces subcommittee chairman Rep. Joe Courtney (D-Conn.) and ranking member Rep. Rob Wittman (Va.), have expressed support for the idea of an unmanned fleet in general, and Moton promised that they'd see the Navy showing engineering rigor in every step along the way—including HM&E reliability testing, command and control testing, adjusting combat systems to operate on unmanned vehicles, developing common control stations, maturing autonomy software and more.

On land-based testing, Moton said, "on the Medium USV, we are right now in the process of executing funding that we received from Congress to go do our work on Medium USV. We are going to have representative equipment that we are buying" that can be tested ashore, where the gear can be run without human preventative or corrective maintenance to see how reliable it would be on an unmanned vehicle operating independently.

"We are buying equipment, and some of the plans specifically about where it's going to go and the testing are still in the work, so I won't say too much, but we are working on Medium USV land-based testing."

LUSV land-based testing is a little farther down the road, he said, but some of the lessons from MUSV will apply directly to LUSV.

"It is true that propulsion plants are not all the same, but a lot of the things that we're doing – the ability to control machinery plants autonomously, the ability to improve the timeline between [planned maintenance], to do things that are relatively straightforward like shift a lube oil strainer without a human having to do it—those things scale between medium and large, so a lot of what we're doing in Medium is going to scale directly to Large," he said.

"Where we are now going to add to our plan for Large is kind of at the big pieces of equipment, and some of this was in the [National Defense Authorization Act] for last year: the propulsion equipment, the electrical equipment. We're still kind of working plans out, but our plan is to take representative pieces of equipment and to test them. I don't want to get quite yet into specifics on where that's going to happen or how that's going to happen, because we're kind of working that out right now, but we are going to go down that path."

Among the challenges is that neither the MUSV nor the LUSV has been designed yet—L3Harris was selected last year to build an MUSV prototype, and six companies are working on LUSV design trade studies—so there isn't a specific propulsion system or electrical distribution system yet that needs to be tested for reliability.

Moton said that the "representative pieces of equipment" that prove themselves in land-based testing will create a pool of "equipment that's essentially been through our qualification process to go on an LUSV, but we are also trying to come up with a way that's flexible" for industry to prove that their components meet Navy systems engineering standards and congressional intent. He said the Navy is working with the American Bureau

of Shipping to develop a framework for qualifying HM&E components as reliable enough for use in USVs.

Moton said much still remains to be determined on MUSV and LUSV—and that's by design. Neither program has a formal capability development document (CDD) yet and are instead working off a less specific top-level requirement (TLR) document for now. Moton said that was done on purpose, to give industry more space to look at cost and capability tradeoffs between potential designs and potential Defense Department requirements. All the at-sea testing happening with the prototypes today, as well as the six LUSV industry studies, will inform the path forward from today's top-level requirements to more specific requirements that will shape what the vessels look like and what capabilities they have.

To keep cost down and to open up opportunities to more shipyards, "we are working our best not to take just a typically manned combatant [specifications] and dial it back down; we are trying to start where we can the other way, kind of a clean sheet and only add requirements back in if they are necessary for the support of the functions of the ship," Moton said.[53]

Annual Procurement Rates

Another oversight issue for Congress concerns the Navy's planned annual procurement rates for the LUSV and XLUUV programs. Potential oversight questions for Congress include, What factors did the Navy consider in arriving at them, and in light of these factors, are these rates too high, too low, or about right?

Industrial Base Implications

Another oversight issue for Congress concerns the potential industrial base implications of these large UV programs as part of a shift to a more distributed fleet architecture, particularly since UVs like these can be built and maintained by facilities other than the shipyards that currently build the Navy's major combatant ships. Potential oversight questions for Congress include the following:

- What implications would the more distributed architecture have for required numbers, annual procurement rates, and maintenance workloads for large surface combatants (i.e., cruisers and destroyers) and small surface combatants (i.e., frigates and Littoral Combat Ships)?
- What portion of these UVs might be built or maintained by facilities other than shipyards that currently build the Navy's major combatant ships?[54]
- To what degree, if any, might the more distributed architecture and these large UV programs change the current distribution of Navy shipbuilding and maintenance work, and what implications might that have for workloads and employment levels at various production and maintenance facilities?

Potential Implications for Miscalculation or Escalation at Sea

Another oversight issue for Congress concerns the potential implications of large UVs, particularly large USVs, for the chance of miscalculation or escalation in when U.S. Navy forces

[53] Megan Eckstein, "Navy Developing Land-Based Unmanned Vehicle Testing Sites as Early Design Work Continues," *USNI News*, April 13, 2021.

[54] For an opinion piece addressing this issue, see Collin Fox, "Distributed Manufacturing for Distributed Lethality," Center for International Maritime Security (CIMSEC), February 26, 2021.

are operating in waters near potential adversaries. Some observers have expressed concern about this issue. A June 28, 2019, opinion column, for example, states

> The immediate danger from militarized artificial intelligence isn't hordes of killer robots, nor the exponential pace of a new arms race.
>
> As recent events in the Strait of Hormuz indicate, the bigger risk is the fact that autonomous military craft make for temping targets—and increase the potential for miscalculation on and above the high seas.
>
> While less provocative than planes, vehicles, or ships with human crew or troops aboard, unmanned systems are also perceived as relatively expendable. Danger arises when they lower the threshold for military action.
>
> It is a development with serious implications in volatile regions far beyond the Gulf—not least the South China Sea, where the U.S. has recently confronted both China and Russia….
>
> As autonomous systems proliferate in the air and on the ocean, [opposing] military commanders may feel emboldened to strike these platforms, expecting lower repercussions by avoiding the loss of human life.
>
> Consider when Chinese naval personnel in a small boat seized an unmanned American underwater survey glider[55] in the sea approximately 100 kilometers off the Philippines in December 2016. The winged, torpedo-shaped unit was within sight of its handlers aboard the U.S. Navy oceanographic vessel Bowditch, who gaped in astonishment as it was summarily hoisted aboard a Chinese warship less than a kilometer distant. The U.S. responded with a diplomatic demarche and congressional opprobrium, and the glider was returned within the week….
>
> In coming years, the Chinese military will find increasingly plentiful opportunities to intercept American autonomous systems. The 40-meter prototype trimaran Sea Hunter, an experimental submarine-tracking vessel, recently transited between Hawaii and San Diego without human intervention. It has yet to be used operationally, but it is only a matter of time before such vessels are deployed….
>
> China's navy may find intercepting such unmanned and unchaperoned surface vessels or mini-submarines too tantalizing to pass up, especially if Washington's meek retort to the 2016 glider incident is seen as an indication of American permissiveness or timidity.
>
> With a captive vessel, persevering Chinese technicians could attempt to bypass anti-tamper mechanisms, and if successful, proceed to siphon off communication codes or proprietary artificial intelligence software, download navigational data or pre-programmed rules of engagement, or probe for cyber vulnerabilities that could be exploited against similar vehicles….
>
> Nearly 100,000 ships transit the strategically vital Singapore Strait annually, where more than 75 collisions or groundings occurred last year alone. In such congested international sea lanes, declaring a foreign navy's autonomous vessel wayward or unresponsive would easily serve as convenient rationale for towing it into territorial waters for impoundment, or for boarding it straightaway….
>
> A memorandum of understanding signed five years ago by the U.S. Department of Defense and the Chinese defense ministry, as well as the collaborative code of naval conduct created at the 2014 Western Pacific Naval Symposium, should be updated with an expanded right-of-way hierarchy and non-interference standards to clarify how manned ships and aircraft

[55] A glider is a type of UUV. The glider in question was a few feet in length and resembled a small torpedo with a pair of wings. For a press report about the seizure of the glider, see, for example, Sam LaGrone, "Updated: Chinese Seize U.S. Navy Unmanned Vehicle," *USNI News*, December 16, 2016.

should interact with their autonomous counterparts. Without such guidance, the risk of miscalculation increases.

An incident without any immediate human presence or losses could nonetheless trigger unexpected escalation and spark the next conflict.[56]

Personnel Implications

Another oversight issue for Congress concerns the potential personnel implications of incorporating a significant number of large UVs into the Navy's fleet architecture. Potential questions for Congress include the following:

- What implications might these large UVs have for the required skills, training, and career paths of Navy personnel?
- Within the Navy, what will be the relationship between personnel who crew manned ships and those who operate these large UVs?

Annual Funding

Another oversight issue for Congress concerns the funding amounts for these programs that the Navy has requested for these programs for FY2022. Potential oversight questions for Congress include the following:

- Has the Navy accurately priced the work on these programs that it is proposing to do in FY2022?
- To what degree, if any, has funding been requested ahead of need? To what degree, if any, is the Navy insufficiently funding elements of the work to be done in FY2022?
- How might the timelines for these programs be affected by a decision to reduce (or add to) the Navy's requested amounts for these programs?

Legislative Activity for FY2022

Summary of Congressional Action on FY2022 Funding Request

Table 1 summarizes congressional action on the Navy's FY2022 funding request for the LUSV, MUSV, and XLUUV programs and their enabling technologies.

[56] Evan Karlik, "US-China Tensions—Unmanned Military Craft Raise Risk of War," *Nikkei Asian Review*, June 28, 2019. See also David B. Larter, "The US Navy Says It's Doing Its Best to Avoid a 'Terminator' Scenario in Quest for Autonomous Weapons," *Defense News*, September 12, 2019; David Axe, "Autonomous Navies Could Make War More Likely," *National Interest*, August 17, 2020.

Table 1. Congressional Action on FY2022 Large UV Funding Request

Millions of dollars, rounded to the nearest tenth

		Authorization			Appropriation		
Navy research and development account	**Request**	**HASC**	**SASC**	**Conf.**	**HAC**	**SAC**	**Conf.**
PE 0603178N, Medium and Large Unmanned Surface Vessels (USVs) (line 28)	144.8	144.8			102.8		
Project 3066: Large Unmanned Surface Vessel (LUSV)	*(144.8)*	*(144.8)*			*(102.8)*		
PE 0605512N Medium Unmanned Surface Vehicles (MUSVs) (line 95)	60.0	101.7			60.0		
Project 3428 Medium Unmanned Surface Vehicle (MUSV)	*(60.0)*	*(101.7)*			*(60.0)*		
PE 0605513N, Unmanned Surface Vehicle Enabling Capabilities (line 96)	170.8	123.8			83.6		
Project 3067: Unmanned Surface Vehicle Enabling Capabilities	*(170.8)*	*(123.8)*			*(83.6)*		
PE 0604536N, Advanced Undersea Prototyping (line 90)	58.5	58.5			47.8		
Project 3394: Advanced Undersea Prototyping-Vehicles, Propulsion, and & Navigation	*(58.5)*	*(58.5)*			*(47.8)*		
TOTAL	**434.1**	**428.8**			**294.2**		

Sources: Table prepared by CRS based on FY2022 Navy budget submission, committee and conference reports, and explanatory statements on the FY2022 National Defense Authorization Act and the FY2022 DOD Appropriations Act.

Notes: PE is program element (i.e., a line item in a DOD research and development account). **HASC** is House Armed Services Committee; **SASC** is Senate Armed Services Committee; **HAC** is House Appropriations Committee; **SAC** is Senate Appropriations Committee; **Conf.** is conference agreement.

FY2022 National Defense Authorization Act (H.R. 4350)

House

The House Armed Services Committee, in its report (H.Rept. 117-118 of September 10, 2021) on H.R. 4350, recommended the funding levels shown in the HASC column of **Table 1**. The recommended increase of $41.7 million for line 95 is for "Carry out execution of CLIN [Contract Line Item Number] 0101." (Pages 415-416) The recommended reduction of $47.0 million for line 96 is for "USV machinery qualification insufficient justification." (Page 416)

H.Rept. 117-118 states:

> *Comptroller General review of enabling technologies for unmanned systems*
>
> The committee recognizes that, as part of the Navy's plan to counter increasing competition among nations in the maritime environment, the Navy intends to field a future fleet composed of a mix of manned and unmanned platforms. In doing so, the Navy identified core technologies and enabling capabilities it believes are necessary for its future unmanned undersea and surface vehicles. The core technologies and enabling capabilities are a broad range of efforts including autonomous management of ship systems and navigation, communications, manned-unmanned teaming, and payload development and integration among others. Congress has previously expressed concern with the Navy's

proposed concurrent approach for the large unmanned surface vessel design, technology development, and integration. While the Navy takes action to address our concerns, the committee would like a better understanding of the Navy's technology development efforts for unmanned maritime systems as a whole.

The committee directs the Comptroller General of the United States to conduct a review of the Navy's core technologies and enabling capabilities for unmanned undersea and surface vehicles and to provide a briefing to the House Committee on Armed Services not later than March 1, 2022, on its findings. As part of this review, the Comptroller General should examine:

(1) the status of the Navy's efforts to develop the core technologies and enabling capabilities for unmanned maritime systems;

(2) the extent to which the Navy has successfully identified all critical technologies necessary for unmanned maritime systems;

(3) the methods and documentation the Navy uses to track technology development for unmanned maritime systems;

(4) the extent to which the technologies developed for unmanned maritime systems will meet Navy requirements and mission needs;

(5) the Navy's process for tracking and prioritizing investments made into its technologies; and

(6) any other areas the Comptroller General deems important. (Page 18)

FY2022 DOD Appropriations Act (H.R. 4432)

House

The House Appropriations Committee, in its report (H.Rept. 117-88 of July 15, 2021) on H.R. 4432, recommended the funding levels shown in the HAC column of **Table 1**.

The recommended reduction of $42.0 million for line 28 is for "LUSV integrated combat system early to need." (Page 265).

The recommended reduction of $87.286 million for line 96 is for "USV machinery qualification unjustified request" ($47.311 million), "Autonomy development concurrency" ($7.125 million), "Unmanned communications excess growth" ($20.35 million), "Elevated sensors excess growth" ($5.5 million), and "USV operations center concurrency" ($7.0 million). (Page 268)

The recommended reduction of $10.707 million for lien 90 is for "Test and evaluation excess to need." (Page 29)

Author Information

Ronald O'Rourke
Specialist in Naval Affairs

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