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# THE EMERGING ERA IN UNDERSEA WARFARE

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# The Emerging Era in Undersea Warfare

## Introduction

U.S. defense strategy depends in large part on America's advantage in undersea warfare. Quiet submarines are one of the U.S. military's most viable means of gathering intelligence and projecting power in the face of mounting anti-access/area-denial (A2/AD) threats being fielded by a growing number of countries. As a result, undersea warfare is an important, if not essential, element of current and future U.S. operational plans. America's rivals worry in particular about the access submarines provide for U.S. power-projection operations, which can help offset an enemy's numerical or geographic advantages.[1]

Broadly speaking, undersea warfare is the employment of submarines and other undersea systems in military operations within and from the underwater domain. These missions may be both offensive and defensive and include surveillance, insertion of Special Forces, and destroying or neutralizing enemy military forces and undersea infrastructure.

America's superiority in undersea warfare is the product of decades of research and development (R&D), a sophisticated defense industrial base, operational experience, and high-fidelity training. This superiority, however, is far from assured. U.S. submarines are the world's quietest, but new detection techniques are emerging that do not rely on the noise a submarine makes, and that may render traditional manned submarine operations far riskier in the future. America's competitors are likely pursuing these technologies while also expanding their own undersea forces. To sustain its undersea advantage well into this century, the U.S. Navy must accelerate innovation in undersea warfare by reconsidering the role of manned submarines and exploiting emerging technologies to field a new "family of undersea systems."

1 Owen R. Cote, Jr., *Assessing the Undersea Balance Between the U.S. and China*, Strategic Studies Program Working Paper (Boston: Massachusetts Institute of Technology, February 2011); David Axe, "China Thinks It Can Defeat America In Battle," *Real Clear Defense*, September 24, 2014, available at http://www.realcleardefense.com/articles/2014/09/24/china_thinks_it_can_defeat_america_in_battle_107461.html.

Over the next year, the Center for Strategic and Budgetary Assessments (CSBA) will explore trends in undersea warfare technology and operations as part of a new research initiative. The goal of this effort is to identify new approaches that exploit the undersea domain in order to maintain U.S. military advantage while preserving the ability to deny use of the undersea to adversaries. This initial report describes how undersea competitions evolved over the last century, the disruptive trends that may lead to a new era in undersea warfare, and the elements that will comprise an effective approach to the next chapter in undersea competition.

## Evolution of the Undersea Competition

To understand how undersea warfare may change in the future, it is useful to review how it evolved over the past century. While mining and mineclearing have existed almost as long as ships, undersea warfare first emerged as a significant area of offensive and defensive military operations in World War I (WWI). Several countries in that conflict began to use submarines on a large scale to attack civilian shipping and, occasionally, enemy warships. This created the need for antisubmarine warfare (ASW) and began a "hider-finder" competition between submarines and ASW forces. In the century following the war, this competition evolved through several distinct phases, each characterized by the predominant ASW detection method.

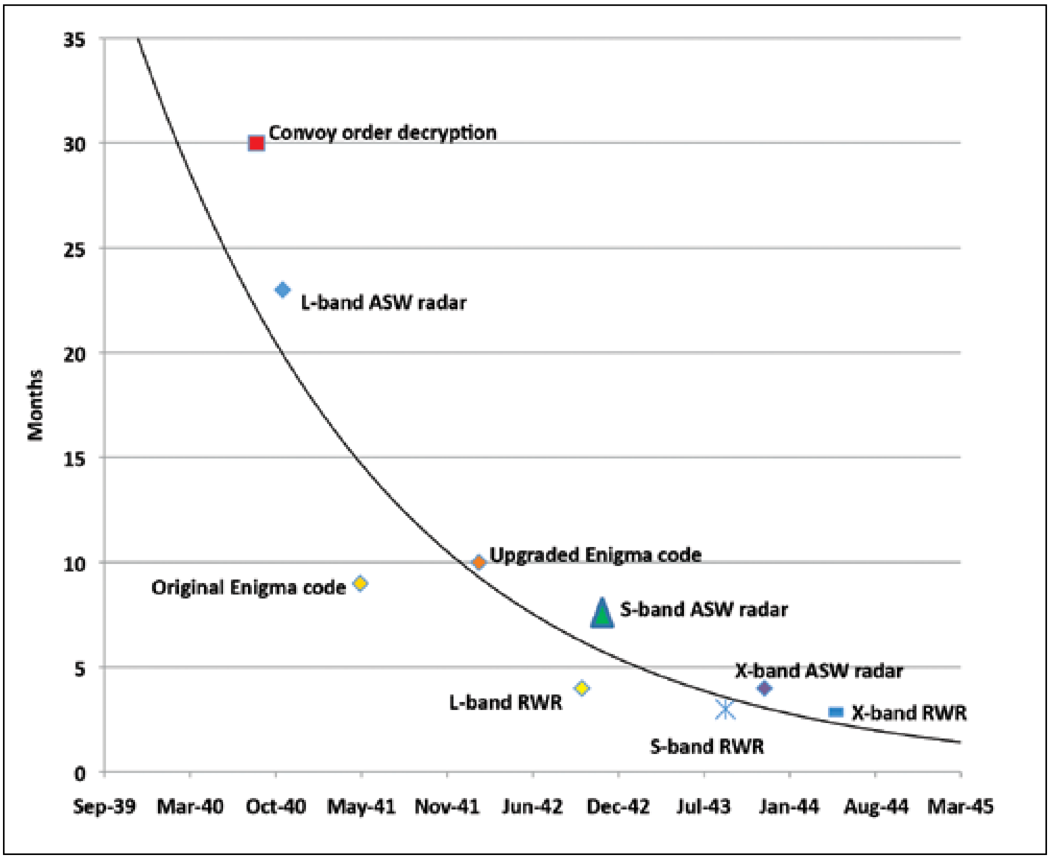
In WWI and World War II (WWII), the hider-finder competition between submarines and ASW forces largely played out above the water, through radio and radar transmissions in the electromagnetic (EM) spectrum. Submarines were relatively slow and limited to short-range visual detection of targets.[2] They needed to be "cued" or directed toward convoys by radio communications from shore or other submarines. These communications could be intercepted by ASW forces, which decrypted submarine orders and reports or geo-located transmitting submarines using high-frequency direction finding (HFDF) equipment. Further, submarines in both wars were vulnerable to visual and (in WWII) radar detection because they were more like submersible ships than true submarines. They could only operate submerged for 1–2 days and spent most of their time on the surface in order to use their diesel engines for faster propulsion, to refresh their atmosphere, and to recharge their batteries.

The WWII hider-finder competition led to a cycle of moves and countermoves; as ASW forces developed new ways to detect submarines, submarines attempted to counter by employing new methods to evade detection. For example, submarine forces deployed radar-warning receivers (RWR) once they realized radar was being employed successfully against them. ASW forces responded by fielding higher-frequency radars that were more effective and not detectable with the existing RWRs. Once submarine forces realized they were being tracked by new radar frequencies, they developed a new RWR to compensate. Similarly, when one side determined its

2 A surfaced World War II submarine had a "height of eye" of about 20 feet or less. Height of eye is the height of a sensor (including a person) above the ocean's surface. The higher the sensor, the farther away the sensor can see because its horizon is farther away. Mathematically, the distance a sensor can see is determined by the formula: *Range (nm)* = 1.14 x $\sqrt{\textit{Height of eye (ft)}}$

communication codes were likely broken, new codes would be introduced to restore the ability to securely coordinate operations. In turn, these new codes would eventually be broken. These cycles repeated with increasing speed until the war ended, as reflected in Figure 1.

## FIGURE 1: LIFETIME OF ADVANCEMENTS IN THE WWII ASW COMPETITION

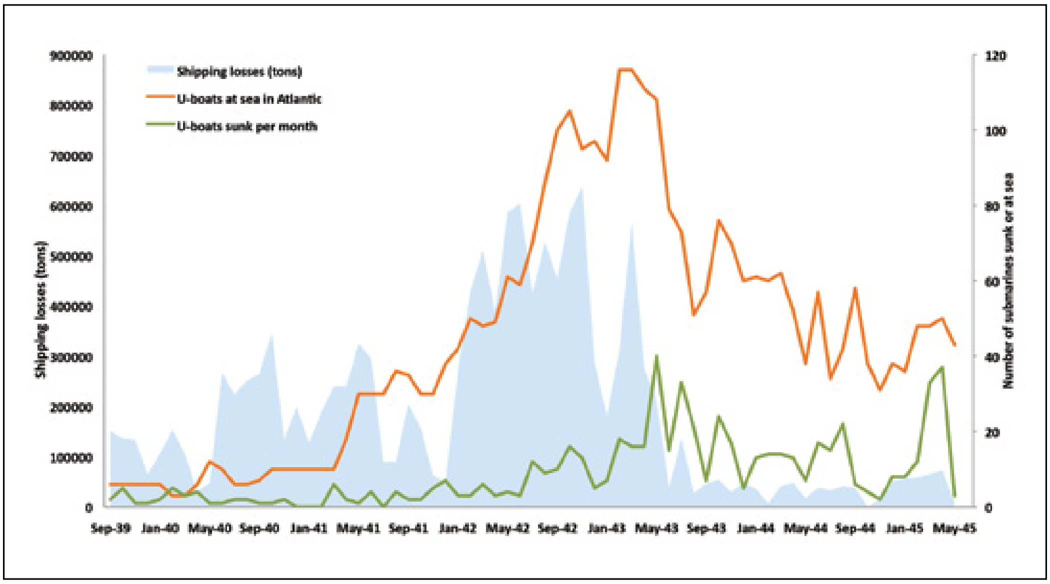



Although ASW forces in both World Wars periodically gained an advantage in the EM spectrum-based hider-finder competition, they were unable to sink a significant number of enemy submarines until late in each conflict. Shipping losses to submarine attack, however, decreased shortly after dedicated ASW efforts began, as illustrated in Figure 2.[3] This suggests that, instead of eliminating submarines, ASW efforts reduced submarine effectiveness by slowing their deployment to patrol areas, preventing them from getting into firing position, and disrupting their coordination of attacks. This ASW approach exploited the inherent disadvantages of submarines in that they are relatively slow, lack self-defense systems, and cannot rapidly assess the effectiveness of

3 This competition is described in detail in John Stillion and Bryan Clark, *Winning Battle Network Competitions in the 21st Century* (Washington, DC: Center for Strategic and Budgetary Assessments, 2015).

an incoming weapon. As a result, even unsuccessful ASW attacks often compelled a submarine to evade and lose the initiative or made it more detectable for ASW re-attacks.

### FIGURE 2: SHIPPING AND SUBMARINE LOSSES IN THE BATTLE OF THE ATLANTIC




The first major disruption in the hider-finder competition came with the introduction of snorkels, improved RWRs, and "burst" communications in the latter part of WWII.[4] This combination of capabilities enabled submarines such as the German Type XXI to remain submerged and minimize their vulnerability to radar detection when snorkeling, effectively ending the EM-based submarine-ASW competition. Submarine forces, however, were unable to deploy these advancements in relevant numbers before the end of the war.

4 The submarine snorkel, similar to those used by swimmers looking at coral reefs, enables a submarine to intake air from above the water while the submarine remains submerged (apart from the top of the snorkel). This enables the submarine to run its diesel engine, which provides greater propulsion power and speed than the battery, and exchange the air in the submarine with fresh air. When radars were used to detect snorkels, RWRs enabled submarines to lower the snorkel and avoid detection. "Burst" communications enabled them to reduce the length of transmissions and their susceptibility to interception. New RWRs were permanently mounted on submarine masts and could be operated while the submarine was at periscope depth. Previously, RWR antennae were temporarily mounted on the submarine's bridge while it was surfaced. They had to be broken down and brought inside before the submarine could submerge. RWRs were also limited in their frequency range. At the end of the war, new RWRs such as the *Tunis* covered the highest frequency ranges that were useful for submarine search and detection ("X-band").

## FIGURES 3 AND 4: GERMAN TYPE XXI SUBMARINE AND THE USS *NAUTILUS*

Navies pursued several efforts after World War II to use sonar for ASW.[5] But submarines proved too quiet to hear with passive sonar when travelling on battery power and disappeared in surface noise or sounded like diesel-powered surface ships when snorkeling. Active sonar was somewhat effective against submarines when they were operating at shallow depths, such as when snorkeling, but the detection range was short due to propagation losses incurred as the sound travelled both to and from the submarine.

This changed with the introduction of the nuclear submarine early in the Cold War. Nuclear submarines did not need to surface or snorkel, making them nearly impossible to find with radar and active sonar. However, during early exercises with nuclear submarines such as USS Nautilus, the U.S. Navy realized the new boats had an unexpected vulnerability—they generated continuous noise from their nuclear and steam plant machinery. This sound could be detected at long range with passive sonars the Navy developed to find diesel submarines. As the Soviets shifted to using mostly nuclear submarines for operations outside their home waters, the U.S. Navy adopted passive sonar as its primary ASW sensor. This began a new hider-finder competition between submarines and ASW forces based on passive sonar.

The U.S. Navy exploited its “first mover” advantage in passive sonar by starting a methodical sound-silencing program for its nuclear submarines and establishing the passive Sound Surveillance System (SOSUS) network off the U.S. coast as well as at key chokepoints between the Soviet Union and the open ocean. These efforts enabled an operating concept from the early 1960s to the late 1970s in which SOSUS, patrol aircraft, and submarines would trail—and be prepared to attack—Soviet nuclear submarines throughout their deployments.

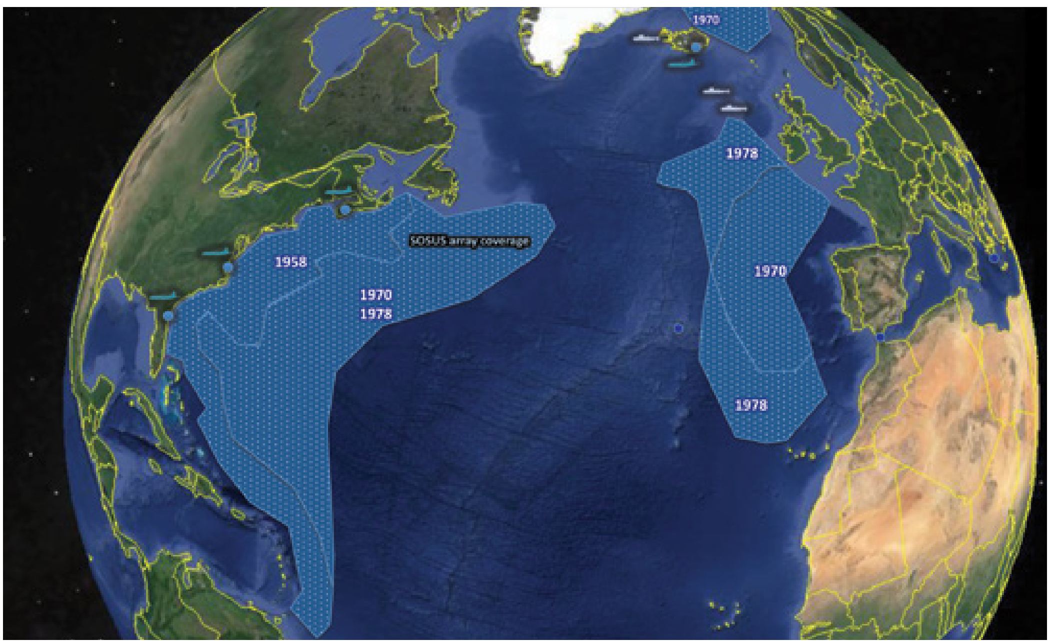
This ASW concept depended on a temporary U.S. submarine silencing advantage that began to erode in the mid-1970s after Soviet leaders learned of their submarines’ acoustic vulnerability

5 “Passive” sonar involves listening for noise emanating from the submarine; “active” sonar bounces sound off submarines to locate them (also known as echo-location).

from the John Walker-led spy ring and subsequently obtained technology for submarine quieting.[6] The resulting silencing program produced Soviet submarines such as the *Akula* and *Sierra* classes that approached the sound levels of contemporary U.S. boats.[7] Consequently, U.S. ASW forces would not be able to continuously track Soviet submarines, and the operating concept of destroying them at the outset of conflict was no longer executable.

In response, the U.S. Navy adopted a new approach in the 1980s that applied lessons from WWI and WWII. Rather than planning to sink Soviet submarines, U.S. ASW efforts would focus on degrading their operational effectiveness.[8] U.S. nuclear-powered attack submarines (SSNs) deployed to waters near Russia (also known as "bastions") to seek out Soviet ballistic missile submarines (SSBNs). This operating pattern compelled the Soviets to keep their best SSNs in the bastions to protect their SSBNs, rather than deploying them out into the Atlantic and Pacific oceans to attack U.S. naval forces. A small portion of the U.S. Navy's dozens of front-line SSNs were needed to conduct this operation, but the costs they imposed on the Soviets were disproportionately large since the Soviets had fewer than 10 comparable submarines.

## FIGURE 5: ATLANTIC SOSUS COVERAGE

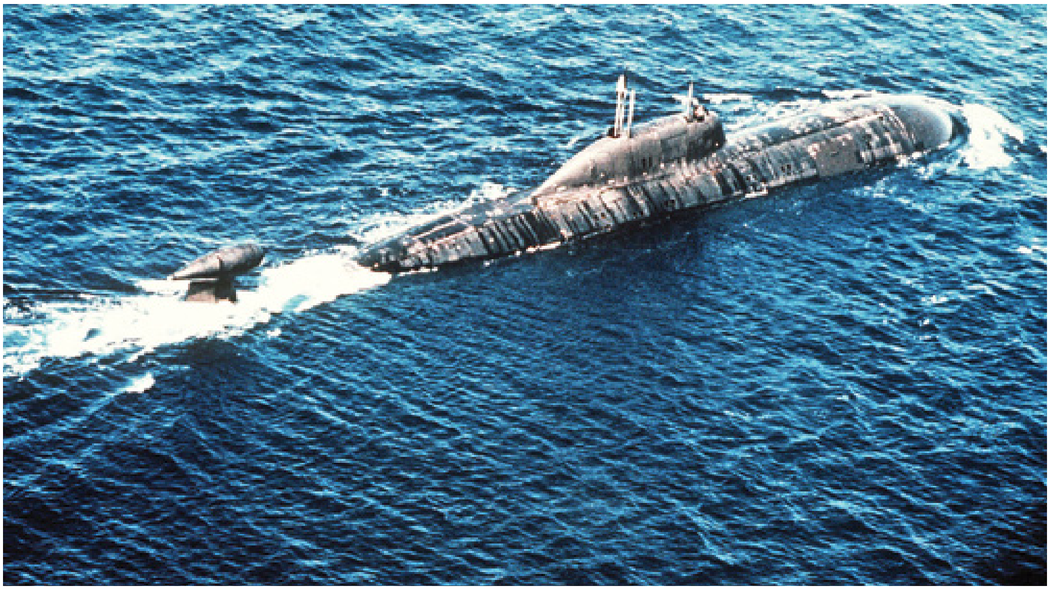



6 Owen R. Cote, Jr., "The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet Submarines," *U.S. Naval War College Newport Papers*, 16, 2003.

7 John R. Benedict, "The Unraveling and Revitalization of U.S. Navy Antisubmarine Warfare," *Naval War College Review*, 58, no. 2, Spring 2005, pp. 93–120.

8 Cote, "The Third Battle"; John B. Hattendorf and Peter M. Swartz, "U.S. Naval Strategy in the 1980s," *U.S. Naval War College Newport Papers*, 33, 2008, p. 33.

FIGURE 6: *AKULA*-CLASS SUBMARINE



This new approach, however, would also be temporary. When the Soviets eventually deployed larger numbers of their own quiet SSNs, they would be able to both protect their SSBNs in the bastions and overwhelm ASW forces defending the U.S. fleet. For the U.S. Navy this meant that ASW forces would once again have to adapt; in this case, moving away from passive sonar to a new way of finding submarines. One promising option the U.S. Navy contemplated was low-frequency active sonar, which was first tested in the late 1980s.[9] But just as in World War II, ASW forces were "saved by the bell" when the Cold War ended before the Soviets could deploy more quiet submarines.

Despite the fall of the Berlin Wall, undersea platforms continued to improve and proliferate, increasing the challenge for ASW forces. Nuclear submarines, such as the U.S. Navy's *Virginia*-class, became quieter while new non-nuclear submarines increased their endurance with air-independent propulsion (AIP) engines and better batteries. Both types can now employ long-range, supersonic anti-ship cruise missiles (ASCM) able to defeat many common shipboard air defense systems. Unmanned undersea vehicles (UUV) and remotely operated vehicles (ROV) also have come into common use for surveying and maintenance of infrastructure offshore and in the deep ocean. And today sensor, processing, power, and communication technologies are on the verge of breakthroughs that could revolutionize the capabilities of undersea platforms.

9 Gordon D. Tyler, Jr., "The Emergence of Low-Frequency Active Acoustics as a Critical Antisubmarine Warfare Technology," *Johns Hopkins APL Technical Digest*, 13, no. 1, 1992, pp. 145–159.

## Undersea Game Changers

Technological advancements, many of them driven by rapid increases in computer processing power (or "big data"), will likely spur a new round of dramatic changes in undersea warfare through:

- New ASW capabilities to find and attack undersea platforms;
- Undersea platform improvements that will enhance their endurance and stealth; and
- New undersea weapon, sensor, and communication systems.

**ASW capabilities.** Since the Cold War, submarines—particularly quiet American ones—have been assumed to be largely immune to anti-access threats. Yet the ability of submarines to hide through quieting alone will decrease as each successive decibel of noise reduction becomes exponentially more expensive and new detection techniques mature that rely on phenomena other than the sounds emanating from a submarine. While the physics behind most of these alternative techniques has been known for decades, they have not been exploitable until very recently because computer processors were too slow to run the detailed models needed to see small changes in the environment caused by a quiet submarine. Today, "big data" is providing the capability to run sophisticated oceanographic models in real time so these detection techniques can be used. And as computer processors continue to shrink, some of them will soon be small enough to fit on ships, aircraft, UUVs, and deployable systems placed on the sea floor. These systems have the potential to make coastal areas far more hazardous for manned submarines, likely driving greater reliance on UUVs to conduct tactical operations in enemy littorals.

Emerging acoustic techniques will continue to exploit new forms of active sonar and methods of analyzing the ambient noise already present in the ocean. Most active sonars on ships and submarines are "medium frequency" (MF), meaning they transmit sound between 1000 and 10,000 hertz (Hz). "Low frequency" (LF) sonar, at less than 1000 Hz, has greater range than MF sonar because the sound suffers less attenuation, but it also provides less precise bearing and range information. Advancements in modeling and computer processing will enhance this target information similar to how photographic images can be enhanced. This will likely make LF sonar useful as a tactical or operational-level ASW sensor. "Big data" could also enable detection of a submarine by comparing expected ambient noise from marine life, waves, and seismic events to measured noise fields, possibly identifying where sounds are being reflected off a submarine or obscured by its hull.[10]

10 Andrew R. Frey, Joseph R. Gagnon, and J.H. Tart, "Detection of a silent submarine from ambient noise field fluctuations," *UMAP Journal*, 17, no. 3, September 1996.

### FIGURE 7: T-AGOS COMPACT LOW FREQUENCY ACTIVE SONAR SHIP


### FIGURE 8: *VIRGINIA*-CLASS SUBMARINE

Emerging non-acoustic detection techniques also show great promise.[11] The theoretical possibilities of detecting minute changes on the ocean's surface caused by a submarine or the wake it leaves underwater have been widely recognized since the Cold War, but only now have processing power and oceanographic modeling improved to the point where these approaches may

11 Daniel G. Daly, *A Limited Analysis of Some Nonacoustic Antisubmarine Warfare Systems*, master's thesis (Monterey, CA: Naval Postgraduate School, March 1994); Sangmook Shin, "Simulation of Two-Dimensional Internal Waves Generated by a Translating and Pitching Foil," *Ocean Engineering*, 72, November 2013, pp. 77–86.

be operationally feasible. Methods to detect radiation or chemicals emitted by a submarine also date from the Cold War and may benefit from the improved sensitivity "big data" could provide.

Lasers and light emitting diodes (LED) can support non-acoustic ASW by bouncing light off the submarine hull, similar to active sonar. Due to material and computer control limitations, previous generations of these systems could only operate in frequency ranges in which the light energy was highly susceptible to attenuation (being turned into heat) or absorption by water or other molecules. Emerging lasers and LEDs, however, can be precisely tuned to wavelengths in which the light energy suffers smaller losses, increasing their range of detection to operationally useful distances.

In combination, new sensors and related improvements to torpedo seekers could enable completely new approaches to finding and attacking submarines. Most significantly, ASW forces could shift away from today's skill- and labor-intensive tactics that result from the short detection range of sensors that are precise enough to support ASW engagements. This limitation requires ASW ships and aircraft to methodically search a wide area for a submarine, then track it until they can get within weapons range for an attack. New sensor and seeker capabilities could instead enable a "fire and forget" approach in which ASW forces detect a submarine at long range and apply computer processing to obtain enough precision for an attack using long-range missiles with torpedo warheads. This kind of attack may not sink the submarine, but would likely compel it to at least evade, breaking its initiative and making it more detectable.

**Platform enhancements.** New technology will also address the limited endurance of non-nuclear undersea platforms and the growing vulnerability of manned submarines. Advances in battery and fuel cell technology are expected to enable non-nuclear submarines, UUVs, and other undersea systems to conduct long-duration military operations far from friendly waters.[12] For example, the newest Japanese *Soryu*-class submarines will use lithium-ion batteries instead of AIP for power when submerged.[13] And large UUVs are expected to achieve one to two months of endurance within the next two years using a combination of fuel cells, batteries, and traditional propulsion sources.[14] These vehicles could carry sensors for coastal surveillance missions and/or large weapons such as torpedoes and mines, making them able to take on some missions conducted today by manned submarines.

12 Alan Burke, "System modeling of an air-independent solid oxide fuel cell system for unmanned undersea vehicles," *Journal of Power Sources*, 158, no. 1, July 2006, pp. 428–435; E. Lennon, A.A. Burke, M. Ocampo, and R.S. Besser, "Microscale Packed Bed Reactor for Controlled Hydrogen Peroxide Decomposition as a Fuel Cell Oxidant Aboard Unmanned Undersea Vehicles," *Journal of Power Sources*, 195, no. 1, January 2010, pp. 299–306.

13 Paul Kallender-Umezu, "Japan to Make Major Switch on Sub Propulsion," *Defense News*, September 29, 2014.

14 David Hambling, "Large Displacement Unmanned Underwater Vehicle Steaming Ahead," *Aviation Week,* April 1, 2012, available at http://aviationweek.com/awin/large-displacement-unmanned-underwater-vehicle-steaming-ahead.

### FIGURE 9: *ECHO RANGER* LARGE UUV

Photo courtesy of Boeing Defense, Space & Security.

## FIGURE 10: RECOVERY OF AN MK-18 UNDERSEA SURVEILLANCE AND MINEHUNTING UUV

The same improvements that are making submarine detection easier may also enable a new generation of sophisticated counter-detection technologies and tactics. Against passive sonar, a submarine or UUV could emit sound to drown out its own radiated noise, similar to the method used in noise canceling headphones, or deploy decoys to create false targets. Against active sonars, undersea platforms could—by themselves or in concert with UUVs and other emitters—conduct acoustic jamming similar to that employed by airborne electronic warfare systems against radar. Both active and passive counter-detection systems will benefit from continued improvements in computer processing and oceanographic modeling that will enable them to control and adapt their operations in real time as part of an overall undersea deception operation.[15] One implication of new stealth-enhancing capabilities may be that manned submarines will need to be larger to host additional on-board and deployable systems.

15 Ning Han, Xiaojun Qiu, and Shengzhen Feng, "Active Control of Three-Dimension Impulsive Scattered Radiation Based on a Prediction Method," *Mechanical Systems and Signal Processing*, 30, July 2012, pp. 267–273.

**Undersea systems.** The ability of large UUVs and submarines to conduct and coordinate operations will improve with the introduction of new weapon, sensor, and communication systems. For example, the U.S. Navy is fielding the Common Very Lightweight Torpedo (CVLWT), which is less than a third the size of the smallest torpedo currently operated by the fleet.[16] Although the CVLWT has a short range, large UUVs could carry substantial numbers of them as offensive weapons and exploit the UUV's quietness to position the torpedoes close to a target. CVLWTs could also be employed as active defense weapons by submarines. Similarly, small, unmanned air vehicles (UAVs) such as the Navy's Experimental Fuel Cell (XFC) UAV have relatively short endurance but can be launched by submarines or UUVs close to an adversary's coast. They can exploit the ongoing miniaturization in electro-optical, infrared, and radar sensors to conduct surveillance or electronic warfare missions, providing targeting information directly via line-of-sight to a submarine or strike aircraft in the vicinity.[17] Such systems could even carry warheads and be used as loitering, anti-radiation homing weapons to attack enemy air defense radars.

## FIGURE 11: COMMON VERY LIGHT WEIGHT TORPEDO

16 P.V. Bharati, S.K. Rao, and A.R. Krishna, "Generation and Analysis of Tactics for Anti-Torpedo Defense System," presentation, IEEE Conference on Information and Communication Technologies, April 2013, pp. 382–387; Anthony Reese, "First Carrier Countermeasure Anti-Torpedo Launched," U.S. Navy, *Navy.mil*, June 6, 2013, available at http://www.navy.mil/submit/display.asp?story_id=74665; U.S. Navy, *Unmanned Underwater Vehicle Master Plan* (Washington, DC: U.S. Navy, November 2004).

17 Daniel Parry, "Navy Launches UAV from Submerged Submarine," U.S. Naval Research Laboratory, press release, December 5, 2013, available at http://www.nrl.navy.mil/media/news-releases/2013/navy-launches-uav-from-submerged-submarine.

## FIGURE 12: EXPERIMENTAL FUEL CELL UAV

New technology will also address the longstanding vulnerability of undersea platforms with regard to communications. In previous competitions, submarines transmitting over operationally relevant distances often did so at the risk of jeopardizing their greatest strength: their stealth. With new ASW technologies, undersea platforms will risk being detected even when passively receiving communications near the surface. These risks could be reduced in the future with new or improved undersea communication methods that will enable undersea platforms to communicate directly with one another, with systems on the ocean floor, and with the above-water joint force while remaining deeply submerged. In general, undersea communications benefit from the same technological advancements as ASW detection methods. In parallel with improvements to active sonar, acoustic communications are increasing their range and bandwidth to the point where they can support undersea operations over relevant distances in real time.[18] In addition to their use in undersea sensing, tunable lasers and LEDs could provide high-bandwidth underwater communications, albeit at shorter ranges than acoustics. And drifting or seabed-mounted cables and floating radio transceivers will enable submerged platforms to communicate with forces above the surface without risking detection.[19] Increasing

18 Douglas Horner and Geoffrey Xie, "Data-Driven Acoustic Communication Modeling for Undersea Collaborative Systems," *Autonomous Underwater Vehicles*, 2012 IEEE/OES, 2012, pp. 1–7.

19 H. Hemmati and A. Biswas, "Improving the Efficiency of Undersea Laser Communications," *SPIE Proceedings*, 8971, March 2014, pp. 1–7.

computing power will also enable undersea systems to do more onboard processing of sensor data to reduce the amount of communication bandwidth needed to pass their information to undersea platforms or battle networks.

## The Next Chapter in Undersea Competition

Undersea research and development has been a distinct U.S. military advantage since the end of WWII, but commercial and scientific interest in offshore resources is prompting a rapid expansion and diffusion of undersea study and expertise. American undersea forces will likely become more vulnerable to inadvertent detection by civilian and foreign entities, while rival military and non-state forces could more easily access and incorporate new technologies in their undersea sensors, unmanned vehicles, and weapons.[20]

Today, many American leaders assume quiet U.S. submarines can access almost any ocean area, even those defended by enemy A2/AD systems. New ASW technologies and improvements to non-nuclear undersea platforms, however, will likely enable adversaries to complement their surface and air A2/AD networks with undersea surveillance and attack systems. These may not have the reach of anti-ship ballistic missiles or modern surface-to-air missiles, but they have the potential to make the undersea littorals of a potential adversary an increasingly denied zone. Consequently, unless U.S. forces adapt to and lead the new competition, the era of unrivalled U.S. undersea dominance could draw to a surprisingly abrupt close.

U.S. forces will need to develop a novel approach for the next chapter in undersea warfare that addresses the use and exploitation of emerging technologies such as those discussed above, while developing new concepts of operation that harness and integrate both new and legacy systems. In particular, the new approach to undersea warfare should consider the following:

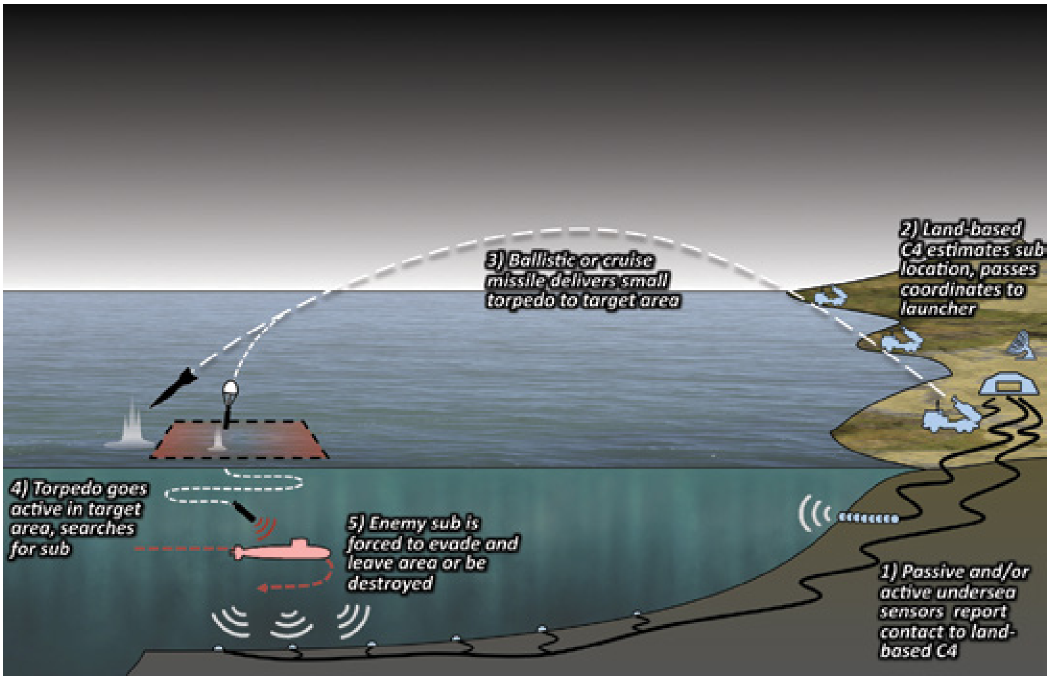
## Technological Considerations

- A new basis for the submarine-ASW competition. The effectiveness of traditional passive sonar will continue to erode as submarines become quieter, their stealth is enhanced with countermeasures, and rivals deploy more unmanned systems that radiate less noise. New detection methods may need to leverage something other than noise emitted from an undersea vessel and function at far greater ranges to enable engagements from beyond the envelope of submarine-launched weapons. Whereas the EM spectrum was the basis for the WWI and WWII undersea competition, and the Cold War competition centered on passive sonar, the detection method of choice in the first half of the 21st century in ASW may be low-frequency active sonar, non-acoustic detection, or some other previously unexploited technique enabled by ongoing advances in computer processing and material science.

20 U.S. Department of Defense (DoD), Office of the Secretary of Defense (OSD), *Military and Security Developments Involving the People's Republic of China 2014,* Annual Report to Congress (Washington, DC: DoD, 2014).

- The advent of undersea "battle networks." New long-range sensors, such as LF active sonar or wake detection, and emerging undersea communication capabilities will enable the development of new undersea fire control networks analogous to those using radio signals in above-the-surface warfare. For example, long-range ASW weapons such as a missile with a CVLWT warhead could be networked with long-range sensors to create an effective standoff ASW capability that delays or drives off submarines by exploiting their inherent limitations in speed, situational awareness, and self-defense. Undersea networks could also enable coordinated surveillance or attack operations with swarms of UUVs operating autonomously or controlled from a manned submarine or other platform.

**FIGURE 13: POTENTIAL UNDERSEA BATTLE NETWORK**




- Disruptive technological shifts. With computer processing power continuing to rapidly increase and become more portable, dramatic breakthroughs are imminent in undersea sensing, communications, and networking. Advancements are also underway in power generation and storage that could yield significant increases in the endurance, speed, and capability of unmanned vehicles and systems. These improvements would compel a comprehensive reevaluation of long-held assumptions about the operational and tactical employment of undersea capabilities, as well as the future design of undersea systems. Of course, they would also have a broad effect on naval and joint force architecture writ large.

## Operational Considerations

- A new (old) ASW approach. During both of the world wars and the Cold War, U.S. forces eventually adopted ASW operating concepts that emphasized preventing enemy submarines from being effective instead of sinking them—approaches that exploited the inherent disadvantages of undersea platforms. U.S. forces will likely have to take a similar tack to counter growing adversary undersea forces in the future.

- A new approach to offensive undersea operations. Manned submarines will likely need to shift from being front-line tactical platforms like aircraft to being host and coordination platforms like aircraft carriers. New ASW sensors will increasingly rely on phenomena other than radiated noise, so acoustic silencing will not be enough to maintain a submarine's stealth. As a result, manned submarines will have incentives to reduce their exposure to risks in hostile littorals while maximizing their use of a growing array of deployable acoustic and non-acoustic decoys and jammers to prevent detection. Large UUVs and other deployed systems will increasingly be relied upon as substitutes for manned submarines in conducting tactical operations with a greater probability of detection such as coastal intelligence gathering, land attack, or anti-ship missions in hostile littorals. In addition to being less detectable than a manned submarine, UUVs should be cheaper than manned submarines, leading commanders to be bolder in using them for extremely high-risk operations. Meanwhile, the next generation of manned submarines may need to be considerably larger than today's *Virginia*-class submarines to accommodate new counter-detection, communication, and command and control systems, as well as to host an array of unmanned vehicles and weapons.

- Expansion of undersea infrastructure. The seabed increasingly supports a burgeoning array of commercial oil and mineral extraction equipment and pipelines, communication transmission cables, power generation equipment, and acoustic and non-acoustic sensors. Civilian systems are becoming more common as scientists and governments increase monitoring and management of undersea resources such as fish stocks and hydrocarbons. An undersea warfare approach will have to take account of this new form of undersea "encroachment," especially in terms of inadvertent detection by non-military sensors, protection of friendly infrastructure, and opportunities to inflict damage on enemy undersea infrastructure during a conflict.

## Conclusion

The U.S. Navy has an unrivalled track record leading and exploiting the evolution in undersea systems and operational techniques over the last one hundred years. American defense leaders and analysts rightly believe that the Navy's dominant position in undersea warfare will remain a key element of U.S. military planning for decades to come. America's potential adversaries recognize this as well and are aggressively working to undermine the U.S. Navy's undersea superiority.

Emerging technologies present a serious challenge in that they may empower development of potent rival undersea forces and erode the stealth of U.S. submarines. But they also provide the United States an opportunity to again be the "first mover" (e.g., as with passive sonar) and establish a dominant position in the next chapter of the undersea competition. America could leverage enduring advantages such as its geography, R&D base, military culture, and operational competence to exploit new ways and means of conducting undersea warfare more rapidly than its competitors.

The emerging era in undersea competition will require a significant rethinking of how military forces conduct undersea warfare. Dramatic changes are occurring in the technological realm that should inform new operational concepts, which will have significant implications for the kinds of undersea capabilities that should be developed and the ways in which larger naval and joint force should evolve to complement them. In particular, a new family of undersea vehicles and systems will be essential to maintain America's undersea edge by reducing the growing vulnerability of today's principal undersea platform, the manned submarine. Failing to aggressively exploit the latent potential of these emerging technologies and the advanced capabilities they make possible could create an opening for rivals to "steal a march" on the United States in this new era of the undersea competition and, in so doing, pose a major threat to U.S. security.

## ABOUT THE CENTER FOR STRATEGIC AND BUDGETARY ASSESSMENTS (CSBA)

The Center for Strategic and Budgetary Assessments (CSBA) is an independent, nonpartisan policy research institute established to promote innovative thinking and debate about national security strategy and investment options. CSBA's analysis focuses on key questions related to existing and emerging threats to U.S. national security, and its goal is to enable policymakers to make informed decisions on matters of strategy, security policy, and resource allocation.

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