Fighting into the Bastions: Getting Noisier to Sustain the US Undersea Advantage

BRYAN CLARK AND TIMOTHY A. WALTON
CENTER FOR DEFENSE CONCEPTS AND TECHNOLOGY, HUDSON INSTITUTE
Fighting into the Bastions: Getting Noisier to Sustain the US Undersea Advantage

BRYAN CLARK AND TIMOTHY A. WALTON
CENTER FOR DEFENSE CONCEPTS AND TECHNOLOGY, HUDSON INSTITUTE
ABOUT THE AUTHORS

Bryan Clark
Senior Fellow & Director, Center for Defense Concepts and Technology
Before joining Hudson Institute, Bryan Clark was a senior fellow at the Center for Strategic and Budgetary Assessments (CSBA) where he led studies for the Department of Defense Office of Net Assessment, Office of the Secretary of Defense, and Defense Advanced Research Products Agency on new technologies and the future of warfare. Prior to joining CSBA in 2013, Mr. Clark was special assistant to the chief of naval operations and director of his Commander’s Action Group, where he led development of Navy strategy and implemented new initiatives in electromagnetic spectrum operations, undersea warfare, expeditionary operations, and personnel and readiness management. Mr. Clark served in the Navy headquarters staff from 2004 to 2011, leading studies in the Assessment Division and participating in the 2006 and 2010 Quadrennial Defense Reviews. Prior to retiring from the Navy in 2008, Mr. Clark was an enlisted and officer submariner, serving in afloat and ashore submarine operational and training assignments, including tours as chief engineer and operations officer at the Navy’s Nuclear Power Training Unit.

Timothy A. Walton
Senior Fellow, Center for Defense Concepts and Technology
Mr. Walton focuses on the development of new operational concepts and the assessment of trends in future warfare and Indo-Pacific security dynamics. Prior to joining Hudson, he was a research fellow at CSBA, where he led and contributed to studies and wargames for the US government and its allies on operational concepts and force planning. Previously, Mr. Walton was a principal of Ailos Consulting Group and an associate of Delex Consulting, Studies, and Analysis, both defense and business strategy firms. During this period, he led and supported studies for the Department of Defense that developed road maps for future technologies, analyzed Indo-Pacific security dynamics, and assessed Chinese and US military concepts. He also facilitated strategic planning, capture shaping, and acquisition due diligence for commercial and defense companies.

The Center for Defense Concepts and Technology at Hudson Institute
Hudson Institute’s Center for Defense Concepts and Technology examines the evolving field of military competition and the implications of emerging technologies for defense strategy, military operations, capability development, and acquisition. The center focuses on a comprehensive view: connecting strategy with new operational concepts; assessing the weapons and systems needed to implement new concepts; and evaluating the necessary commitment of resources.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Executive Summary</strong></td>
<td>7</td>
</tr>
<tr>
<td>1. Field a Team for Offensive Undersea Operations</td>
<td>8</td>
</tr>
<tr>
<td>2. Use Uncrewed Systems to Free Up SSNs</td>
<td>9</td>
</tr>
<tr>
<td>3. Make SSNs More Effective</td>
<td>10</td>
</tr>
<tr>
<td>4. Develop SSN(X) and Manage Its Costs</td>
<td>11</td>
</tr>
<tr>
<td>The Operational Imperative</td>
<td>12</td>
</tr>
<tr>
<td><strong>1. Introduction: No Longer a Sanctuary</strong></td>
<td>13</td>
</tr>
<tr>
<td><strong>2. Sustaining the US Offensive Undersea Advantage</strong></td>
<td>22</td>
</tr>
<tr>
<td>Command, Control, and Communications (C3)</td>
<td>23</td>
</tr>
<tr>
<td>Intelligence Preparation of the Environment (IPOE)</td>
<td>25</td>
</tr>
<tr>
<td>Suppression and Defeat of Enemy Undersea Sensors</td>
<td>27</td>
</tr>
<tr>
<td>Anti-submarine Warfare</td>
<td>28</td>
</tr>
<tr>
<td>Surface and Strike Warfare</td>
<td>30</td>
</tr>
<tr>
<td>Mine Countermeasures (MCM)</td>
<td>31</td>
</tr>
<tr>
<td>Offensive Mining</td>
<td>33</td>
</tr>
<tr>
<td>A Need for Urgency</td>
<td>34</td>
</tr>
<tr>
<td><strong>3. Implications for Force Structure</strong></td>
<td>35</td>
</tr>
<tr>
<td>XLUUV</td>
<td>38</td>
</tr>
<tr>
<td>LDUUV</td>
<td>39</td>
</tr>
<tr>
<td>MUUV</td>
<td>39</td>
</tr>
<tr>
<td>SUUV</td>
<td>39</td>
</tr>
<tr>
<td>Mines</td>
<td>40</td>
</tr>
<tr>
<td>Expeditionary Warfare and Support Ships</td>
<td>40</td>
</tr>
<tr>
<td>Submarines</td>
<td>41</td>
</tr>
<tr>
<td>Implementation</td>
<td>42</td>
</tr>
<tr>
<td><strong>4. Conclusion and Recommendations</strong></td>
<td>45</td>
</tr>
<tr>
<td><strong>Endnotes</strong></td>
<td>47</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

Airpower enthusiasts concluded after World War I that “the bomber will always get through.”1 Fast, high-flying aircraft seemed to hold a decisive edge over air defenses and offered commanders the assurance they could attack targets deep inside an opponent’s territory. But airpower advocates’ spirits were quickly dampened during World War II by the advent of interceptor fighters, radar-guided artillery, and electromagnetic warfare (EW), which together demonstrated that bombers could be stopped—often with devastating results. Air forces adapted, adding escort fighters, radar jammers and decoys, and higher-altitude bombers to sustain their ability to strike behind enemy lines. During the Cold War, this move-counter-move competition continued. New surface- and air-launched missiles targeted bombers, and countries developed specialized aircraft and weapons to suppress and destroy enemy air defenses or use stealth to avoid detection and targeting altogether.

Today, the US submarine force faces a similar challenge. The US fleet of nuclear-powered attack submarines (SSNs) has long been considered an asymmetric advantage against potential adversaries like the People’s Republic of China (PRC) and Russia, which lacked robust and effective anti-submarine warfare (ASW) capabilities. Relying on this advantage, the US Department of Defense (DoD) has increasingly relied on SSNs to compensate for the im-

Photo: The USS Ronald Reagan and a Los Angeles-class fast-attack submarine in waters east of the Korean Peninsula on September 30, 2022. (US Navy photo by Mass Communication Specialist 3rd Class Gray Gibson)
pact of improved air defenses on the ability of bombers and strike fighters to execute attacks. However, the unfailing ability of US SSNs to reach their targets is eroding as emerging technologies and weapons proliferation combine in new approaches to ASW that could neutralize America’s underwater advantage.

During the last decade, the PRC and Russian Federation began fortifying their underwater defenses in the South and East China Seas and Arctic Ocean, respectively. Leveraging geographic constraints, US adversaries have instrumented these bastions with networks of fixed and mobile acoustic and non-acoustic sensors, complemented by aircraft and ships capable of pouncing on contacts or deploying dense mine barriers. Improved adversary defenses could degrade or defeat US underwater operations, preventing US submarines from conducting critical missions such as sinking a Chinese invasion fleet or tracking Russian ballistic missile submarines (SSBNs).

To sustain its offensive underwater advantage, the US Navy will need to take some lessons from air warfare and begin supporting submarines with systems designed to suppress or destroy enemy underwater defenses. This imperative will fundamentally shift the paradigm for US submarine operations from “alone and unafraid” to “it’s all about team.” Moreover, the emergence of new generations of capable long-range active sonars will demand that the US submarine force increasingly rely on jamming and deception to counter enemy sensors, much as their counterparts already do above the water. The US submarine force will need to learn how to use noise, rather than avoid it.

The Navy should pursue four lines of effort, outlined below, to sustain its offensive underwater advantage. Except for features to be incorporated into the next-generation nuclear-powered attack submarine, the SSN(X), the concepts and capabilities proposed in this report leverage mature or maturing technologies and can be fielded within five years. Implementing these recommendations will require the US Navy to refine its use cases for offensive underwater warfare to use available unmanned vehicle technologies, rather than continue pursuing purpose-built systems that may take a decade or more to be fielded.

1. Field a Team for Offensive Undersea Operations

Although unmanned systems such as mines and torpedoes conduct offensive underwater operations, US commanders will want a human operator to verify that rules of engagement (ROE) are met before an attack is initiated. Submarines will therefore remain the centerpiece of US offensive underwater warfare because they can place operators close enough in time and space to underwater attacks to be accountable for ROE. Like today’s stealth bombers and strike fighters, to achieve this proximity submarines will increasingly need teams of systems that deceive, disrupt, or destroy enemy underwater sensors and weapons, as summarized in figure ES-1.

To support future operations, before conflict unmanned surface vehicles (USV) and unmanned underwater vehicles (UUVs) would rigorously map the ocean floor and water column to find likely adversary sensors, power and communication networks, mines, and UUV support infrastructure. When offensive underwater missions are needed, US naval forces would prevent SSNs from being accurately targeted by destroying adversary sensor networks.

Figure ES-1: Fielding a Team for Offensive Undersea Operations

Depending on the threat environment, unmanned vehicles and sensors can be deployed from shore, ships, submarines, and aircraft.

Long and short duration unmanned vehicles of varying sizes map the environment, locate threats, and jam, decoy, or destroy threats, creating operational access for SSNs.

Source: Authors.
undersea sensors, communications, or weapons using UUVs; by dispersing USV-based mast decoys on the ocean’s surface; or by deploying UUV-based acoustic jammers or decoys near adversary sonar arrays. These concepts fundamentally shift US submarine operations from a hider-finder competition to a competition about sensing and sense-making.

The Navy faces several challenges to fielding offensive undersea warfare teams. Beyond the cultural shift to using, rather than avoiding noise, the US Navy’s most significant challenge may be how to deploy uncrewed systems. Pre-conflict surveys of adversary bastions like the Barents Sea or South China Sea will likely need to be conducted clandestinely to avoid alerting the opponent that its undersea defenses have been discovered. But payload space on a submarine comes at a premium, and every UUV that takes up a torpedo stow or missile cell displaces a weapon that can be reloaded only at a ship or pier outside of the conflict area. Therefore, submarine-launched medium UUVs (MUUVs) that can be carried only in the torpedo room should be reusable and few. In contrast, small UUVs (SUUVs) that can be carried in external countermeasure launchers or lockers inside the submarine could be expendable and deployed by SSNs without impacting their weapons capacity.

These constraints, and the potential detectability of launching and recovering UUVs in general, point to some ways of aligning uncrewed systems and deployment mechanisms with particular use cases. For example, during offensive operations, deception and jamming will need to happen away from the protected submarines, but the SUUVs well-suited for these functions are relatively slow. An SSN could therefore deploy SUUVs near adversary sensors while transiting to an operating area, where the SUUVs would loiter or sleep and activate at a predetermined time or on an acoustic signal if conditions allow. Uncrewed air systems (UAS) or USVs could also deploy SUUVs and might be preferred for some use cases, such as quickly distributing numerous SUUVs near enemy sonar arrays.

Larger UUVs such as the large displacement uncrewed undersea vehicle (LDUUV) and extra-large uncrewed undersea vehicle (XLUUV) offer greater endurance and payload volume that can be used for long-duration pre-conflict survey missions as well as deployment of smaller vehicles such as SUUVs or mines. These vehicles could be launched from shore, but some are relatively slow. To maximize their time on station, LDUUVs and XLUUVs could be deployed from amphibious transport docks or other ships with suitable well decks or rigging equipment.

2. Use Uncrewed Systems to Free Up SSNs

The need for SSNs to conduct ASW is a significant constraint on their availability for offensive undersea warfare. Uncrewed systems cannot replace SSNs, but they can perform some functions submarines commonly are called upon to deliver, thereby expanding the scale of US undersea operations and freeing SSNs for higher-priority tasks. Two missions where uncrewed systems can be most impactful are ASW sensing and engagement, as summarized in figure ES-2.

Adversary submarines can be detected, tracked, and trailed by uncrewed passive acoustic sensors like the fixed Sound Surveillance System (SOSUS) or relocatable Transformational Reliable Acoustic Path System (TRAPS); by sonobuoys deployed by uncrewed vehicles; and by sonar arrays towed by USVs or UUVs. Uncrewed vehicles can also enable US undersea forces to exploit active sonar to detect and track increasingly quiet PRC and Russian submarines without risking counter-detection of a crewed US ship. For example, in addition to multi-static active coherent (MAC) sonobuoys that could be deployed by MQ-9B Reaper uncrewed aerial vehicles (UAVs), USVs can tow low-frequency active (LFA) sonar arrays that could enable them to trail enemy submarines at long range.5

The current US ASW approach is to track enemy submarines until they can be attacked and sunk by torpedoes launched from submarines or aircraft.6 However, the lightweight Mk-54
torpedoes carried by surface ships and aircraft have a low probability of destroying submarines due to their relatively short range and small warheads. Submarine-launched Mk-48 heavy-weight torpedoes have the highest probability of sinking modern enemy submarines, but US SSNs should focus on engaging enemy surface combatants, only tasking SSNs to destroy threat submarines when they pose an imminent threat to US SSBNs or the US homeland. Instead, non-SSN ASW forces should focus on suppressing enemy undersea operations by exploiting the self-defense, speed, and sensing limitations of submarines; these qualities incentivize commanders to break off and leave an area when detected, rather than standing and fighting like a surface combatant or evading attacks like an aircraft. Small torpedoes like the Compact Rapid Attack Weapon (CRAW) or depth bombs launched by uncrewed vehicles can exploit these limitations to destroy and drive submarines away without tying up a US SSN in a time-consuming prosecution.7

Mines are the most proven form of ASW engagement and if detected would substantially constrain enemy submarine operations. Mines like the Hammerhead could be deployed by uncrewed vehicles such as the XLUUV, and the powered Quickstrike could be emplaced in contested areas by UAVs like the MQ-9 without risking crewed platforms.8 New generations of mobile, smart mines could combine USVs with torpedoes or explosives to create systems that could be launched from shore, crewed vessels, or large aircraft and loiter or navigate in designated areas until commanded to activate and attack selected targets based on their visual, infrared, acoustic, or magnetic signatures.9 And like the ASW suppression operations described above, the presence of mines is likely to keep enemy submarines away, regardless of the mines’ estimated lethality.

3. Make SSNs More Effective
The US Navy and Congress are funding efforts to increase the delivery rate of new SSNs and reduce the US submarine maintenance backlog.10 These efforts should be sustained, but an equal effort should be made to improve the capabilities of current and programmed SSNs so that they are better able to fight their way into and within enemy bastions. Three priorities stand out in this regard, summarized in figure ES-3.

First, new capabilities should be incorporated into SSNs that improve their ability to understand and respond to threats. As noted above, the relatively slow speed and lack of self-defenses on a submarine require commanders to evade nearly all attacks—including those that would have ultimately missed the submarine. Improved decision-support tools would enable US SSN commanders to avoid or break off offensive operations only when necessary, in the same way the Aegis Combat System and threat warning systems assess incoming missile attacks against surface combatants or aircraft, respectively. To build on sustained improvements to organic submarine sensors, the Navy should also improve SSNs’ ability to receive off-board sensor data while traveling at speed and depth using optical communications or radiofrequency-to-acoustic gateway buoys.

A second priority should be improved defenses. For decades US submarines have relied on their acoustic superiority and
countermeasures to defeat attacks. With improving adversary ASW capabilities—particularly in the bastions—and as Russian SSNs approach acoustic parity with US Virginia-class SSNs, US submarines will need to incorporate defenses that allow them to stand and fight. The CRAW should be incorporated into each SSBN and SSN as quickly as possible to provide both a short-range rapid response capability and an anti-torpedo torpedo for self-defense, just as SM-6 interceptors protect surface combatants from missile attacks. To complement CRAW against air threats, the US undersea force should also quickly field on US SSNs surface-to-air missiles that can engage rotary- and fixed-wing maritime patrol aircraft (MPA).11

Third, SSNs should incorporate new systems that better enable them to complete offensive kill chains. The Navy is already investing in longer-range torpedoes and Maritime Strike Tomahawks that would allow SSNs to engage enemy vessels from outside the densest undersea defenses.12 However, an SSN cannot evade its launch area fast enough to avoid enemy ASW aircraft, which could be rapidly deployed to where the noise of a torpedo ejection or the infrared (IR) signature of a missile launch was detected. The US Navy could reduce this vulnerability and enable sustained offensive operations by fielding encapsulated missiles and torpedoes; these would allow SSNs to displace a weapon launch from the submarine in space and time.13

To identify potential targets and help inform SSN commanders if nearby threats could endanger the submarine after a launch, the Navy should field submarine-launched UAS (SLUAS) with longer range and endurance than the current Blackwing small SLUAS.14 And because larger SLUAS and MUUVs could take up torpedo stows, the Navy will need to field smaller submarine-launched weapons to increase both the number of offensive engagements SSNs can conduct and their time on station. For example, multiple CRAWs could be carried in a single long-range torpedo housing, which could transport the CRAWs to an attack area and deploy them on an acoustic or wire-guided command.15

4. Develop SSN(X) and Manage Its Costs
The US Navy plans on replacing today’s Virginia-class SSNs during the mid-2030s with SSN(X), which is intended to provide greater reliability, speed, and torpedo capacity than Virginia.16 However, as noted above, active sonars are becoming more prevalent in ASW as potential adversaries adopt a “reconnaissance-strike” approach to defeating US submarines rather than the “hunter-killer” approach typified by US Cold War ASW operations. Like modern bombers and fighters, US submarines will need to incorporate features that reduce their active sonar returns, as well as payload volume and apertures for deploying UUVs to deceive, degrade, or defeat active undersea sensors.
Another potential concern with SSN(X) is cost. The Congressional Budget Office estimates that each SSN(X) will likely cost around $6.2 billion (in FY2022 dollars), which is nearly twice as much as a Virginia-class Block V SSN and three-quarters as much as the Columbia-class SSBN. SSNs are currently procured at a rate of two per year; if SSN(X) costs twice as much as Virginia, the Navy may be unable to sustain this rate—much less ramp up to a higher rate of three to four SSN(X) per year once Columbia-class construction ebbs and more construction capacity becomes available. Consequently, the Navy should critically evaluate the desired attributes for SSN(X) and consider appropriate changes that can reduce costs. For example, investments in improved sound silencing could be weighed against those in active sensor countermeasures and longer-range weapons that could provide equivalent improvements in survivability.

The Operational Imperative

Submarines are the US military’s crown jewel and are relied upon to deliver decisive effects in campaigns against adversaries like the PRC and Russia. However, unless it begins to use noise and field teams for offensive operations, the US submarine force could be denied or simply rendered ineffective in waters where future confrontations are most likely to occur. To sustain its undersea advantage, the Navy should adopt proven approaches from aviation for suppressing, defeating, and circumventing adversary defenses. Unless the US undersea force embraces these new concepts and capabilities, it risks becoming marginalized when it is needed most.
1. INTRODUCTION: NO LONGER A SANCTUARY

The US Navy long relied on undersea warfare as its asymmetric advantage against the Soviet Union and continues to do so against Russia and the People’s Republic of China (PRC). Able to penetrate undetected into an enemy’s home waters, nuclear-powered attack submarines (SSNs) have afforded generations of US leaders the ability to gather intelligence, shadow adversary naval operations, and threaten attacks with little warning deep inside enemy territory. Through continued innovations in acoustic superiority, US SSNs were able to sustain their advantage despite opponents’ anti-submarine warfare (ASW) efforts.

A combination of geography, strategy, and technology is now undermining America’s long-standing undersea advantage. Because Russia and the PRC are adjacent to targets for aggression such as Ukraine or Taiwan, respectively, they will benefit from interior lines of communication in most potential conflicts against the United States. And over the last decade, both nations’ militaries established long-range sensor and weapon networks that imperil aircraft, ships, and ground forces hundreds of miles away from their territory. Today these capabilities protect Russian and PRC gray-zone operations and undermine US security assurances by threatening to delay or prevent the arrival of reinforcements during a conflict. In the case of Russia, these

Photo: The USS Tennessee, a United Kingdom Royal Navy Vanguard-class nuclear submarine, an E-6B Mercury, and an MH-60R Sea Hawk helicopter conduct bilateral at sea training in the Atlantic Ocean on November 22, 2022. (US Navy photo by Naval Aircrewman 1st Class Aaron Abbott)
networks remain in place despite the war in Ukraine, allowing Russian forces in Kaliningrad, for example, to threaten retaliation against NATO for its assistance to Kyiv. The PRC, for its part, has increased the reach of its sensor and strike capabilities by expanding its space-based surveillance and targeting network and by fielding new generations of bombers and intermediate-range ballistic missiles that can attack moving targets like aircraft carriers as well as US bases in Guam and beyond.18

China, which the US Department of Defense (DoD) describes as its “pacing threat,” is pursuing a strategy of systems warfare, also known as systems destruction warfare, which seeks to dismantle the systems of systems the US military relies on for sensing, communication, decision-making, and action.19 The sensor and precision weapons networks of the People’s Liberation Army (PLA) are part of this strategy, as are Beijing’s substantial investments in electromagnetic warfare (EW), cyber, and counter-space capabilities.

PRC leaders view US submarines as the most challenging threat to PLA operations in the western Pacific.20 Nevertheless, the bulk of modernization spending in the first decade after the 1996 Taiwan Strait Crisis was devoted to the PLA’s reconnaissance-strike complex, which could hold at risk US carrier strike groups like those President Bill Clinton used to brush back Beijing’s aggression before Taiwan’s presidential election.21 Since the mid-2000s, however, the PLA has been ramping up its underwater and ASW capabilities to blunt the perception that US submarines can defeat Chinese military operations against Taiwan.22

To a great extent, the PLA’s underwater capabilities are designed as part of its counter-intervention strategy and are not used to project power overseas. The PLA undersea fleet is almost entirely composed of conventionally powered submarines that are limited to a month or less of submerged operation—often at slow speed—before they must snorkel to recharge their batteries.23 Newer conventional submarines incorporate features to reduce their detectability but their diesel exhaust and masts could still be detected by the growing variety of commercial and government-owned electro-optical/infrared (EO/IR) and synthetic aperture radar (SAR) satellite constellations over the western Pacific. Therefore, although they deploy abroad in peacetime, the PRC’s conventional submarines would likely remain close to China during a conflict where they could be protected by mainland-based aircraft and missiles. This suggests that PLA Navy submarines are viewed primarily as another set of weapon launchers to threaten the PRC’s neighbors and slow intervention by US and allied forces in China’s near abroad.

The newest PLA conventional submarines, the Type 039B/C Yuan air-independent propulsion (AIP) submarines (SSP), are reportedly very quiet when running their engines on liquid oxidants. The PLA has fielded 17 Yans, the newest of which incorporate flank sonar arrays on their hulls (like those on US Virginia-class SSNs) as well as towed sonar arrays.24 This suggests some Yans could be employed for ASW, but their inherent speed and endurance limitations would likely confine them to defensive missions in the East and South China Seas, such as defending PRC ballistic missile submarines (SSBNs). Yans are likely to be employed primarily for missile attacks against US surface naval forces, for which they carry the YJ-18 supersonic anti-ship missile (ASM). With a range of more than 200 nm, the JY-18 could enable Yans to attack from beyond the detection range of US surface fleet sonars and helicopters.

Outside of the Yuan, the PLA submarine fleet includes 10 improved Russian Kilo diesel-electric submarines (SS), 13 indigenously built Type 039 Song-class SS, and a shrinking number of retiring Type 035 Ming-class SS.25 Ming SS are only capable of torpedo attacks against US naval forces. Kilo and Song SS can also launch modern ASMs such as the Russian Kalibr and Chinese YJ-8, respectively, that could threaten surface naval forces more than 100 nm away.26 The standoff range of sub-launched ASMs could enable PLA SS to reduce their likelihood of being counterattacked even if they need to snorkel periodically.
The PLA also has fielded a small but growing number of SSNs that are, for now, relatively easy to detect and track.\textsuperscript{27} The PLA operates six Type 093 Shang-class SSNs, which carry torpedo-tube-launched (TTL) ASMs or land-attack cruise missiles (LACM) and have quieting comparable to 1970s Soviet submarines.\textsuperscript{28} The Type 093 is being succeeded by the Type 095 Tang-class SSN, which likely has an acoustic signature on par with that of late Cold War Soviet SSNs and carries ASMs and LACMs in a vertical launch system akin to those on newer US or Russian SSNs.\textsuperscript{29} The PRC has enhanced its cooperation with Russia on submarine design and expanded the capacity of its SSN construction facilities, likely with the intent of building quieter SSNs in the future.\textsuperscript{30}

The PLA’s submarines could be effective in their main mission of countering enemy naval forces around the western Pacific thanks to the estimated reach and lethality of its ASMs.\textsuperscript{31} In general, the PRC’s submarines do not appear to be an element of the PLA’s ASW architecture.\textsuperscript{32} Only the newest PLA submarines incorporate both the quieting and towed and flank sonar arrays needed to track a US submarine without being counter-detected. Moreover, the PRC’s submarines operate in ways that

---

**Figure 1: US SOSUS Coverage in the Pacific during the Cold War**

suggest they are focusing on surveilling or trailing adversary surface combatants rather than carrying out the clandestine intelligence-gathering and ASW operations US SSNs are known for.

Rather than using submarines to protect its home waters from US SSNs, the PLA appears to be conducting ASW by extending its reconnaissance-strike complex undersea. Just as the PLA uses multiple overlapping radars, passive radio frequency (RF) detectors, and EO/IR sensors to monitor the western Pacific from shore or space, it is now establishing a multidimensional surveillance network undersea to detect and target submarine or uncrewed underwater vehicle (UUV) threats and create a protected bastion for the PRC’s own submarine operations.

Recent undersea warfare efforts by the PRC mirror some of the US Navy’s own approaches. During the 1950s, US and allied navies began installing the Sound Surveillance System (SOSUS) to monitor Soviet submarine movements along the US coast and in areas where Russian fleets were concentrated. As shown in figure 1 for the Pacific Ocean, the US Navy expanded the SOSUS network of seafloor-mounted hydrophones throughout the Cold War. However, starting in the late 1970s, SOSUS coverage began to shrink as a new generation of quieter Soviet submarines entered the force. In response to improvements in Soviet submarines, the US Navy added arrays and hydrophones to maintain SOSUS coverage. Near the end of the Cold War, the Navy further expanded the system’s coverage by combining SOSUS with Surveillance Towed Array Sensor System (SURTASS) ships to form the Integrated Undersea Surveillance System (IUSS). Today, the Navy continues to expand its bottom-mounted sonar networks driven by concerns regarding the PRC’s growing submarine fleet.

In response to improvements in Soviet submarines, the US Navy added arrays and hydrophones to maintain SOSUS coverage. Near the end of the Cold War, the Navy further expanded the system’s coverage by combining SOSUS with Surveillance Towed Array Sensor System (SURTASS) ships to form the Integrated Undersea Surveillance System (IUSS). Today, the Navy continues to expand its bottom-mounted sonar networks driven by concerns regarding the PRC’s growing submarine fleet.

Whereas the US Navy IUSS was and remains a government-built and -operated surveillance network, the PRC employs a combination of civilian, commercial, and military sonar systems to monitor waters across the western Pacific. Close to China, research institutions controlled by Beijing operate undersea observatories in the South and East China Seas, focused on areas near PLA submarine bases for the North, East, and South Sea Fleets. Although their passive sonars might not be able to hear quiet US submarines at long ranges, these observatories could detect missile and torpedo launches or uncrewed vehicle deployment. Chinese companies also conduct undersea mapping and hydrological data collection across the East and South China Seas.

Beyond the East and South China Seas, Chinese researchers also deploy sophisticated acoustic arrays between the US submarine base in Guam and the Philippines. Like the ocean observatories close to China, these sensors are notionally for research purposes, but they can pick up faint noises hundreds of miles away and would be useful for ASW. Other sensors may also be capable of detecting submarines, such as free-floating acoustic buoys and submarine fiber-optic cables that can register pressure changes, including those associated with noise from submarines. Lastly, People’s Armed Forces Maritime Militia vessels, including fishing trawlers, can detect and report the location of submarines or other unmanned assets, and they can ensnare submarines or recover uncrewed systems in their fishing nets.

The PLA augments academic and commercial research arrays with government-owned systems described as the Blue Ocean Information Network. Built and operated by state-owned China Electronic Technology Corporation (CETC), the network comprises eight fixed or floating observation stations positioned around Hainan Island in the South China Sea. Hainan is home to the PLA’s Yulan submarine base, where its most modern submarines, including its new SSBNs, are based. The Blue Ocean Information Network observatories are not advertised as having sonar capabilities, but the southern platforms positioned between Hainan and the Paracel Islands, shown in figure 2, would be well-positioned to monitor undersea activity along approaches to the Yulan base.
The increasing use of civil and commercial entities to support undersea surveillance reflects the Chinese Communist Party’s (CCP) concept of military-civil fusion (MCF), which requires relevant commercial and private sector technology development and investment to support military operations. The quasi-governmental effort to instrument the seabed also reflects the CCP’s focus on controlling and exploiting the deep sea for commercial and military purposes. And beyond these publicized systems, it is likely that the PLA has a variety of classified military sensor networks devoted to detecting and tracking US submarine movements and operations.

The PRC complements its stationary sensor systems with a growing fleet of military and civilian ships deploying passive sonar arrays. Most newer PLA surface combatants, such as the Luyang guided missile destroyer (DDG) and Jiangkai guided-missile frigate (FFG), carry a passive towed sonar array. And to fill in coverage gaps of fixed sensors, civilian vessels—including a handful of new small waterplane area twin hull (SWATH) vessels—carry passive towed sonar arrays like those on US Navy SURTASS ships. However, unless US SSNs or nuclear guided missile submarines (SSGNs) are generating excess noise by launching weapons or vehicles, they are unlikely to be detected by PRC passive sonars mounted on the seafloor or towed by SWATH ships and surface combatants. To address this continued shortfall, the PLA is also fielding a growing number and variety of active sonars. Although it was the most prevalent ASW sensing technology during World War II, active sonar was supplanted during the Cold War by passive sonar, which could track the continuous noise generated by reactor machinery on nuclear submarines at longer ranges. Moreover, active sonar had the additional liability that it reveals the presence and location of the emitting platform. However, decades of sound silencing efforts by the US and Russian navies have reduced the detection range and utility of passive sonar for ASW.

New technologies are now making active sonar a more useful and secure ASW tracking technology. Leveraging miniaturization in microelectronics and transducer construction, low-frequency active (LFA) sonars that operate below 1,000 Hz can now be
small enough to deploy from multi-mission warships or uncrewed vessels. Compared with traditional surface ship sonars that operate at 3 Ghz or higher, LFA sonars suffer lower propagation losses and can achieve longer detection ranges against quiet submarines. Moreover, by varying the depth at which the sonar transmits, sound can be directed into channels that further enhance its detection range to 100 miles or farther. And although active sonar does not provide the acoustic intelligence that passive sonar provides, improved acoustic processing, including artificial intelligence–enabled algorithms, could enable LFA sonars to identify and maintain target-quality tracks on threat submarines.

While the US Navy is only now building its first warships equipped with LFA variable depth sonar (VDS), the PLA has more than 40 Type 056A ASW corvettes in service that carry LFA VDS. The PLA is also equipping the newest version of its Type 052D Luyang destroyers with LFA VDS, which will allow them to contribute to ASW in addition to conducting their primary missions of air defense and surface warfare. As US and Russian submarine developers have emphasized stealth during the last several decades, the advent of numerous and capable LFA sonars creates the potential for ASW forces to regain an advantage in the hider-finder competition.

Non-acoustic technologies are also increasingly capable of detecting and targeting submarines—especially in shallow waters where adversaries are establishing bastions, or in potential conflict areas like the Taiwan Strait, as shown in figure 3. New technologies and improved processing could enable aircraft or satellites to find and track submarines operating close to the surface, including radar and infrared sensors that can track periscopes and masts; sensitive magnetometers that can detect the magnetic signature of submarines; and blue-green lasers that could penetrate the water to precisely locate submarines.

In contrast to the US ASW approach, which methodically prosecutes enemy submarines using IUSS, aircraft, ships, and submarines until a torpedo attack is likely to succeed, the PLA appears to be planning reactive engagements against possible detections of US submarines, as shown in figure 4. The PLA is incorporating torpedo warheads into anti-ship missiles to create the Yu-8 and ET-80, which would allow ships and shore-based launchers to attack submarines up to about 20 miles away. For longer ranges, the PLA’s currently small fleet of Y-8Q maritime patrol aircraft (MPA) seems sized to investigate and attack submarine detections by fixed arrays or shipborne sonars rather than mount large-area ASW search operations of its own. Moreover, the PLA has built thousands of anti-submarine mines that could be pre-positioned in chokepoints or deployed responsively against submarine detections.

Although they are not widely fielded yet, the PLA is also developing uncrewed systems that could be used as part of its
undersea reconnaissance-strike complex in the South and East China Seas. Generally, uncrewed surface vehicles (USVs) and UUVs will lack the speed, range, and endurance to chase down submarines, but they could be positioned to help fill gaps in the undersea surveillance network or deployed in chokepoints and other likely operating areas to attack US submarines with torpedoes and depth bombs.55

The PLA ASW approach described above would embrace lessons from historical ASW campaigns by focusing on suppressing rather than destroying US submarines. Submarines are not fast enough to easily evade torpedoes as an aircraft might evade a missile, and they lack the self-defenses to stand and fight as surface combatants would. Once attacked, US submarine commanders will need to either continue their missions knowing they have been detected or break off and attempt to regain their stealth. And although the lethality of air and surface torpedo engagements is generally low, the importance of SSNs to US war plans may leave commanders unable to accept the risk of being damaged or destroyed by sustained PLA attacks.56 Furthermore, commanders are incentivized to withdraw promptly after being detected because delaying evasion

---

Figure 4: Operation of the PRC Undersea Reconnaissance-Strike Network

Source: Authors, based on Peter Costes, “China’s SeaWeb Undersea Surveillance Network,” Submarine Matters (blog), June 2, 2016.

Note: ASROC = anti-submarine rocket.
increases the likelihood of needing to use higher speeds, which could expose their submarine to detection by the PLA’s mobile and fixed passive sonars. Mines present a similar challenge to US SSNs. Whereas US passive sonars and processing are superior in detecting noise from opposing ships or submarines, finding modern mines may...
be difficult without using active sonar. In waters close to China, active sonar would give away the SSN’s position and expose it to attack, leaving a commander to either continue the operation at high risk or withdraw.57

An ASW campaign by the PRC against US submarines might share some dynamics with the Allied effort against German U-boats in the Battle of the Atlantic. As figure 5 shows, Axis submarine presence in the Atlantic grew until 1943, when Allied ASW capabilities began to impose more losses. However, after 1943, dozens of U-boats remained in the Atlantic—more than twice as many as early in the war—but Allied shipping losses dropped to nearly zero. The implication of the data is that Axis submarines were dramatically less effective late in the war, but were also not being destroyed by Allied ASW efforts. Instead, Axis submarines were being suppressed or did not aggressively engage due to the risk aversion of their commanders.58

The challenges to US submarines from PRC active and passive sonar arrays and shore-based, shipboard, and airborne weapons launchers are like those posed by PLA air defenses to US strike aircraft. During the last 50 years, US air forces developed and refined concepts and capabilities to jam, deceive, and attack air defenses. Undersea forces will now need to field the systems and tactics needed to suppress or defeat enemy undersea defenses.

To suppress sensors, for example, US naval forces could deploy UUVs carrying acoustic jammers or decoys that confuse or obscure adversary active or passive sonars; this would mirror the ways in which EA-18G Growler airborne electronic attacks degrade adversary air defense radars, or ALQ-214 digital radio frequency memory (DRFM) self-protection jammers deceive missile radar seekers. To destroy adversary sensors, deeper-diving UUVs could map out opposing seabed networks in advance of a conflict, and naval forces could use small UUVs (SUUVs) with explosives to destroy key sensing or communication nodes.

Submarines are the US military’s crown jewel and are relied upon to deliver decisive effects in campaigns against adversaries like China and Russia. In the next chapter, this study proposes new operational concepts for the US Navy to sustain its undersea advantage, drawing upon lessons from air warfare that highlight the need for teams of systems to overcome enemy air defenses. Chapter 3 details the capability implications of these new approaches and places them in context with the Navy’s overall investment in undersea warfare. Chapter 4 concludes by summarizing this report’s recommendations. Unless it embraces new concepts like those proposed that disrupt the “lone wolf” model of undersea warfare, the US submarine force risks becoming marginalized when it is needed most.
2. SUSTAINING THE US OFFENSIVE UNDERSEA ADVANTAGE

As detailed in Chapter 1, improved Chinese undersea sensor networks and ASW capabilities could undermine one of the US military’s few remaining advantages against the PLA. To sustain their ability to access China’s bastions and counter PRC aggression, US undersea forces will increasingly need to adopt techniques from air warfare. During strike operations, US air forces rely on EA-18G Growlers to obscure the enemy radar picture with high-power ALQ-99 or ALQ-249 jammers and, if necessary, destroy antennas using radiation-homing weapons such as the AGM-88 Advanced Anti-Radiation Missile (AARGM). If suppression or destruction of enemy radars is not practical or feasible, air forces attempt to deceive enemy sensors by using systems such as the Miniature Air-Launched Decoy (MALD). If these operations are unsuccessful, aircraft use EW self-protection systems to defend themselves from surface-to-air missiles.

Suppressing and defeating air defenses, however, comes at a cost. As shown in figure 6, US strike packages had to double in size to accommodate EW and escort aircraft after the North Vietnamese Army fielded the Soviet-made SA-2 integrated air defense system during the Vietnam War. Because

Photo: A UUV in the Arabian Gulf on September 28, 2016. (US Navy photo by Petty Officer 2nd Class Tyler Thompson)
many of the newly added aircraft were converted fighters or attack aircraft, the number of weapons employed against North Vietnamese targets per strike package decreased over the course of the war.

As in the air warfare case shown in figure 6, the systems and expendable vehicles used for suppression and defeat of undersea defenses will demand payload capacity that could otherwise be used for weapons. Furthermore, some of these systems, such as acoustic jammers or decoys, are designed to be detected and could inadvertently reveal the location of a nearby submarine. To maximize their payload capacity and protect their stealth, US submarines should therefore rely on off-board systems to suppress and defeat enemy undersea defenses. Moreover, to contain their cost, these systems should be predominantly uncrewed.

Addressing the threat posed by enemy sensors and weapons will require the US undersea force to revise its concepts and capabilities for offensive operations to use—rather than avoid—noise and embrace manned-unmanned teaming. The concepts below, designed for the 2030 timeframe, employ a combination of off-board systems deployed from submarines, aircraft, and amphibious warships to counter undersea defenses, enable submarine strike and surface warfare, and create a more adaptable and resilient US undersea force. The technologies assumed in the concepts below either are already resident in the US Navy or are in systems being developed by the Navy, industry, and government research organizations. And as addressed in chapter 3, the systems of systems proposed below are designed to align use cases with available technologies to help speed the Navy’s efforts to field useful uncrewed systems.

Command, Control, and Communications (C3)

C3 is the most challenging, and important, aspect of conducting offensive undersea operations. Air warfare, missile defense, or surface warfare can be conducted using RF communications, which travel at the speed of light and can achieve data rates of thousands of bytes per second even in low probability

Figure 6: US Strike Package Composition in Operation Rolling Thunder: 1965 vs. 1968


Note: AAA = anti-aircraft artillery; ELINT = electronic intelligence; GCI = ground-controlled interception; SAM = surface-to-air missile; SEAD = Suppression of Enemy Air Defenses; SOJ = Stand-off Jammer; SRO-2 IFF = Indication Friend or Foe system.
of intercept/low probability of detect (LPI/LPD) modes. Coordinating undersea operations with those above the surface demands communications across the air/water boundary. Because RF transmissions can penetrate only a short distance in water and acoustic communications can travel only a short distance in air, undersea warfare operations generally employ multiple communication phenomenologies. The resulting reduction in communications reliability and latency will require submarines to conduct or direct most offensive undersea actions, because they can place operators close enough in time and space to verify rules of engagement (ROE) are met before an attack is authorized.59

Submarines can use acoustic communications to direct and receive data from UUVs, but need the ability to coordinate with USVs and crewed ships or aircraft that are deploying uncrewed systems, locating targets for submarine attack, or conducting attacks of their own. Several proven mechanisms could be employed by submarines and UUVs for communications across the air/water boundary:

- **Gateways.** These are USVs, UUVs, or buoys that float on the ocean surface to transmit and receive acoustic messages with undersea vehicles or systems below the water and RF communications with forces above the water. Larger buoys or USVs can be deployed in an operational area to act as persistent communication hubs, although their presence will quickly become known to the enemy. Smaller buoys or UUVs with less endurance or power can be launched by submarines, aircraft, or ships to transmit pre-loaded messages or support a specific operation.60

- **Towed communications buoys.** These are gateways that are continuously connected to a submarine. To preserve the submarine's stealth, the buoy would normally remain slightly below the surface, limiting it to receiving relatively low-throughput high-frequency and low-frequency RF transmissions. The buoy could be allowed to float on the surface to transmit, with a commensurate reduction in stealth.61

- **Laser communications.** These can transmit across the space/air/water boundary but require the platform above the water to be relatively close to the submerged submarine or UUV to compensate for attenuation and signal spreading. Laser communications can, however, achieve very high throughput on par with that of satellite communication.62

Communications between submarines and UUVs will be less complex compared to those with forces above the water, but will be constrained by low data rates, high latency, or challenging geometries. Digital acoustic modems enable reliable communications between undersea platforms, but the frequency—and therefore data rate—of acoustic transmissions must be lowered as range increases between the communicating platforms due to attenuation. Longer ranges will also noticeably increase the latency of communications, because the speed of sound in water is about 1,500 meters a second, while RF communications travel at 3X10^9 meters a second in air. Lasers and light-emitting diodes (LEDs) have also been proven for underwater communications, offering higher throughput and lower latency than acoustic methods at comparable ranges. However, light-based communications require alignment of modems, which can constrain the geometry between participating systems and the operational concepts they can pursue.63

The communications challenges involved in undersea warfare suggest the Navy also needs to make commensurate investments in Command and Control (C2). Undersea warfare C2 tools can help commanders construct tactics and combinations of crewed platforms and uncrewed systems—also known as mission threads—that accomplish needed objectives. Forces above the water can build mission threads assuming relatively reliable and low-latency local RF communications, which eases the planning burden. In contrast, undersea mission threads need to accommodate highly variable data rates and latency as well as maintain acceptable geometries between submarines and UUVs. For today's undersea force of crewed submarines and a small number of UUVs, tactics can be predesigned before
a mission and adjusted manually by operators. Designing and refining the complex mission threads needed for future offensive undersea warfare—including coordinating suppression and defeat of undersea defenses—will demand computer-aided C2 tools that can address the impacts of cross-domain and acoustic or light-based communications.

Decision-support tools could build mission threads in ways that limit the need for undersea communications and enable UUVs to operate automatically within the limits of today’s level of technology. For example, since SUUVs will lack the endurance to both find seabed sonar hydrophones and conduct extended jamming or decoy operations, larger UUVs could be used to survey and map hydrophone arrays, transmitting results via RF messages on the surface to UAVs that deploy SUUVs to the area where jamming or decoy operations need to occur.

**Intelligence Preparation of the Environment (IPOE)**

UUV-based acoustic decoys or jammers will be power-limited, and every hour they spend driving to an operating area and locating the sensor of interest will reduce the intensity or duration of their effects. UUVs used to attack undersea infrastructure will be constrained to torpedo-sized or smaller explosive warheads, so they can be launched from a variety of platforms. Therefore, suppression or destruction of enemy undersea sensor networks will depend on a detailed understanding of the seabed and subsea environment that allows placing UUVs in proximity to their targets.

Above the water, space-based and airborne electronic intelligence (ELINT), radar, or EO/IR reconnaissance systems map out an opponent’s sensors and air defenses. This enables planners to route strike aircraft and missiles around threats to improve their survivability as well as precisely target EW and an-

---

**Figure 7: Approaches for Surveying and Assessing the Undersea Environment before Conflict**

Source: Authors.

Note: ELINT = electronic intelligence; LDUUV = large displacement uncrewed undersea vehicle; MUUV = medium UUV; UAS = uncrewed air systems.
ti-radiation missile attacks against enemy air defenses. A similar set of operations, summarized in figure 7, will be needed to support offensive undersea warfare.

In conducting IPOE, the Navy will be challenged by the endurance and depth limitations of most UUVs. High-fidelity surveys of adversary subsea and seabed networks, infrastructure, or sensors in places like the South China Sea will require UUVs that can dive more than 3,000 meters to closely examine potential systems using specialized side-scan sonars and EO/IR sensors. SUUVs like the Navy’s Lionfish may not have the endurance, buoyancy control, or hardened systems needed for these missions. Larger vehicles such as the Razorback MUUV (medium UUV) or a future LDUUV (large displacement UUV) would be needed for efficiently surveying the seabed and water column in areas where future offensive undersea operations may occur. Submarines have high-priority intelligence-gathering and surveillance missions to conduct in peacetime, and ideally would not be conducting IPOE surveys of the waters in places like the South or East China Seas. Moreover, since many of the systems being surveyed are sensors, using US SSNs for these missions could inadvertently provide valuable intelligence to future opponents. Therefore, for IPOE operations the Navy should pursue approaches that host UUVs on other vessels, including amphibious ships like the LPD-17 amphibious transport dock, whose well deck can allow for rapid launch and recovery of dozens of MUUVs or LDUUVs, as shown in figure 8.

Another element of IPOE will be assessing the common deployment patterns, tactics, and capabilities of PLA ASW platforms. Because vessels like the Type 056 will likely be using

Figure 8: Artist’s Depiction of UUVs and USVs in Well Deck of LPD-17

Source: Huntington Ingalls Industries.
active sonar to search for quiet US SSNs, passive sensors that could be carried by SUUVs or MUUVs could provide intelligence on PLA ASW capabilities. UUVs could be deployed closer to the area of interest using airdrops from crewed aircraft such as C-17s, C-130s, or P-8As, or from UAVs like the MQ-9B Reaper, which could simultaneously conduct ELINT against PLA ASW forces.66

**Suppression and Defeat of Enemy Undersea Sensors**

The US submarine force’s operations rely on acoustic superiority to avoid threats and counter-detection. In bastions like the South China or Barents Seas, stealth may not defeat active sonars, and offensive operations like missile or torpedo attacks are likely to reveal a US submarine to passive sensors. The US submarine force will need to embrace concepts that use noise, rather than avoid it, to sustain the US undersea advantage.

Today the Navy cannot disrupt, deceive, or destroy opposing undersea sensors at the scale needed for offensive operations such as interdicting an amphibious invasion of Taiwan. Although the PRC is still building up its airborne ASW capacity, the PLA could suppress US submarine operations by employing its dozens of Type 056 corvettes and thousands of cruise, ballistic, and ASW missiles to attack each potential detection of a US SSN. And while Russia has expended much of its high-end missiles in Ukraine, the Russian Armed Forces operate a capable surveillance network across the Barents and White Seas that would make their modest ASW force more effective. Countering either adversary’s undersea defenses will require generating dozens of false submarine targets, jamming potentially hundreds of sensors, and destroying tens of network nodes. Figure 9 shows some approaches US forces could use to suppress or defeat enemy undersea defenses.

**Figure 9: Suppression and Defeat of Undersea Defenses**

![Suppression and Defeat of Undersea Defenses Diagram](image-url)

Source: Authors.

Note: EAB = Expeditionary Advance Base; XLUUV = extra-large uncrewed undersea vehicle.
Adequate surveys in advance of conflict will be essential to maintaining the stealth of US submarine operations. Although Chinese and Russian passive seabed sonar arrays are likely not as sophisticated as the US IUSS, US SSNs could be detected if they stray too close to an array or conduct noisy operations in the vicinity. However, avoiding adversary sensors may not be possible during a conflict. To reduce the likelihood of US SSNs being targeted, SUUVs carrying sound generators could operate nearby to increase the level of broadband background noise in the area. The SSN could deploy SUUVs from countermeasures launchers without impacting its own torpedo or missile capacity; or preferably, the SUUVs could be deployed by a larger UUV such as an extra-large uncrewed undersea vehicle (XLUUV) or a UAV like the MQ-9B.

While raising the general noise level around an SSN would help reduce its likelihood of being identified, the increased acoustic activity will still attract attention to the area. US undersea forces could shift enemy focus away from SSN operations using SUUV decoys tailored to different sensing technologies. Against the PRC’s government and quasi-government passive sonar networks, SUUVs could simulate narrowband SSN tonals like today’s Expendable Mobile Anti-Submarine Warfare Training Target (EMATT).67 To exploit the PRC’s growing space and airborne SAR and EO/IR surveillance satellite constellations, SUUVs could operate on the surface and episodically expose mast or periscope simulators that PLA ASW forces will need to investigate. And perhaps most important, SUUVs could simulate active sonar returns from SSN hulls using DRFM technology like that employed by RF jammers.68 By recording, manipulating, and retransmitting radar or sonar emissions, DRFM technology can alter the size and location of the decoy as perceived by the enemy. As ASW increasingly shifts from passive to active sonar, technologies like DRFM will become essential to protect submarine operations.

Attacking and destroying enemy undersea sensor and communication networks will likely require larger UUVs than the SUUV. Overcoming sea pressure will demand a sizable explosive payload on par with that of a torpedo. The UUV will need long endurance to allow its host platform to remain outside enemy weapons or sensor range and enable the UUV to loiter while awaiting an attack order to ensure undersea operations are effectively orchestrated. Finally, when it arrives at the target, the UUV will need a multi-phenomenology sensor package capable of confirming the target to ensure ROE are met before the engagement.

Aircraft could deploy some MUUVs or LDUUVs into less-contested areas or during lower states of escalation. However, the larger platforms able to launch them, such as P-8A Poseidon or cargo aircraft, might not be survivable during open hostilities in highly contested areas where some of the attacks would be needed. As shown in figure 9, Navy or Marine units at Expeditionary Advance Bases (EABs) in places like the Philippines or Japan could deploy LDUUVs or MUUVs from shore to conduct attacks.69 MUUVs could also be launched by submarines using acoustic communications to direct the MUUV to attack, although this method would reduce the SSN’s torpedo or missile capacity.

Anti-submarine Warfare

During peacetime, US SSNs conduct extensive tracking and intelligence gathering against rival navies’ submarines. However, in wartime US commanders plan to use SSNs predominantly for strike and surface warfare; surface combatants and MPA like the P-8A would conduct almost all ASW operations.70 A severe limitation on US ASW capacity, however, is that manned aircraft and surface combatants will have a variety of missions in wartime, and may not be available for ASW operations against a large submarine fleet like that of the PLA. Moreover, manned US platforms may not be survivable in the best submarine hunting areas, like maritime chokepoints across the Japanese and Philippine archipelagoes.

A previous Hudson Institute study proposed a new ASW approach that would enable scaling up ASW operations while low-
er the demands on and threats to manned platforms by using uncrewed platforms for the bulk of ASW detection and tracking; manned platforms would be dedicated to C2 and engagement.\textsuperscript{71}

The overall concept proposed by the study is described in figure 10. In this concept, stationary uncrewed sensors such as the Transformational Reliable Acoustic Path System (TRAPS) or USVs with towed passive sonar arrays conduct barrier searches along chokepoints where enemy submarines are likely to travel. To initially track submarines detected by passive sonar, USVs will deploy SUUVs carrying sonobuoy sensor payloads, such as the multi-static active coherent (MAC) system; or a UAV like the MQ-9B could deploy MAC-equipped sonobuys. The UAV would remain in the area to process MAC field data and pass it to a P-8A managing the ASW operation, which could direct one or more USVs with LFA VDS systems to trail the submarine until it becomes a threat to US naval forces or facilities ashore. Threat submarines would be engaged by P-8As normally, but UAVs could suppress submarine operations using small torpedoes or depth bombs to force them to break off and leave the area, as the PLA may do against US SSNs.\textsuperscript{72}

**Figure 10: Uncrewed ASW concept applied in the Philippine Sea**


Note: MFTA = multi-function towed array; TA = towed array.
Although uncrewed systems and P-8As could conduct the bulk of ASW operations using the above approach, there are situations in which US SSNs would need to find, track, and engage enemy submarines. The lightweight torpedoes employed by aircraft and surface combatants are not as likely to destroy an enemy submarine as the Mk-48 heavyweight torpedo carried by US SSNs. In situations where an enemy submarine must be definitively destroyed, a US SSN may be needed to engage the threat. SSNs will also be needed for ASW operations deep inside highly contested areas, such as enemy SSBN operating areas or near ports, where SSNs could be complemented by XLUUVs delivering stationary or mobile mines.

A challenge for US SSNs will be the absence of sensors normally used for initial detection and tracking in the open ocean or closer to the US coast, including IUSS arrays, SURTASS ships, and ELINT or maritime patrol aircraft. To help find enemy submarines during far-forward ASW operations, US SSNs could employ UUVs as part of a distributed sensor network. The threat environment will generally prevent aircraft or ships from deploying UUVs close enough to adversary SSBN patrol areas or ports to support ASW searches. But SSNs could deploy SUUVs using countermeasures launchers without impacting their torpedo capacity. As explored in Defense Advanced Research Projects Agency (DARPA) programs, including Mobile Offboard Clandestine Communications and Approach (MOCCA) and Distributed Agile Submarine Hunting (DASH), active sonars on UUVs could enable SSNs to bi-statically detect and track quiet enemy submarines like the PRC Yuan or Russian Yasen classes. However, a risk of UUV-borne active sonars is that they could inadvertently illuminate the US SSN. To mitigate this risk, passive sonar arrays could be deployed on or towed by SUUVs to enable coordinated multi-axis detection and geolocation of enemy submarines. Multi-sensor passive or active ASW will depend on highly directional acoustic communications, which were assessed in the MOCCA, DASH, and other Navy and DARPA programs.

Surface and Strike Warfare

The main purpose of US submarines fighting their way into enemy bastions is to conduct surface and strike warfare against enemy forces in defense of US allies like NATO countries, Japan, or Taiwan. US operational plans have long depended on the ability of US SSNs to operate in adversary waters to increase the uncertainty of enemy success and thereby deter aggression. With the improving extent and sophistication of adversary undersea sensor networks and ASW capabilities, US SSNs are likely to be engaged shortly after they begin anti-ship or strike attacks. Although US SSNs will be difficult to find and are unlikely to be destroyed by small torpedoes and ASW grenades, the need to evade attacks will degrade the ability of US submarines to sustain offensive operations.

To reduce their risk of being located, US SSNs could employ encapsulated weapons to displace the noise of their launches or attacks in space and time. As shown in figure 11, encapsulated torpedoes or missiles could be launched from torpedo tubes or vertical launchers, including the multiple all-up-round canisters on Virginia-class SSNs. Capsules could float near the surface until a time delay or RF or acoustic communication signal directed capsules to eject their payload. Similarly, torpedoes could be contained in neutrally buoyant capsules that would eject the torpedo after a time delay or on an acoustic command.

Against surface targets, US SSNs could use their own sonars for detection and tracking at ranges useful for torpedo attacks. To support longer-range surface ship engagements or strikes using missiles, US SSNs and SSGNs would need predetermined targets or the ability to obtain targeting information during the operation. The communication schemes for undersea warfare C3 described above could be used by the submarine to coordinate with commanders above the water or obtain targeting information.

Because communications with other forces may be disrupted or degraded, US SSNs will need the ability to obtain targeting
information for targets on the surface or shore that are beyond the range of their onboard sensors. Submarine-launched UAS (SLUAS) such as the current Blackwing small SLUAS or future medium SLUAS could find and track targets using passive RF or EO/IR sensors and send data to the attacking SSN via a RF-to-acoustic gateway or towed buoy antenna. SLUAS could also provide submarine-launched weapons with target updates in transit. For example, a Mk-48 torpedo could take more than 30 minutes to travel 25 nm, during which time an enemy warship moving at 25 knots could change location by a dozen or more miles. SLUAS and other air or space-borne platforms could provide targeting updates to weapons using RF communications, but long-range torpedoes may need to periodically “porpoise” close enough to the surface for a small mast or wire to receive RF transmissions.76

**Mine Countermeasures (MCM)**

Perhaps the greatest threat to US submarines conducting offensive undersea operations is mines. The lightweight torpedoes and depth bombs an adversary like the PLA would be able to deploy from ships and aircraft are unlikely to severely damage or sink a US SSN, and the threat further decreases as acoustic decoys and jammers complicate enemy weapons placement. However, because the enemy can choose the time and location

---

**Figure 11: Maritime Strike and Surface Warfare Operations Using Encapsulated Weapons**

Source: Authors, Northrop Grumman Mission Systems.
for its aggression, it could emplace mines with large explosive charges exactly where US SSNs would need to go for effective offensive operations.

If the PRC plans to invade Taiwan, the PLA could mine the Taiwan Strait’s north and south entrances to slow or stop US SSNs seeking to conduct torpedo or missile attacks against PLA amphibious forces. Similarly, if the PRC planned to occupy some outlying Japanese, Philippine, or Taiwanese islands, the PLA could mine the surrounding waters to prevent US submarines from entering, while preserving a “Q-route,” or an area known to be clear of mines, for PRC ships to pass safely.

To ensure US naval forces can defend allies or defeat aggression, US SSNs will need the ability to circumvent or defeat PLA mines. As shown in figure 12, US SSNs could deploy MUUVs to conduct mine-hunting operations in advance of the submarine, coordinating with the submarine via fiber-optic cable or secure acoustic communications. The submarine could thereby create its own Q-route through the minefield. Because the planned Razorback MUUV would be recoverable, an SSN could reduce the impact on its payload capacity by carrying only one or two MUUVs for mine-hunting. Although this approach would be slow, it would provide submarines with an organic ability to identify mines and other undersea defenses when inorganic information was unavailable or out of date.

US submarines could deploy SLUAS above the minefield’s expected location to observe adversary minelaying or mine-servicing activity, which could help clarify the minefield’s location and status. This intelligence, surveillance, and reconnaissance (ISR) operation could also provide targeting to enable a submarine to stop a mining operation by attacking the minelaying ship with an encapsulated missile. In some situations, a Q-route may

Figure 12: Undersea Mine Countermeasure Operations

Source: Authors.
Note: ISR&T = Intelligence, Surveillance, Reconnaissance, and Targeting.
not be possible, and US undersea forces will need to destroy mines to clear a path for submarine operations. To minimize the impact on submarine weapons capacity, mine neutralization could be conducted by SUUVs deployed from the SSN's countermeasures launcher. Alternatively, a surface ship like a LPD could deploy larger UUVs from standoff range, which could loiter and await direction from the SSN via acoustic communications to destroy selected mines.

**Offensive Mining**

Although a priority for opposing navies, the US Navy has not emphasized offensive mining. This is understandable due to the difficulty of clearing unused mines after a conflict, a task that often falls to nations like the US and its NATO and western Pacific allies, who value free and open access to the maritime commons. However, new generations of mines can enable smaller fields to achieve outsized effects, thereby reducing the effort involved in clearing them after a confrontation. Moreover, new generations of mines can be remotely activated, deactivated, or scuttled to allow target selectivity, eliminate the danger of inadvertent damage or injury, and perhaps obviate the need to clear them following a crisis.

Because the Navy is likely to conduct offensive undersea operations in waters used by both allies and opponents, it would need to target mining operations more precisely compared to an aggressor like the PRC. For example, the PLA could slow the movement of US and allied naval forces to areas like the South China Sea or Taiwan Strait simply by placing large minefields at chokepoints such as the Luzon Strait. In contrast, US forces would need to deploy small numbers of mines at PLA port entrances to hinder PLA ships from leaving or channelize them into areas where they could be attacked more easily by US SSNs or aircraft. The need to place mines close to adversary territory will require that they be deployed clandestinely or rapidly to reduce risk to the deploying platform.

The current US mine portfolio reflects those priorities and comprises the submarine-launched mobile mine (SLMM) and the air-launched Quickstrike series. The SLMM, which entered service in 1983, is being replaced with the Mining Expendable Delivery Unmanned Submarine Asset (MEDUSA) MUUV that delivers new Clandestine Delivered Mines (CDMs). The MEDUSA enables multiple mines to be deployed by a vehicle that takes up only one torpedo stow, an improvement over the SLMM, which is a single, torpedo-sized mine.

The Mk-62, -63, and -65 Quickstrike mines are converted bombs that can be deployed by P-8A Poseidons, F/A-18E/F Super Hornets, and some Air Force bombers. Using a tail kit like that on a Joint Direct Attack Munition (JDAM) to hit the water at precise locations, Quickstrikes enable rapid deployment of a relatively large minefield and can be activated by a passing ship’s magnetic, acoustic, or pressure signature. The Navy is upgrading the Quickstrike series with wing kits that would enable mines to glide up to 40 nm from the deploying aircraft before hitting the water. The Navy is also developing the air-launched Hammerhead mine, which is an encapsulated torpedo that would sit on the ocean floor and be launched when a target is detected nearby.

Although they can precisely place mines close to enemy territory, US SSNs give up torpedo or missile capacity to do so. Thus,
US commanders could find themselves with too few weapons platforms to engage enemy ships that are trapped in “kill boxes” by minefields until the opponent can clear a path out. The Navy could reduce the impacts of mines on SSN weapon capacity by extending the MEDUSA concept to XLUUVs, which could carry and deploy CDMs or Hammerhead mines within the current level of UUV automation. As shown in figure 13, an XLUUV could be configured to carry several Hammerhead mines or a larger number of CDMs.

The Navy could build upon its current efforts to adapt uncrewed vehicles and mines to create mobile smart mines that combine small USVs (SUSV) with heavyweight torpedoes or explosives. Using available automated target recognition algorithms and EO/IR or ELINT sensors, these systems could be launched from shore or vessels and commanded to loiter or navigate into designated areas, where they could engage enemy ships when directed. Ukraine recently employed similar vehicles to attack Russian warships in Crimea. Like traditional mines, these smart mines could not only serve defensive purposes, but could also be sent deep into highly contested waters, including ones that might be prohibitively dangerous for SSNs.

A Need for Urgency
Sustaining the US Navy’s undersea advantage will require implementing new approaches like those described above for conducting offensive operations inside highly contested areas. As US air forces discovered during World War II and the Vietnam War, the introduction of even ineffective air defenses can substantially erode a military’s power projection capacity over the course of a conflict. Like their counterparts above the water, US undersea forces will need to rely on inorganic suppression and destruction of enemy defenses to deliver the strikes and anti-ship attacks needed by US war plans and sustain the deterrence afforded by US undersea superiority.
Implementing concepts like those described in chapter 2 will require the Navy to field a portfolio of uncrewed vehicles and use C3 capabilities to integrate them with crewed ships, submarines, and aircraft. The Navy has a long history of fielding uncrewed systems, as shown in figure 14, but its most successful efforts have resulted from evolutionary improvements to existing systems that support well-defined use cases. For example, the Navy’s mainstay Mk-18 family of UUVs evolved from Remus 100 and 600 vehicles developed by Hydroid for commercial applications. After more than a decade of refinements, the Mk-18 Mod 1 and Mod 2 are used by Navy underwater construction and explosive ordnance disposal (EOD) teams for everything from mine clearing to pier inspections.83

In addition to being evolutionary developments, nearly all the operational uncrewed systems shown in figure 14 perform a narrow set of functions and must be combined with other systems and human operators to complete a mission. For example, the Fleet-class USV grew out of the Common USV program and is designed to tow or carry equipment like the AQS-20 mine-hunting sonar or passive RF sensors on preplanned routes; sensor data are provided to operators or other systems for action. The US Marines’ MQ-8A Reaper similarly evolved from previous vehicles and, although highly automated when performing sensing functions, requires operator intervention to deploy weapons or conduct electronic attack.

The Navy has been less successful in developing uncrewed systems that attempt to perform multiple functions in contested environments—essentially replacing a crewed platform in conducting one or more missions.
Increasing a vehicle’s functionality and the intensity of the threat environment increase the number of decisions and actions a vehicle is required to accommodate, which decreases the length of time a vehicle can operate without external support. This relationship is shown in figure 15, with vehicle sophistication on the vertical axis and duration of independent operation on the horizontal axis.

For example, today’s USV technology can enable ISR missions such as ELINT or acoustic surveillance for months without significant external support by using wind, ocean currents, or solar power for energy and propulsion; passive RF detection to avoid other vessels; and satellite communications to offload data. In contrast, an SUUV decoy can operate for only a few hours before the SUUV will need updated guidance regarding what, where, and when to decoy to avoid inadvertently attracting attention to US submarine operations. And some applications, such as torpedoes conducting anti-ship attacks, require that an operator can verify ROE are met, which limits their duration of independent automated operation to less than an hour because the positions of enemy, friendly, and noncombatant ships are constantly changing.
Figure 15: Relationship between Vehicle Sophistication and Duration of Operation without Outside Support

Some combinations of complexity and duration will be unachievable with available uncrewed vehicle technology, as shown in the upper right-hand side of figure 15. Systems that need to operate in this range, including several of the Navy’s high-profile uncrewed vehicle programs, drive research and development efforts that will take years to culminate. For example, a medium USV (MUSV) conducting counter-ISR operations needs to assess the environment, jam or decoy sensors based on mission plans, maneuver to improve ISR and counter-ISR efforts, and avoid other ships. Moreover, to relieve crewed vessels in conducting this complex set of actions, the MUSV must be able to mitigate or negate the impact of electrical and mechanical failures, which would be likely during months-long deployments needed to reach and return from contested areas. The large number of decisions and actions drives MUSVs into what is currently an infeasible area for uncrewed system technology.
However, figure 15 also suggests an alternative approach for the Navy: it could field new uncrewed vehicles more quickly by adjusting the duration uncrewed systems need to operate without outside support or by reducing vehicles’ required complexity by integrating them into a system of systems. For example, while waiting for a Razorback MUUV-like to achieve capabilities for quiet torpedo tube launch and recovery and automated mine-hunting, the Navy could use other MUUVs launched by surface ships or USVs and a combination of acoustic and RF communications to send mine locations to submarines. Similarly, rather than operating for months independently, MUSVs could be deployed on missions of several weeks in less-contested areas, such as passive ASW monitoring of chokepoints, while smaller USVs with simpler propulsion systems could be used to penetrate deeper into adversary-controlled areas for ISR and counter-ISR.

By establishing specific use cases to govern vehicle designs, the Navy could better align its uncrewed vehicle requirements with available commercial or government technology, as the US Congress directed the Navy to do in its FY2023 appropriations. Use cases define in broad terms how long an individual system needs to operate on its own and how it and other systems combine to create the effect or outcome desired by the commander. In contrast, vehicles pursued by the Navy today—such as the XLUUV, TTL&R (torpedo tube launch and recovery) MUUV, MUSV, and LUSV (large uncrewed surface vehicle)—are being developed to support a wide range of potential applications, which increases the complexity and duration of independent operation needed in vehicles and the time and effort needed to develop them.

Reference use cases are sometimes used in technology development to ensure a new system can deliver a minimum viable product for its most important application. The Navy’s portfolio of uncrewed aircraft and surface vessels supports a wide variety of operations across air, surface, and undersea domains. Reference use cases can therefore be difficult to define. In contrast, UUVs are intended to primarily support undersea warfare, and the offensive undersea warfare concepts described in chapter 2 provide what are likely the most important use cases for UUVs.

The undersea force could accelerate the fielding of manned-unmanned teams by establishing reference use cases for each of the categories of UUVs under development and using those to set priorities for uncrewed system characteristics. Reference use cases would address priority problems faced by operational commanders today and rely on systems of systems and operator intervention where needed to align vehicle requirements with available technology.

**XLUUV**

The Navy is buying five Orca XLUUVs as prototypes, but the program has been plagued by challenges in manufacturing and testing. These difficulties are in part a result of transitioning a hand-built demonstration vehicle from Boeing into a production-scale system constructed by a shipbuilder, HII. Challenges for XLUUV development also result from overly ambitious autonomy requirements that demand the XLUUV be able to operate for weeks at a time, including snorkeling to recharge batteries using an onboard diesel generator.

The Navy could ease the requirements for XLUUV by establishing a reference use case in which payloads like mines or SUUVs are deployed during direct out-and-back missions. This reference mission would support the operational concepts for suppressing or defeating undersea defenses and mining of chapter 2 without the need for extended deployment or snorkeling. Going forward, the Navy should continue to increase the duration of XLUUV operations, including concepts that posture XLUUVs on the seafloor from where they can deploy SUUVs on demand to support suppression of undersea sensors.

**LDUUV**

When launched from a dry-deck shelter on the back of an SSN or SSGN, the Snakehead LDUUV was intended to extend a submarine’s surveillance reach and persistence. But this de-
ployment scheme ties up shelters that are in high demand by special forces, and it largely prevents the host submarine from conducting other operations. An alternative approach of deployment from Virginia-class submarine payload modules was considered but abandoned due to the cost, complexity, and acoustic vulnerability associated with the operation. As a result of these concerns and developmental delays, the Snakehead program was defunded by the Navy and Congress in 2022.

For IPOE, the Navy still requires a vehicle with multiday endurance and the volume to encase mission systems in pressure vessels able to withstand depths of more than 3,000 meters. Although MUUVs like the Razorback could conduct these operations, they lack the range to reach survey areas from locations where they could be launched from shore or amphibious ships. If deployed by submarines for IPOE, MUUVs would take up torpedo stows and tie up SSNs that have other peacetime demands.

To support the IPOE reference use case, the Navy should therefore pursue a UUV that has the LDUUV's general characteristics and that could be deployed from vessels such as amphibious ships or by Marine Stand-In Forces ashore at EABs. Instead of starting a new LDUUV development program, the Navy should use a competitive prototyping approach under the Middle Tier of Acquisition (MTA) path to evaluate existing vehicles, including the REMUS 6000, those developed by Penn State University Applied Research Laboratory (ARL) and used today by UUV Squadron (UUVRON) One, and the Anduril Ghost Shark extra-large autonomous undersea vehicle (XLAUV) being developed for the Royal Australian Navy. To achieve the endurance needed for IPOE, these existing vehicles could incorporate high-capacity lithium-ion batteries, such as the fault tolerant (LiFT) battery already developed by General Atomics for the Snakehead program.

MUUV

MUUVs are the Navy’s most mature category of uncrewed vehicle. Today this category is dominated by the 12.75” diameter Mk-18 Mod 2 Kingfish MUUVs used by the EOD community for surface-launched mine-hunting and bottom mapping. Mk-18s are now being complemented in the mine-hunting mission by the new Knifefish MUUV that is part of the Littoral Combat Ship (LCS) MCM mission package. They will be joined by the Navy’s 12.75” diameter Razorback MUUV, which is intended to support a variety of missions and be capable of deployment from a submarine torpedo tube or from surface ships and shore using rigging equipment like that used for the Mk-18 Mod 2.

The concepts discussed in chapter 2 highlight ways that MUUVs could be used to help submarines avoid mines, perform short-range IPOE in shallow water, and attack or suppress undersea sensors. Of these, the most critical use case—and the one only MUUV can do—is hunting for mines and other threats from the submarine. Employing the recoverable Razorback MUUV to clear Q-routes for submarines would make the trade for a torpedo stow worthwhile, and the characteristics needed for this mission would make the MUUV valuable in other applications such as counter-ISR.

The Navy recently awarded the Razorback MUUV development and procurement contract, but it should ensure the program does not repeat the approach used for XLUUV and LDUUV. When those programs started, few military or commercial vehicles existed to serve as a starting point. But today both programs can exploit available technology as directed by the US Congress. The MUUV program has an even greater range of commercial analogues it could leverage, including the Iver-4 class vehicles produced by Leidos and the Remus 600 series from HII.

SUUV

Perhaps the greatest improvements in Navy undersea superiority will come from SUUVs. Today this category comprises the Littoral Battlespace Sensors used by Navy oceanographers and the 8” diameter Mk-18 Mod 1 Swordfish used for mine-hunting, surveys, and ISR. The next generation of SUUVs, such as the
Lionfish SUUVs are intended to support a greater variety of functions using modular components that allow the vehicle to carry different payloads depending on the function needed.95

Based on the Remus 300, the Lionfish will be small enough to deploy from a wide array of platforms. Its 150-pound weight will allow it to be man-portable for launch from small boats, or carried in large numbers from UAS like the MQ-9 or crewed aircraft like the P-8A.96 With an expected diameter of about 7.5”, the Lionfish could be adapted to deploy from submarines using a 6” diameter external countermeasures launchers or the 10” diameter trash disposal unit without impacting torpedo room capacity. Alternatively, SUUVs could be launched from a torpedo-tube insert and stored elsewhere on the submarine, given their comparatively light weight.

SUUVs like Lionfish will have sufficient onboard power to conduct acoustic jamming or acoustic and visual decoy operations that could protect submarine missions for more than a day. If they carry payloads like those used on the Navy’s ADC series of torpedo countermeasures, SUUVs could also confuse multiple enemy torpedoes during a sustained attack.97 Although SUUVs could support other operations described in chapter 2, such as IPOE, mine-hunting, or surface attack, they will lack the size, speed, and power needed to support these operations as well as larger UUVs. Therefore, counter-ISR should be the reference mission of the Lionfish and other SUUVs, though their potential to expand into other missions as technologies mature should be recognized.

Mobile Mines

As highlighted in chapter 2, mines could play a critical role in a reference use case of constraining the movement of adversary surface forces from their ports or toward potential landing areas. Depending on the state of a conflict, mines can be emplaced by a variety of air, surface, and subsurface platforms, and mobile smart mines can be launched from shore, vessels, or aircraft. Aircraft enable the fastest establishment of large mine-fields using systems such as the extended range of powered Quickstrike, but with the disadvantage of alerting the opponent as to the location and existence of mines. Undersea-delivered mines such as CDM and Hammerhead could be clandestinely deployed by XLUUVs to prevent an impact on submarine weapons capacity. Although the Navy should field undersea-delivered mines, at scale, XLUUVs will be challenged to deliver them in the locations and timing needed by operational commanders.

The most promising approach for the Navy to support the reference use case is accelerating development of a new generation of mobile, smart mines. These systems would combine small or medium USVs with torpedoes or explosives to create systems that could be launched from shore, vessels, or mobility aircraft and commanded to loiter or navigate into designated areas. Based on direction from a human operator, the vehicles would use automated target recognition algorithms to search for suitable military targets, the mines would explode or sprint to engage them.98 Like traditional mines, these systems could not only serve defensive purposes, but could also be sent deep into highly contested waters, including ones that may be prohibitively dangerous for SSNs and impractical for XLUUVs.

Expeditionary Warfare and Support Ships

As described in chapter 2, LDUUVs and XLUUVs will need to be launched from platforms or shore facilities relatively close to their operating areas to preserve energy for their missions and allow fielding of operationally useful systems with today’s level of vehicle automation and reliability. Marines at EABs could host XLUUVs and LDUUVs, deploying them into the South or East China Seas from shore. For more remote locations, LPDs could deploy XLUUVs or LDUUVs directly from the well deck. In addition to deployment, LPDs could also provide forward-deployed facilities to repair, maintain, and swap modular UUV payloads such as sensors, mines, or acoustic jamming and decoy systems.

Amphibious assault continues to drop as a priority for the Navy and Marine Corps, although the demand for and utilization of
expeditionary warfare ships remains high due to their versatility in crisis response and disaster relief.\textsuperscript{99} The Navy is planning to stop LPD-17 Flight II production at four ships, which will join the 13 LPD-17 Flight I ships already built or under construction.\textsuperscript{100} To ensure capacity to support UUV operations in areas where threats preclude using civilian vessels and distances make shore deployment impractical, the Navy should continue building LPDs every other year, which will eventually result in a steady state inventory of about 20 LPDs.

US Military Sealift Command ships crewed by civilian mariners will continue playing important roles in launching, recovering, and maintaining unmanned and remotely operated vehicles in permissive environments. Today, oceanographic survey ships (T-AGS) and oceanographic survey ships (T-AGOR) carry and deploy UUVs as part of their missions, and could similarly deploy new SUUVs, MUUVs, or LDUVs for operations such as IPOE and counter-ISR outside of conflict.\textsuperscript{101} The Navy’s Navajo-class tug and salvage ships (T-ATS) and proposed Next Generation Logistics Ships may also be capable of deploying and recovering as well as refueling, rearming, and resupplying unmanned vehicles.\textsuperscript{102} Depending on their crane and other configuration details, they may also be capable of deploying or recovering LDUVs or XLUUVs.

**Submarines**

The Navy is already building Block V Virginia-class submarines, with plans for Blocks VI and VII before embarking on a new (next-generation) attack submarine, SSN(X).\textsuperscript{103} Within this study’s time frame (through 2030), the Navy will be building Block VII Virginia-class SSNs in a multiyear contract likely extending to 2032. The Navy has made significant efforts to extend the lives of older Los Angeles-class SSNs and maximize production and improve the readiness of Virginia-class submarines, so this study will not weigh in on additional actions that could be taken to grow the size or availability of the US submarine force.\textsuperscript{104}

There are, however, options available to significantly improve the ability of current and programmed SSNs to fight into and within bastions. One priority should be to incorporate new capabilities into SSNs that allow them to detect or receive information on threats such as mines, vessels, and aircraft earlier. Some of these sensors, decision-support tools, and systems to enable communications at greater speed and depth should be integrated into SSNs, while others, such as SLUAS and MUUVs, could be launched from SSNs.\textsuperscript{105}

A second priority should be improved defenses. US submarine designers traditionally chose to devote payload space to sonar systems and acoustic quieting features rather than active defenses like anti-torpedo torpedoes because commanders could count on detecting and shooting enemies first. Acoustic countermeasures like the ADC series would allow a submarine to evade torpedo attacks under the assumption adversary weapons placement would be imperfect and the submarine could promptly regain its stealth to avoid subsequent attacks. In contrast, navies whose submarines had inferior acoustic performance to US submarines were forced to adopt suites of active countermeasures to help them even the odds.\textsuperscript{106}

The importance of submarines to US war plans and improving undersea defenses of the PRC and Russia require that US submarines be able to sustain operations in high-threat areas even after their initial missile or torpedo launches reveal their locations. Moreover, as Russian SSN acoustic performance approaches parity with new US Virginia-class SSNs and Russia shares technology with the PRC, US submarines will increasingly find themselves in “knife fights” where each submarine detects the other at about the same time.\textsuperscript{107} To survive and win these confrontations, US SSNs will need new and improved defenses such as small torpedoes like the Compact Rapid Attack Weapon (CRAW) that can intercept enemy torpedoes as well as missiles that can engage enemy helicopters and maritime patrol aircraft.\textsuperscript{108}

As a third priority, SSNs should field weapons that improve submarine offensive capacity or survivability. Employing organ-
ic or inorganic targeting information, longer-range torpedoes could help SSNs engage vessels outside the detection range of enemy targets or outside the densest undersea defenses. Alternatively, using encapsulated torpedoes and missiles would allow SSNs to displace the weapon launch or the engagement from the submarine in space and time, reducing their risk of counterattack. Smaller weapons are also needed. To avoid wasting an Mk-48 heavyweight torpedo on smaller targets, multiple CRAWs could be carried in a single heavyweight torpedo stow. Similarly, SUUVs could be used to neutralize enemy sensors or mines instead of relying on an MUUV for these operations.

The fourth priority is designing future submarines for a more contested undersea environment. The US Navy plans on shifting from procuring Virginia-class SSNs to an SSN replacement, termed SSN(X), in the mid-2030s. Service leaders intend for SSN(X) to “require less maintenance, be fast, quiet, and packed with torpedoes”—thus combining the best features from the Seawolf, Virginia, and Columbia classes. The operational concepts described in chapter 2 suggest SSN(X) should emphasize capacity for horizontal payloads such as torpedoes, TTL-capable encapsulated weapons, and UUVs. Although the Navy should attempt to reduce the impact of UUVs on weapons capacity, SSN(X) could carry a substantial counter-ISR capacity by incorporating additional stowage space and deployment apertures for smaller vehicles such as SUUVs and SLUAS larger than the current Blackwing. Continued microelectronics and energy storage improvements in SUUVs mean that in addition to supporting jamming and decoy operations, they will likely be able to conduct missions previously reserved for MUUVs such as bottom survey, IPOE, mine-hunting, and destruction of adversary undersea infrastructure.

The most substantial change in ASW that SSN(X) will face is the emergence of active sonar as the dominant sensing phenomenology. US SSN designs have thus far focused on reducing radiated noise. As noted above, UUV-based decoys and jammers will increasingly be needed to confuse or deceive active sonars attempting to find and submarine or detect its wake, requiring submarine commanders to focus on making more noise, rather than less. To complement offboard counter-ISR systems, SSN(X)’s design should incorporate features that reduce its echo return strength and wake by, for example, shrinking the sail or shaping the hull.

The Congressional Budget Office estimates SSN(X) will likely cost around $6.2 billion (in FY2022 dollars) each, which is nearly twice as much as a $3.3 billion Virginia-class Block V SSN (that has the Virginia Payload Module) and three-quarters as much as the Columbia-class SSBN. SSNs are currently procured at a rate of two per year. If SSN(X) costs twice as much (or is much larger and in turn requires much more work to construct), it may be difficult to sustain that procurement rate—much less ramp up to a higher rate of three to four SSN(X) per year once Columbia-class construction ebbs.

Consequently, the Navy should critically evaluate the desired attributes for SSN(X) and consider appropriate changes that can reduce costs. One attribute of the vessel that has not received significant attention is personnel. As a result of differences in the use of automation, damage control practices, and deployment length, US SSNs require considerably larger crews than comparable submarines of foreign design. Investments in automation and changes in procedures could reduce the complement required on SSN(X), saving space, reducing operating costs, and making it easier to crew the submarine amidst future demographic challenges.

**Implementation**

As threats posed by adversaries above the water become more acute, Pentagon leaders have touted US undersea forces as an enduring asymmetric advantage. The 2022 US National Defense Strategy highlighted the priority of undersea systems, and Secretary of Defense Lloyd Austin noted the “major investments” being made in undersea warfare to strengthen US de-
The tri-service strategy “Advantage at Sea,” published by the US Coast Guard, Marine Corps, and Navy, asserts that the United States will maintain its undersea advantage through investing not only in submarines, but also in maritime patrol and reconnaissance aircraft, IUSS infrastructure, mine warfare capabilities, and UUVs. However, the Department of the Navy’s budget requests into undersea warfare capabilities since the 2018 National Defense Strategy do not follow through on its strategy. Shipbuilding and Conversion spending more than doubled as the Navy continued to procure two SSNs per year and started Columbia-class procurement. However, improvements in other areas has been mixed. As shown in figure 16, RDT&E funding has quadrupled, but the growth in Other Procurement funding for undersea surveillance systems such as the Fixed Surveillance System and Surveillance Towed Array Sensor Systems (SURTASS) has been more modest. Furthermore, although DoD has highlighted the importance of spending more on munitions to fill major inventory shortfalls, budgets for weapons have remained low. These trends started to change with the Navy’s FY2024 budget request, which included a major increase in funding for sensor procurement as well as torpe

Figure 16: US Navy Undersea Warfare Budget Requests (Exclusive of Shipbuilding and Conversion [SCN] and SSBN RDT&E)

![Graph showing US Navy Undersea Warfare Budget Requests (Exclusive of Shipbuilding and Conversion [SCN] and SSBN RDT&E)](image)

Source: Authors using US Department of the Navy budget requests.

Figure 17: Navy UUV Procurement since FY2015 (Estimated)

![Graph showing Navy UUV Procurement since FY2015 (Estimated)](image)

Source: Authors, based on industry surveys.

Note: LBS AUV = littoral battlespace sensing autonomous undersea vehicle.
does and mines. The decline in OPN funding and the relative stasis in Weapons Procurement, Navy (WPN) can be partially explained by the Department of the Navy’s focus on developing new classes of UUVs, mines, and other undersea warfare systems. However, as noted above, this dynamic reflects the flawed approach of developing vehicles to replace crewed platforms rather than establishing use cases that allow buying existing vehicles.

The lack of procurement for new vehicles significantly impacts the UUV industry. Submarine builders and suppliers received billions of dollars in additional investment during the last decade to improve infrastructure, expand capacity, and grow the workforce in anticipation of demands for Virginia Block V SSNs and Columbia SSBNs. Over the same period, expecting that the Navy would follow through on its strategy and vision to substantially grow the uncrewed portion of the fleet, the UUV industrial base developed its own capacity and infrastructure using internal investment.

Decreased funding for UUVs during the last few years resulted in a procurement trough, which has shut down production lines and idled the UUV workforce and supply chain. Despite the stated priority of expanding the uncrewed vehicle fleet, decisions during 2022 only widened the trough. For example, in addition to the cancellation of the LDUUV program, the SUUV full-rate production contract was delayed into FY2023, and the MUUV program shifted from its original intent of a two-vendor award into a single-vendor award.

For a still-nascent industry, the boom and bust cycle shown in figure 17 can be devastating. With the current employment environment, technically competent workers who are qualified to work on UUV programs are unlikely to wait for production to resume and will instead take other opportunities, leaving the UUV industry unable to ramp up when the Navy decides it is ready to expand production. Given the urgent need to start fielding systems that can help overcome operational challenges, the Navy should establish reference use cases that align with available technologies and expeditiously acquire them.
4. CONCLUSION AND RECOMMENDATIONS

Long considered the US military’s asymmetric advantage, US attack submarines face an increasingly contested environment undersea. China and Russia are deploying passive acoustic arrays on the seafloor across the South and East China Seas and the Barents Sea, and could deploy dense minefields. US submarines are the world’s quietest, but if they deploy vehicles or shoot weapons in these waters, they could quickly be detected and attacked by missiles and aircraft-deployed torpedoes. Regardless of whether the attacks are ultimately successful, they would force US submarines to immediately break off operations and evade. And even if they remain quiet, US submarines will face growing fleets of Russian or PRC frigates and corvettes equipped with LFA sonars.

Retaining America’s undersea edge will require US submariners to employ techniques developed by aviators to overcome air defense systems. Bombers and fighters depend on EW aircraft to suppress air defenses by jamming radars and radios or destroying enemy systems with anti-radiation missiles. Similarly, submarines making their way into adversary bastions will need jammers or decoys to suppress enemy undersea sensors, as well as weapons able to destroy adversary undersea infrastructure or mines. In many cases, this will require US undersea forces to make more noise, not less.

The Navy cannot simply build more or more capable SSNs to escape this dilemma. The submarine industrial base is at maximum capacity and a few more hulls will not make a substantial difference against the PLA’s growing ASW capacity, which needs only to harass US SSNs to succeed. To sustain its undersea ad-

Photo: Aerographer’s Mate 3rd Class Alexander Wallace secures a six-ton crane to a Mk-18 Mod 2 UUV in the well deck of the Royal Fleet Auxiliary ship (RFA) Cardigan Bay in the Red Sea on July 29, 2015. (US Navy photo by Mass Communication Specialist 2nd Class John Paul Kotara II)
vantage, the US Navy will need to field a relevant set of UUVs that enable submarines to survive and be effective, while undermining the confidence of China’s leaders in their undersea “Great Wall.”

The Navy should take the following actions, as detailed in this report:

- For each class of UUV, establish reference use cases that align programs with available technology by creating systems of systems combining uncrewed vehicles with crewed platforms and C3 capabilities.
- Accelerate production of SUUVs, which offer the fastest improvement in US undersea superiority by providing capabilities for counter-ISR that are lacking in today’s undersea force.
- Develop a wider variety of UUV deployment mechanisms. The Navy has a long experience with smaller UUVs like the littoral battlespace sensing or Mk-18 vehicles, but even they are often hand-deployed into the water by operators. Amphibious ships like the LPD, and aircraft such as Marine MQ-9A UAS or Navy P-8A MPA, should also be able to deliver UUVs.
- Make SSNs more effective by incorporating new capabilities that improve their ability to sense the environment, enhance their defenses, and field improved offensive weapons.
- Field USVs and UUVs that support SSN operations by sensing, jamming, and attacking targets—especially vehicles that can be deployed independently of submarines.
- Deliver undersea systems that free up SSNs for offensive operations. Current and programmed mines, as well as mobile, fixed, and deployable sensors such as TRAPS and MQ-9B UAS, can improve offensive undersea warfare and ASW capacity at a reasonable cost while making more SSNs available for offensive missions.
- Develop a highly capable SSN(X) and manage its costs. With appropriate design choices and robust RDT&E, SSN(X) could provide a major improvement over the Virginia-class SSN and be affordable enough to procure and operate that more than two per year could be acquired after Columbia-class SSBN procurement. However, absent some difficult trade-offs, SSN(X) risks being ill-suited for fighting inside bastions and too expensive to acquire and operate at the numbers needed in the fleet.

Submarines are the US military’s crown jewel and are relied upon to deliver decisive effects in campaigns against adversaries like China and Russia. However, absent prompt improvements, US SSNs could be denied or simply rendered ineffective in waters where future confrontations are likely to occur. To sustain its undersea advantage, the Navy should adopt proven approaches from aviation for suppressing, defeating, and circumventing adversary defenses. Unless the US undersea force embraces these new concepts and capabilities, it risks becoming marginalized when it is needed most.
FIGHTING INTO THE BASTIONS: GETTING NOISIER TO SUSTAIN THE US UNDERSEA ADVANTAGE

ENDNOTES


5 For more information on this concept, please see Bryan Clark, Seth Cropsey, and Timothy A. Walton, Sustaining the Undersea Advantage: Disrupting Anti-Submarine Warfare Using Autonomous Systems (Washington, DC: Hudson Institute, 2020).


40 Joseph Trevithick, “China Reveals It Has Two Underwater Listening Devices within Range of Guam,” The Drive, June 30, 2019,
https://www.thedrive.com/the-war-zone/17903/china-reveals-it-has-two-underwater-listening-devices-within-range-of-guam.


45 Active sonar generally suffers from shorter detection ranges than passive sonar. This is because active sonar signals suffer propagation losses and spreading going to and from the target, whereas signals for passive sonar suffer those losses only one way.


Navy leaders have stated on numerous occasions that automated and uncrewed vehicles would still need humans to ensure appropriate conditions are met before the use of force is authorized; see John Konrad, “US Navy Admiral Says AI Wars ‘Must Obey,’” gcaptain, April 6, 2023, https://gcaptain.com/us-navy-admiral-says-ai-wars-must-obey/.


The Navy canceled the Snakehead LDUUV in FY2023, but a future vehicle in this class could conduct the IPOE mission. MUUV-class vehicles like the Remus 620 could also conduct IPOE, albeit with less endurance than an LDUUV; see Lee Willett, “REMUS 620: HII’s New Medium-Class UUV,” Naval News, November 9, 2022, https://www.navalnews.com/naval-news/2022/11/remus-620-hiis-new-medium-class-uuv/.


Given payload constraints, MQ-9B would focus on the delivery of SUUVs.


For more details on this approach, see ibid.


Ohio-class SSGNs also carry multiple all-up-round canisters but are not a focus of this study, as they are retiring between 2027 and 2030; see Office of the Chief of Naval Operations, Deputy Chief of Naval Operations for Warfighting Requirements and Capabilities—OPNAV N9, Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2023 (Washington, DC: Department of the Navy, 2022), https://media.defense.gov/2022/Apr/20/2002980535/-1/-1/0/PB23%20ShipBUILDING%20PLAN%202018%20APR%202022%20FINAL.PDF.


113 For example, a Virginia-class SSN requires a minimum of 134 personnel, while the United Kingdom Astute-class submarine has a complement of 98 personnel, the Russian Yasen-M has a complement of 64 personnel, and the French Barracuda-class SSN has a complement of 60 personnel.

