THE SECRETARY OF THE NAVY
WASHINGTON DC 20350-1000

February 18, 2016

The Honorable John S. McCain
Chairman, Committee on
Armed Services
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

The attached report on Autonomous Undersea Vehicle Requirements (AUV) for 2025 addresses questions identified in the Senate Report 114-49, page 41, accompanying S. 1376, the National Defense Authorization Act for Fiscal Year 2016. The attached report specifically addresses:

- The missions expected to be conducted by different AUV classes and how this mission set relates to current and future submarine mission sets;
- The different AUV classes, as well as other deployable undersea sensor and communications systems, anticipated in this timeframe and their host platform(s), as appropriate; and
- The required number of AUVs in each class and the impact, if any, on submarine force structure requirements.

If I can be of further assistance, please let me know.

Sincerely,

Ray Mabus

Copy to:
The Honorable Jack F. Reed
Ranking Minority Member

REPORT TO CONGRESS

Autonomous Undersea Vehicle Requirement for 2025

February 2016

Prepared by:

Chief of Naval Operations

Undersea Warfare Directorate

2000 Navy Pentagon

Washington DC 20350

The estimated cost of report for the Department of Defense is approximately $32,500 for the 2016 Fiscal Year.

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Reporting Requirement

The Senate Report 114-49, accompanying S. 1376, the Fiscal Year 2016 National Defense Authorization Act, directs the Secretary of the Navy to provide the Senate Armed Services Committee with a report describing its projected Autonomous Undersea Vehicle (AUV) force structure requirement for 2025 that addresses the following:

(1) The missions expected to be conducted by different AUV classes and how this mission set relates to current and future submarine mission sets;

(2) The different AUV classes, as well as other deployable undersea sensor and communications systems, anticipated in this timeframe and their host platform(s), as appropriate; and

(3) The required number of AUVs in each class and the impact, if any, on submarine force structure requirements.

Executive Summary

Autonomous Undersea Vehicles are a key component of the Navy's effort to improve and expand undersea superiority. These unmanned vehicles will be able to operate independently from or in cooperation with manned vehicles, conducting tasks in support of maritime missions such as Intelligence, Surveillance, and Reconnaissance (ISR), Seabed Warfare, and Deception. This expansion of undersea superiority will also rely upon fixed undersea sensors and systems, which provide similar benefits in specific geographic locations. AUVs and undersea fixed systems will operate where manned submarines and ships can't or shouldn't.

Dozens of AUVs are conducting sea sensing and mine countermeasure tasks today with human-in-the-loop supervision. Developmental work to expand AUV endurance, autonomy, and sensor/payload capability will eventually enable AUVs to operate for days or weeks with the minimum human interaction needed to ensure successful task completion. Beyond the increased independence, this evolution will also allow AUVs to expand into far forward operations and increase the number of tasks that can be performed.

While nominal force structure requirements for 2025 cannot be determined yet, the Navy is committed to growing both the size and composition of the AUV force. Navy surface ships and submarines are multi-mission capable, flexible, and crewed by trained and motivated sailors; AUVs and undersea systems will not be able to replace Navy force structure in the foreseeable future. In the near-term, AUVs present a critical opportunity to increase undersea superiority and create valuable offsets against adversary efforts. Capable AUVs, effectively employed by experienced warfighters to conduct tasks critical to mission success, will enhance platform performance and increase the Navy's area of regard, reach, and influence.

This report will describe the Navy's projected AUV inventory requirement for 2025. It will also examine the taxonomy used to cover the range of AUV classes and capabilities. It will describe the key differences between operations far forward, in open oceans, and in home waters. It will differentiate between undersea warfare missions and AUV tasks and provide an overview of the advantages and disadvantages of different host platform options for AUV employment.

Undersea Warfare Missions (Current and Projected for 2025)

Prior to describing missions or tasks to be conducted by AUVs, it is first necessary to define missions applicable to undersea forces in general. Currently, undersea warfare forces leverage concealment and far forward assured access to conduct multiple missions:

- Strategic Deterrence
- Intelligence Surveillance and Reconnaissance (ISR)
  - Indications and Warning (I&W)
  - Initial Preparation of the Environment (IPOE)
- Anti-Submarine Warfare (ASW)
- Anti-Surface Warfare (ASUW)
- Strike
- Naval Special Warfare (NSW)
- Mine Warfare

All of these missions will continue to be relevant in the future. Inevitably, these missions will evolve and expand, including alternate methods, and will be executed at greater ranges and with greater precision and lethality. To manage operational risks and mitigate force structure shortfalls, new tools, off-board sensors, and decoys will be added to enhance submarines' situational awareness, targeting capabilities, and to complicate an adversary's ASW challenges.

Several nascent mission areas are increasing in relevance and importance. These can be expected to become critical elements of a successful Navy-wide undersea warfare effort in 2025. New mission areas may include:

- Seabed Warfare
- Counter-AUV Warfare
- Electromagnetic Maneuver Warfare (EMMW)
- Deception
- Non-Lethal Sea Control

Seabed Warfare: Undersea forces will continue to require access to the world's oceans, seas and littorals in scenarios where adversary capabilities pose unacceptable risks to other maritime forces. The payload volume and complexity involved in executing this diverse set of missions from inside an adversary's Anti-Access/Area Denial (A2/AD) envelope ensures the continuing need for manned submarines to be both present and capable of action. Potential adversaries recognize this undersea offset and are pursuing technologies and tactics to deny U.S. undersea force assured access. Beyond their investments in mixes of ASW aircraft, ships, and submarines, these countries are also investing in future seabed weapon and sensor systems to detect, target, and attack other nation's submarines. To ensure continued undersea dominance and access, the Navy must develop the capability to deny potential adversaries the benefit of seabed systems and simultaneously exploit concealment to achieve U.S. military objectives. Adversary seabed infrastructure and unmanned anti-submarine sensors and systems will be vital future military targets to be disabled, confused, deceived, and/or destroyed in a new seabed warfare mission capability.

Counter-AUV Warfare: As the United States evolves its own organic AUV capability, competitors will also be developing their AUV capabilities and operating them in proximity to our own forces. Undersea forces need to develop and deliver the methods, techniques, and tactics to counter AUV detection, survey, and if necessary attack adversary AUVs. This includes operations to impact the local environment that

make it difficult to operate AUVs and UAVs without impacting our own vehicles. This includes far forward operations and defensive operations in and near home waters.

Electromagnetic Maneuver Warfare: Leveraging far forward access, submarines and unmanned undersea systems will provide unique opportunities for EMMW (to include information operations) capability. Multi-domain ISR collections will continue to provide crucial intelligence and assessments of adversary capabilities during peacetime to inform warfighting requirements and operations planning. The ability to extend U.S. targeting and impair an adversary's situational awareness, targeting, and decision making are key to maintaining the warfighting initiative and assured access will enable this capability.

Deception: As assured access is increasingly challenged and operations at periscope depth become more difficult due to adversary A2/AD capabilities, the ability to control the information received by adversary sensors will become particularly useful. Deception will allow U.S. forces to exert some control over adversary perspectives of contested waters and airspace. This may result in de-escalation or improved engagement opportunities based on the misdirection of adversary forces.

Non-Lethal Sea Control: Current undersea capabilities limit options for undersea engagement of undersea and surface targets to either observation/reporting or complete destruction. Capabilities to support non-lethal options against sea control targets could be used in conditions short of war (i.e. Phase 0 and Phase 1 activities), supporting de-escalation or political messaging during times of heightened tensions. Undersea platforms are ideal users of such capabilities, since their covert nature enhances the value of the non-lethal attack, preventing attribution unless desired.

Autonomous Undersea Vehicles (AUVs)

AUVs, also referred to as unmanned undersea vehicles (UUVs), is a term used to classify a variety of vehicles which share common attributes:

- Submerged operations
- Command and Control (C2) via man in the loop is not required
- Capable of propulsion in execution of tasks

AUVs can be grouped into three broad classes:

- Self-propelled
- Environmentally-powered
- Other systems

Self-Propelled AUV Classes

- **Extremely Large AUVs:** AUVs with diameters larger than 84". Shore or ship launched with sufficient handling facilities such as cranes, well decks, etc.
- **Large AUVs:** AUVs between 21" and 84". Deployed from Dry Deck Shelter (DDS) (installed horizontally on the back of LOS ANGELES-class SSNs, VIRGINIA-class SSNs, or SSGNs), VIRGINIA Payload Tube (VPT) (87-inch vertical tube in the bow of Block III and later VIRGINIA-class SSNs), SSGN Payload tubes (87-inch vertical tube on SSGNs), and VIRGINIA Payload Module (VPM) (87-inch vertical tubes on Block V and later VIRGINIA-class SSNs, due to enter service around 2025) and appropriately capable surface ships. These AUVs will require appropriate handling equipment to support stowage, launch and recovery on any seaborne host platform. Hosting in a vertical submarine SSGN, VPT, VPM tube will require a handling system

like the Universal Launch and Recovery Mechanism to support launch, recovery and stowage. Large AUVs can also be shore or ship launched with handling equipment.

- **Medium AUVs:** AUVs between 10" and 21" in diameter. Submarine deployment would occur from standard torpedo tubes (21-inch, on all submarines), large torpedo tubes (26-inch on SEAWOLF submarines only), Vertical Launch System tubes (21" vertically oriented inaccessible tubes), or the VIRGINIA Lock-out Trunk (30" hatch). Deployments would also occur from DDS. Medium AUVs can be launched from the shore or a surface ship and be recovered with handling equipment.
- **Small AUVs:** AUVs between 3" and 10" in diameter. They can be man-portable, and capable of employment from a variety of platforms or even larger AUVs. Submarine deployment is possible from the ships loadable 3" launcher and the 10" Trash Disposal Unit, VIRGINIA Lock-out Trunk (30" hatch), or externally loaded and launched from 6" countermeasure launchers or the Universal Modular Mast (UMM) receptacle in the sail. Ship deployment would be based on weight, but small AUVs could be easily launched and recovered from the side. Submarines will generally launch but not recover AUVs of this size.

Environmentally-powered AUVs (Wave Gliders also classified as Unmanned Surface Vehicles [USVs])

- **Buoyancy Gliders:** Generically these AUVs are small to medium sized AUVs that convert changes of buoyancy to forward motion via fixed wings. This method of propulsion is very limited in its speed capability although some buoyancy gliders augmented with a propeller may be capable of one to two knots for a limited time period. Power is generally conserved for sensor payloads and communications requirements which results in AUVs with endurance measured in months. Most can be launched and recovered from a small boat/RHIB.
- **Wave Gliders:** These AUVs consist of a surf board-like float attached by a semi-stiff umbilical to a glider several meters below the surface with winglets. One to two knots propulsion is generated by wave motion which is converted to thrust by the winglets under the water and can be augmented with a propulsor. In addition to batteries, the top of float is covered with solar cells to recharge the glider batteries. Endurance for these AUVs are measured in months and transoceanic transits have been demonstrated. Wave gliders are ship and shore launched and recovered.

Other Deployable Undersea Sensor and Communications Systems:

- **Unattended detection systems:** Ocean acoustic and non-acoustic detection systems are emplaced bottom sensors coupled with a gateway communications systems. The sensors detect acoustics and/or non-acoustics; data is collected, processed, and analyzed to provide undersea situational awareness, and serve as a stop gap system in deep water until a permanent system can be installed or restored to service or the need for acoustic monitoring of the area expires.
- **Energy replenishment, data management, and communications infrastructure:** By 2025 the operational and technological challenges associated with using a system to provide energy replenishment, data management, and communications infrastructure for undersea vehicles and sensors may be possible.

Mission Performance for AUVs

To forecast missions that differing AUV classes might conduct by 2025 and relate them to current and future submarine mission sets, it will be useful to distinguish between a mission and a task to better characterize expectations for AUV utility in this time frame. Joint doctrine defines missions and tasks as:

> *Mission: The task, together with the purpose, that clearly indicates the action to be taken and the reason therefore. Source: JP 3-0*

> *Task: A clearly defined action or activity specifically assigned to an individual or organization that must be done as it is imposed by an appropriate authority. Source: JP 1*

The key distinction is that, unlike tasks, missions contain the element of "purpose". Purpose is what links missions to tactical or operational objectives. In contrast, tasks are specific actions, sequenced either alone or with other tasks, to accomplish a mission. Essentially, missions are a set of one or more tasks sequenced to a common purpose.

To date, military missions have been assigned to manned (or man-in-the-loop) units (e.g., remotely piloted aerial vehicle, marine rifle company, naval combatant). Manned units are capable of both executing the mission's "tasks" as well as understanding the mission's "purpose". Understanding "purpose" is the basis for decentralized C2 of far forward operating units. Since conditions sometimes change from the time the mission is ordered to when it is executed (especially in wartime), forward operated manned units are trained and expected to apply judgment and decision making—guided by mission purpose—to modify tasks when necessary to achieve mission success.

Achieving intelligent levels of comprehension of "purpose" within AUVs in the undersea warfare environment by 2025 will be difficult given the inherent C2 challenges. Autonomous systems with organic decision making capability (and not just a narrow range of preprogrammed responses to potential changes in operational conditions) will take time and dedicated effort to develop and reliably demonstrate. Complete autonomy may not develop linearly without incremental experience and learning informing subsequent steps. Lacking sufficient sensors, the power it takes to run these sensors and onboard information processing hinders an organic capability to interpret unexpected conditions outside those for which an autonomous system is designed. To mitigate this shortfall, an AUV will rely on external communications and a manned command center or node with the incumbent operational risks and potential delays that these external communications entail.

Accordingly, AUVs will be assigned specific tasks. The Navy has had success with single task AUVs capable of conducting operations such as open ocean bathymetric collections, bottom surveys, and mine warfare related tasks. AUV tasks will improve overall Undersea Warfare (USW) performance and capability; extend the reach of the host's organic visual, acoustic, and electronic sensors to detect targets outside its current range of influence; and, as AUV endurance and tasking experience grows, increasingly facilitate the simultaneous execution of multiple missions by host platforms, eventually including multi-mission autonomy from AUVs.

AUVs will enable more efficient undersea warfare operations by independently performing, or cooperatively enhancing, certain tasks performed by manned submarines. Examples include the following:

- AUVs will provide access to areas that are prohibitively expensive, time consuming, or too hazardous to reach with manned platforms. This access will involve payload delivery as well as

sensor/payload employment on the AUV, including real-time long distance Over-The-Horizon-Targeting in areas that current operations will not allow.

- AUVs will provide capacity to conduct cost effective, important, well defined repetitive tasks that other forces might have conducted or that may not warrant the full attention of a manned asset. AUVs will provide greater area coverage, and more persistent coverage, than can be provided by manned systems alone.

- AUVs will address a current gap in our capability to control the seabed, which will develop into a vital mission unique to unmanned undersea systems. As previously discussed, the seabed has rapidly growing economic and military importance. U.S. and allied seabed systems will require monitoring, while adversary seabed systems must be detected, surveyed, and if necessary, attacked. AUVs will reduce the risk to manned platforms as remote sensors for missions such as minefield detection, penetration, and neutralization; trip-wire or long term signature collection sensors in remote high traffic or very shallow water areas, and potentially provide an electronic warfare/cyber-related payload capability.

- AUVs will enhance submarine survivability as decoys and support deception and other influence operation tasks.

- AUVs will act as a "data fusion" node together to pull and push actionable intelligence to the hands connecting undersea networks of the warfighter and the fleet tactical/operations communication centers to enable more informed decisions.

- AUVs will address emerging undersea threats including adversary unmanned vehicles, sensors, systems, and infrastructure.

Projected AUV Tasks (2025)

In 2025, AUVs will perform tasks in support of USW missions near or in areas where SSNs operate now. They are likely to operate closer to the bottom and/or deeper than manned SSNs can go and by 2025 they will likely operate farther forward than the manned platforms can, in shallower, denied waters. Because of this challenging operating environment, far forward AUVs will differ from those that operate for commercial industry, in home waters or in the open ocean. They will require longer endurance, enhanced reliability and survivability, may support multiple tasks/sensors, be more passive vice transmitting frequently, and will require increased autonomy to reduce reliance on remote station control and communications networks (due to the impact on stealth). These attributes are required for these AUVs to reach areas where they will be unsupported by manned platforms and must perform various tasks including managing and maintaining their stealth.

AUV capabilities will be driven by four core characteristics:

- Endurance (how far and how fast can the AUV go, and how many sensors need to be supported)
- Sensors/Payloads (what can the AUV sense and can it interact)
- Autonomy (what decisions can the AUV make, based on what it knows and how it communicates)
- Command, Control, and Communications

AUV decision-making limitations will likely constrain the ability for vehicles in development to take over any missions performed by submarines or surface ships. Improvements in AUV endurance and decision-making may eventually reduce stress on the submarine force in the future. However, there is also the

potential that the enhanced capacity for undersea warfare provided by AUVs, especially far forward, might actually increase submarine force structure requirements or warrant the design of a new class of submarine with new interfaces and capabilities needed to optimize employment of AUVs. Surface ship missions tend to focus on visible presence and significant capacity or sensors, but AUVs may eventually provide some degree of covert capability for surface forces.

The tasks that AUVs in 2025 should be able to conduct can be extrapolated from today's tasks and in progress AUV development programs:

Maritime Missions	AUV Task Capability In 2025	Attack Submarine	AUV Type						Other Systems		
			Vehicle				Glider		Unattended Detection/Signature Collection		Support Node
			Small	Medium	Large	XL (Not fielded by 2025)	Buoyancy	Wave	Deep	Shallow	
ISR	Optical	X		S	M			X			
	EM	X		S				X			
	Acoustic	X		S	S		X	X	X	X	
IPOE	Bottom Mapping	X	L	S							
	Bottom Bathymetry	X	L	S	M			shallow			
	Water Column	X	S	S			X	X			
ASuW	Detection/Classification	X		M	M			L			
	Cueing	X						X			
	Tracking	X									
	Engagement	X									
ASW	Detection/Classification	X					L	L	X	X	
	Cueing	X					L	L			
	Tracking	X							X		
	Trail	X									
	Engagement	X									
Strike	Land Engagement	X									
	Undersea Engagement										
Mining	Survey		L	S	M	Navy UON					
	Mine Laying	X		S							
MCM	Survey/Detection	L	S	M	M						
	Classification	L	S								
	Neutralization		S	S							
SOF	Host	X									
	Survey (Landing)			S	S						
	Transport (Equipment)				S						
Seabed Warfare Offensive	Detection/Classification	L	L	M	M						
	Cueing	X	L								
	Tracking	L	L	S							
EMMW	Monitoring	X		S	M			X			
	Injection	X		S				L			
Deception	Physical/Radar		S	M	M						
	EM							X			
	Acoustic			S							
Seabed Warfare Defensive	Detection/Classification		S	M	M			L			
	Cueing		S								
	Tracking		S								
C3	Data Transfer/Transition	X	S	M	M			X			
	I&W Reporting	X	S	M	M			X	X	X	M
	SOF Support	X	S	S	M			X			
	Home Waters Seabed Defense Support		S	M	M			X			

X: Task Capable (from single platform/system)
L: Limited Task Capable (from single vehicle/sortie)
S: Single Task Capable (from single vehicle/sortie)
M: Multiple Task Capable (from single vehicle/sortie)

Launch and Recovery of AUVs

AUVs are designed to operate in home waters near ports and transit lanes, in broad open ocean waters and chokepoints, or in far forward contested waters. Deployed AUVs will transit from their launch position to their pre-determined operating areas and then back to a recovery position unless they are disposable and scuttle. Launch and recovery will occur, at sea, from a surface ship or submarine, or from shore. The effectiveness of an AUV will frequently be directly linked to the launch point/platform utilized for employment.

Reliable and effective AUV concepts of operations are being developed, tested, and iterated by Detachment UUV, which will inform vehicle development and operations. This CONOPS work is being done in parallel with pursuit of AUV capability. The intent is to support the experimental and prototype AUVs currently available to the fleet, and to prepare to employ the AUVs that will be fielded in the next several years.

There are several phases in an AUV operation that will be supported by a host platform (ship or submarine) and/or shore facilities regardless of where they are launched or recovered and these include *(italics indicate shore-based components)*:

Preparation:

- *Pre-Load Certification: Certifies AUV readiness for Load and Operations; will generally be conducted by a shore-based support or vendor facility.*
- *Load: Embarking the AUV for Transport on the Host Platform (if applicable)*
- Transport: Carrying the AUV from the point of loading to the launch point to leverage Host Platform transit and C2 capability.
- AUV Task Preparation: Mission planning and loading; this phase will also include presortie AUV systems checks and validations.

Operations:

- Launch: To get the AUV from the Host Platform into the water for operations
  - Pre-launch checks will verify AUV and handling system readiness for the launch operation, establish operational situational awareness in the launch area and ensure host platform (and potentially remote C2 node) lineups and readiness postures for launch.
  - Transition – will physically transfer the AUV from a transport posture to independent or remotely controlled operations in the water.
  - Post-launch checks will involve final in-water testing to confirm AUV system performance to release the AUV on mission support tasking and a likely turnover to a remote C2 node (if applicable).
- Tasking will include AUV operations at sea, with varying, task-dependent, remote C2 infrastructure (shore/ship-based) control as dictated by task priorities, complexity, duration, environmental risks, operational sensitivities, responsiveness requirements, and intrinsic AUV autonomous capabilities.
- Reporting will include a spectrum of options that will be task and AUV-dependent. For expendable AUVs this may include no reporting or download, download of data via a network

Radio Frequency , undersea cable, separate data mule/vehicle), or a rendezvous with a host for a proximate download prior to scuttling. For a recoverable AUV this will involve download via the means described above and/or after recovery as a minimum. For a recoverable AUV, a health and status reporting capability is expected and protocols to support reporting of time critical information via a network is anticipated.

- Recovery will involve getting the AUV from the water back onto a Host Platform (may not be original host platform), a Recovery Platform, or potentially a shore recovery.
    - Pre-recovery checks will verify AUV integrity, anti-tampering, and ensure handling system readiness for recovery. As in launch a host platform will establish operational situational awareness and, as applicable, remote C2 node readiness postures for recovery.
    - Transition will involve physically transferring the AUV from the water to a transport posture on the Host
    - Post-recovery checks will include testing to confirm AUV integrity, stowage/seaworthiness, and the securing of handling equipment.
    - Post sortie processing will depend upon the task and sortie/mission requirements and will involve a spectrum of options including: post mission drive/data checks with nothing more than physical or information integrity checks; direct transfer of data via a network by the host with no onboard processing; use of optical modem to uncouple recovery from data transfer; or onboard download and post sortie processing, evaluation and dissemination. This last option will likely be time consuming, require special equipment/processing/software, and personnel with special expertise or training.

Inter-Operations Handling will be unique to AUVs capable of multiple sorties from the host platform.

- Servicing will include:
    - Sustaining actions such as battery recharge, refueling, and or resupply.
    - Basic maintenance will include minor, Host-platform capable repairs and maintenance.
    - Payload change-outs (e.g., different deployable payloads or sensors to support additional or differing tasking), which will be undertaken on the Host Platform provided sufficient access and space to enable additional sorties prior to transport home
- Then recommence the applicable preparation to operations cycle described above.

Post-Operations Handling will be required after the final recovery from final tasking:

- Transport to carry the AUV from the point of Recovery to the point of Off-Load
- *Off-Load: disembarking the AUV from the Host Platform for follow-on Maintenance or disposal.*
- *Maintenance which will involve repairs and refurbishment beyond Host Platform capability, modernization, or major component change-out that requires an "intermediate or factory level" Support Facility and re-certification*

The most challenging responsibility for an at sea platform is recovery. Recovery will require coordination and a measure of navigational precision to arrange a rendezvous in the same water space. Allowances for a primary and back up opportunities to affect a recovery will be standard along with procedures to allow for contingency recovery in the event of unmanned system malfunction. Weather, sea state, and the operational security of the rendezvous are generic contingencies that will need addressing before recovery operations will be countenanced. In some cases inexpensive AUVs may be expendable, negating the need for recovery.

By 2025, most AUV operations will focus on tasks that directly support the mission performance of deployed forces operating in open oceans or farther forward. Specifically, the platforms that launch and recover the AUVs will be the immediate beneficiaries of the AUV capabilities by being the initial recipients of the data collected. The operational nature of the platforms or facilities will impact AUV

operations. For this reason, certain platforms or facilities lend themselves to specific operating areas or operational profiles.

Shore Launch

Advantages: Launching an AUV directly into an operational status from a shore facility will not burden a manned platform with a support role for AUV operations. The handling and monitoring equipment and personnel necessary to get the AUV into the water are not constrained by platform limitations; therefore the AUV size and design are not constrained by host platform handling limitations, providing capability for significantly larger AUVs and therefore substantial payload capacity and endurance. Once the AUV is launched, post-launch checks can be easily observed by support personnel and any issues can be resolved without necessarily having to recover the AUV. The only moving vehicle during shore-based launch or recovery operations is the AUV itself. Shore-based launch is less susceptible to at-sea weather or operationally related conditions and hazards. It also supports use of novel high density energy sources and propulsion systems.

Disadvantages: Shore launch will require days or weeks of transit for the AUV to enter its operating area. This transit penalty will place a substantial energy, autonomy, and reliability burden on the AUV above and beyond what is needed to accomplish the assigned task or tasks. This transit penalty will also apply at any point the AUV needs to be recharged, serviced, have payloads restocked (see Inter-Operations Handling, above). The AUV support team must rely on historical data for the operating area to prepare the AUV for operations, as they will not know the specific conditions once the AUV arrives in the operating area. Command and control for shore-launched AUVs will generically involve a remote ground station and long range communications. Any update or alteration to its tasking that requires touch maintenance or management of the AUV will not be possible without returning to a recovery platform or shore facility. Extremely Large AUVs, if disabled at sea, will present significant recovery and retrieval challenges.

Ship launch

Advantages: Surface platforms can launch and support AUVs in open ocean areas and nearer to far forward operating areas than a shore launched AUV, shrinking the transit penalty incurred. Surface platforms have large decks and sufficient storage spaces to support AUV employment, with some weight and volume limitations on the AUV design. Surface ship crews possess significant experience employing off board assets such as small boats and helicopters. During AUV launch and operations, the host platform and the vehicle will operate in different water strata, minimizing the possibility of mutual interference except at the point of launch and recovery. Surface ships are capable of persistent C2 of the AUV when necessary, reducing the autonomy burden for some specific tasks. Surface ship certification of AUV energy options (e.g. fuel cell, lithium battery) would be less difficult than submarine certification. Finally, AUVs will provide some covert offboard capability for surface ships. For large bottom mounted sensor packages that should be deployed in a controlled fashion, surface ships will provide the only capability to do this in 2025.

Disadvantages:

Surface ships will be challenged to conceal AUV launch, recovery, or seabed system installation activity far forward. Some standoff distance will be required, so a degree of transit penalty will remain for AUVs, with subsequent impact on energy, autonomy, and reliability in AUV design and performance. Depending on the transit range penalty and the endurance of the AUV, impacts to host platform mission tasking flexibility to periodically service the AUV are foreseeable. As with a shore launch, a surface platform will not know the specific operating area conditions for the AUV at time of launch, but may be able to leverage tactical databases and available near real-time environmental reports to support mission planning. 2025 AUV tasking is expected to focus on below water sensing and engagement, which does not traditionally support key surface warfare missions; this is expected to change later on. The key

interface limitations for the AUV design will be weight and volume. The dry weight will be more challenging for surface ships to deal with during topside and over the side handling evolutions. Launch and recovery in significant sea state presents additional challenges or limits to the operational envelope.

Submarine launch

Advantages: Submarine employment of AUVs will benefit from the submarine crew's enhanced understanding of the underwater operating environment and expertise with covert USW missions. Submarines will be better positioned to conceal the launch, employment, and recovery of AUVs, enabling end-to-end stealth for far forward AUV tasks. AUVs will conduct tasks in support of key USW missions. such as ISR, Subsea Warfare, ASuW, EMMW, and Offensive Mining. Most importantly, the submarine will employ the AUV far forward, minimize the transit penalty, enable operations with an operator in-the-loop, and ensure that AUV autonomy, energy, and reliability are primarily focused on task accomplishment as opposed to transit safety and security. Since the AUV will expend significantly more of its available energy on the task, the submarine will have the flexibility and sufficient time to conduct other missions and tasking. This arrangement will maximize the number of AUV sorties and leverage the operational experience of the submarine crew to consider optimizing AUV performance for the expected task, or to support rapid retasking far forward.

Disadvantages: Submarine operational time is in high demand and AUV related tasking will need to be made efficient enough to allow for the execution of this mission without overly burdening the crew's ability to conduct other high priority missions. Depending upon the task to be conducted, by 2025 this will likely still involve special equipment installs, dedicated training, and a cadre of specialists to augment the submarine crew. As development continues, system reliability and efficiency improves in the future these operations will become routine and a core capability of the force. Submarine recovery presents the most challenging component for AUV employment. Two vehicles will operate in the same waterspace, with the manned platform recovering the unmanned platform. More so than with surface ship employment, interface limitations will lead to AUV design limitations; in the case of the submarine and a waterborne launch and recovery process, the volume of the AUV will be a more critical factor than the weight. While less than the other launch options, off board remote Command, Control, and Communications (C3) will still be needed depending upon the AUV task. Unless the task is of high enough priority to demand dedicated submarine overwatch and C2 support, the submarine will generally not support C2 for the AUV during conduct of its task.

AUV Inventory Requirements

The specific AUV inventory requirements in 2025 are not accurately known in 2016. Analysis based on capability gaps and the potential for AUVs to provide the most cost effective material solution to these gaps will be required to properly determine AUV inventory requirements in 2025. These requirements will be driven by available AUV capabilities and AUV host platform handling capabilities. There are technologies available to the U.S. Navy today. Near-term insertion of small and medium sized AUVs should be the focus within the next one to five years. Lessons learned from those efforts will help generate and expand capability into the Large and Extremely Large vehicles beyond the near term. That progress will help determine the inventory requirements of 2025 and beyond. Adversary efforts in the maritime domain, especially undersea, will also inform the 2025 AUV inventory requirements. Finally, the newly established Deputy Assistant Secretary of the Navy for Unmanned Systems will be leading the effort to develop a comprehensive, Unmanned Systems roadmap strategy during 2016, per direction from the Secretary of the Navy. This will be the first Department-wide Unmanned Systems roadmap strategy, and will help to inform the Navy of future inventory requirements and investment decisions.

One key driver for far forward AUV requirements will be the 25 percent decrease in SSN force structure over the next fifteen years. Submarines will have more options for mission execution when they employ AUVs and far forward AUVs are most effective when they are employed from submarines. Over the next ten years, the SSN force will drop by seven SSNs (-13 percent). In the five years after 2025, six additional SSNs will retire (to a low of 41 SSNs), as well as all four SSGNs and three SSBNs without replacement. This substantial decrease in presence and capability will occur while there is increasing need for undersea presence and warfighting. The Large Displacement Unmanned Undersea Vehicle (LDUUV) program is being developed to offset this submarine gap, and the projected 2025 LDUUV inventory is twelve systems.

SSNs are highly leveraged multi-mission platforms with experienced crews and leadership. Even with the most optimistic capability and performance projections, no force size of AUVs will be able to replace SSN force structure in 2025. However, far forward AUVs will be able to improve the performance of the available SSNs in peacetime and wartime to mitigate reduced SSN force size. Submarines will deliver AUVs to their operating areas, maximizing vehicle energy for the missions with minimal transit penalty and the additional costs in power, reliability, and C3 that would otherwise need to be provided. Submarine crew experience and insights regarding the AUV operating environment will be depended upon to make the necessary in-situ judgments needed to deploy, delay, modify or curtail AUV related operations. Developing and fielding far forward AUVs capable of conducting tasks that support SSN missions is one of the chief priorities of the Navy's plan for future undersea capabilities.

Conclusion

AUVs are a key component of the Navy's effort to improve and expand undersea superiority. These unmanned vehicles will be able to operate independently from or in cooperation with manned vehicles, conducting tasks in support of maritime missions such as Intelligence, Surveillance, and Reconnaissance, Seabed Warfare, and Deception. This expansion of undersea superiority will also rely upon fixed undersea sensors and systems as well, which provide similar benefits in specific geographic locations. AUVs and undersea fixed systems will operate where manned submarines and ships can't or shouldn't.

Dozens of AUVs are conducting sea sensing and mine countermeasure tasks today with human-in-the-loop supervision. Developmental work to expand AUV endurance, autonomy, and sensor/payload capability will eventually enable AUVs to operate for days or weeks with minimal human interaction needed to ensure successful task completion. Beyond the increased independence, this evolution will also allow AUVs to expand into far forward operations and increase the number of tasks that can be performed.

While nominal force structure requirements for 2025 cannot be determined yet, the Navy is committed to growing both the size and composition of the AUV force. Navy surface ships and submarines are multi-mission capable, flexible, and crewed by trained and motivated sailors; AUVs and undersea systems will not be able to replace Navy force structure in the foreseeable future. In the near-term, AUVs present a critical opportunity increase undersea superiority and create valuable offsets against adversary efforts. Capable AUVs, effectively employed by experienced warfighters to conduct tasks critical to mission success, will enhance platform performance and increase the Navy's area of regard, reach, and influence.