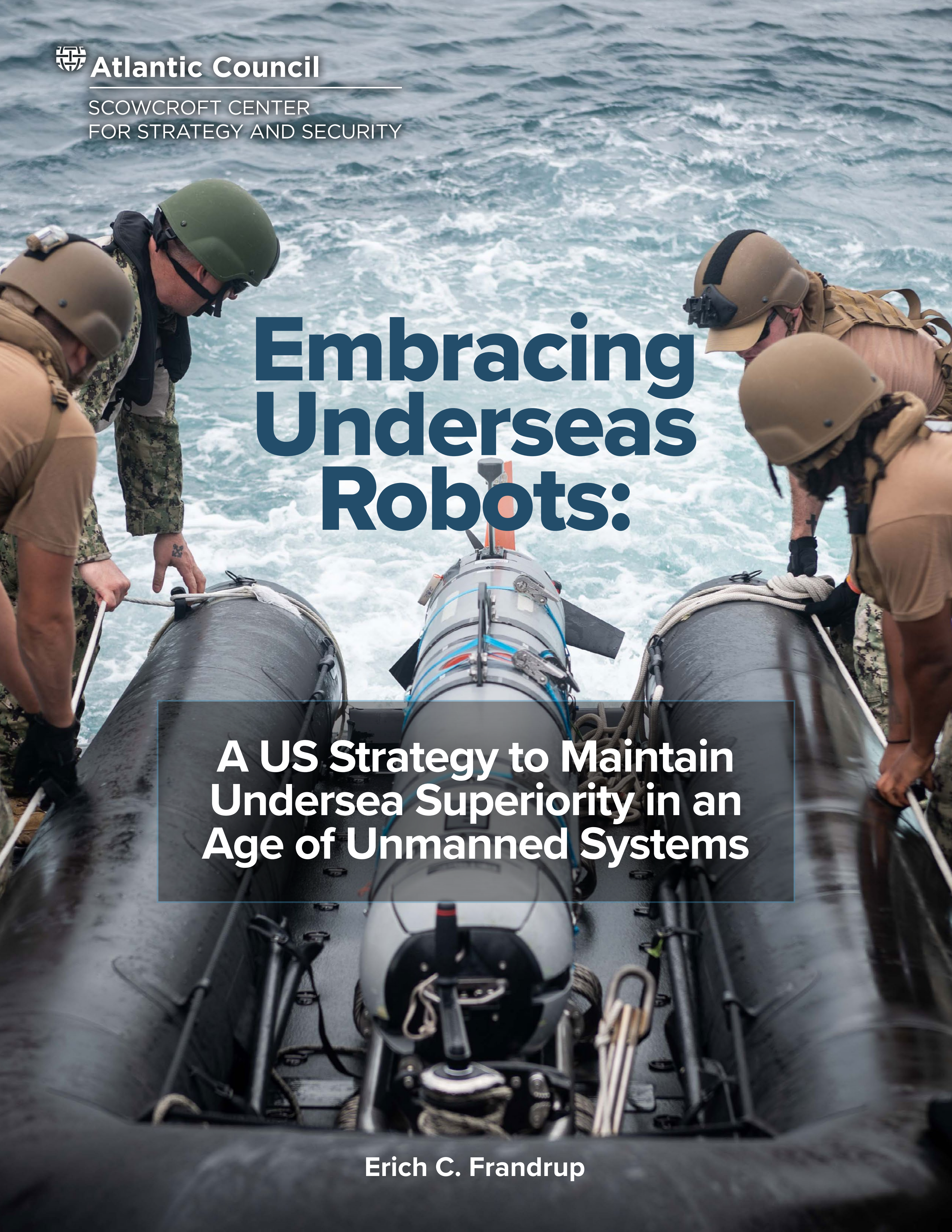

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Embracing Underseas Robots:

A US Strategy to Maintain Undersea Superiority in an Age of Unmanned Systems

Erich C. Frandrup

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Cover image: PACIFIC OCEAN (Aug. 13, 2020) Sailors assigned to Coastal Riverine Squadron (CRS) 3 and the expeditionary mine countermeasure company of Explosive Ordnance Disposal Mobile Unit (EODMU) 5 retrieve a Mark 18 Mod 2 unmanned underwater vehicle (UUV) during a transit through the Northern Mariana Islands. EODMU-5 and CRS-3 operate together onboard a Mark VI patrol boat to transport, launch and retrieve the UUV for underwater survey collections in support of Navy Expeditionary Forces Command Pacific-Task Force (CTF) 75. CTF-75 is the primary expeditionary task force responsible for the planning and execution of coastal riverine operations, explosive ordnance disposal, diving engineering and construction, and underwater construction in the U.S. 7th fleet area of operations. (U.S. Navy photo by Mass Communication Specialist 2nd Class Cole C. Pielop) 200813-N-BR087-1100. *https://www.flickr.com/photos/usnavy/50247237398/in/photolist-TpPtET-2jybe6h-pXFoUv-diuF6H-enBakJ-2hemBTb-ZBEUNP-XgCxTu-9ToBnA/*

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Executive Summary

The United States Navy currently enjoys "undersea superiority." In other words, and slightly altering the doctrinal definition of "maritime superiority," the United States military has a degree of dominance over any other opposing force within the undersea domain which permits US undersea forces (and its related surface, land, and air forces) to conduct undersea operations at a given time and place without prohibitive interference by the opposing force.[1] This is a considerable advantage, and one that is largely due to the strength, versatility, and vastness of the US submarine force. In an age of emerging technologies with increased development and use of unmanned systems, this strategy maps out how the United States will maintain undersea superiority against its competitors.

There are four major elements to this strategy. First, developing foresight on both the promise that Unmanned Undersea Vehicles (UUV) possess and the threats that they pose within the undersea domain is critical. Second, there needs to be a transition to manned/unmanned system joint operating concepts. This paper provides a "deep-dive" on two potential operating concepts pertaining to mine warfare. Third, the capabilities required within these operating concepts need to be developed smartly and comprehensively. Fourth, opportunities to engage US partners and allies with unmanned systems should be considered, even outside the bounds of military purposes.

Finally, concerning this strategy's implementation, this paper argues that developing offensive capabilities should be prioritized over defensive capabilities, that existing technologies both within industry and within the military should be leveraged, and that a "crawl-walk-run" approach to fully operationalizing the concepts is essential.

1 *Dictionary of Military and Associated Terms*, US Department of Defense, February 15, 2016, *https://fas.org/irp/doddir/dod/jp1_02.pdf*, 147.

Strategic Context

Naval power is a pillar to US prosperity. It ensures the defense of US maritime borders. It enables the United States to project military might globally, and in doing so, is a source of security to protect US interests in regions far beyond its borders. Naval power is the backbone that ensures sea lines and maritime trade lines carrying global commerce remain protected and flow uninterrupted. It allows the United States to rapidly, and with scalable force, respond to global contingencies and crises. Perhaps most importantly, naval power is a deterrent to US adversaries and a symbol of assurance to US global allies and partners.

A key component of a nation's naval power is the strength and breadth of its undersea force, and for the past couple of hundreds of years, the submarine force is how this strength and breadth materialized. Submarines have been used in war since the American Revolution and provide the preponderance of a navy's undersea power capabilities.[2] Among other advantages, submarines offer precision strike capabilities, covertness, an ability to operate in denied areas, and an ability to operate independently for long periods of time without refueling (especially nuclear-powered submarines). In addition to these characteristics, nuclear-armed submarines offer an added advantage of contributing to nuclear deterrence.

Today, and looking into the future, these characteristics and capabilities are packaged together within the US Navy through its current use and future development of various classes of submarines to include the *Los Angeles*-class, *Seawolf*-class, *Virginia*-class, *Ohio*-class, and *Columbia*-class vessels.[3] Today, the US submarine force is arguably the best globally, but some of the United States' biggest competitors have formidable submarine forces of their own.[4,5] Specifically, it is worth comparing attributes of the US submarine force to other global power competitors—namely China and Russia.

Regarding China, its submarines are primarily conventionally (i.e., non-nuclear) powered, and its use of submarines is limited in scope, focusing more on regional missions.[6] Further, unlike US submarines, Chinese submarines are not capable of dual missions. In other words, each submarine is not capable of performing both anti-submarine warfare and land-attack missions but can only perform one of those missions.

Russia is the closest global peer to the United States with regards to its submarine force. While the United States emerged from the Cold War as the undisputed global undersea warfare power, Russia emerged as a competitor in this arena in the twenty-first century.[7] Most notably, its newest class of submarines, the *Yasen*-class, rivals the capabilities of the newest US fast-attack submarines, the *Virginia*-class. The *Yasen*-class submarines give Russia a nuclear-powered, highly automated, and quiet platform that can be used both for anti-submarine warfare and for strike missions.

While manned submarines will continue to be a staple of undersea naval power for the foreseeable future, the recent boom in, and rapid evolution of, emergent technologies provide a glimpse into the promise of unmanned systems within the undersea domain. Automation will continue to develop and, if and when feasible, opportunites to remove "man" and replace him with "machine" will continue. Computer processing speeds will continue to increase, the degree of autonomy of unmanned systems will grow, data management and data transfer processes will improve, and batteries and other sources of energy will enable machines to perform missions for longer periods of time without the need to consistently recharge.

Today's UUVs, in US naval applications, are generally used for mine counter-measure (MCM) operations; intelligence, surveillance, and reconnaissance (ISR) operations; and for conducting oceanographic surveys.[8] However, there have been recent developments by the US Navy to capitalize on UUVs, to include awarding Boeing a contract for its Orca Extra-Large Unmanned Undersea Vehicle (XLUUV). Based on a previously developed prototype UUV, the XLUUV

2 Norman Friedman, "Submarine," *Encyclopaedia Brittanica*, June 10, 2019, *https://www.britannica.com/technology/submarine-naval-vessel*.

3 Andrew Tunnicliffe, "From attack submarines to spies: US Navy asks more of its underwater fleet," Naval Technology, January 3, 2020 *https://www.naval-technology.com/features/us-nuclear-attack-submarines/*.

4 Kyle Mizokami, "The Reason Why the U.S. Nuclear Submarine Force is the Best in the World," *National Interest*, March 15, 2020, *https://nationalinterest.org/blog/buzz/reason-why-us-nuclear-submarine-force-best-world-133027*.

5 Dimitrios Mitsopoulos, "All the Nuclear Missile Submarines in the World in One Chart," *Popular Mechanics*, June 8, 2018, *https://www.popularmechanics.com/military/navy-ships/a21204892/nuclear-missile-submarines-chart/*.

6 *The PLA Navy: New Capabilites and Missions for the 21st Century*, Office of Naval Intelligence, 2015, *https://fas.org/irp/agency/oni/pla-navy-2015.pdf*.

7 Kyle Mizokami, "Russia vs. America: Who Has The World's Best Submarines?," *National Interest*, September 20, 2019, *https://nationalinterest.org/blog/buzz/russia-vs-america-who-has-worlds-best-submarines-82166*.

8 Robert W. Button, John Kamp, Thomas B. Curtin, and James Dryden, *A Survey of Missions for Unmanned Undersea Vehicles*, RAND Corporation, 2009, *https://www.rand.org/pubs/monographs/MG808.html*.

could potentially be used for MCM, anti-submarine warfare, anti-surface warfare, electronic warfare, and/or strike missions. However, the US Navy has not revealed specifics of its intended operations.[9] But just as autonomous systems in the aerial domain brought new capabilities to, and to some degree revolutionized, land warfare, the US Navy is only beginning to tap into the potential that UUVs could bring to undersea warfare.[10]

Meanwhile, China and Russia continue to develop their own UUV capabilities. In October of 2019, China most notably revealed a UUV program marked "HSU001." While the capabilities of this large-diameter UUV are only speculative at this point, there is suspicion that it can execute a wide arrange of missions both at sea and within the littorals and can deliver various payloads or even deploy smaller UUVs and/or sensors. While its level of autonomy is unknown, the HSU001 will likely be capable of long-endurance missions that last weeks or even months.[11]

In Russia, several types of UUVs are being developed. Perhaps most concerning, a UUV program named "*Poseidon,*" first revealed by Russia in 2015, gives Russia an intercontinental, autonomous, nuclear-powered torpedo.[12] While its intended use remains unclear, estimates indicate that the vehicle will be in service around 2027. Further, Russia claims that this torpedo could even be fitted with a nuclear warhead.[13] Another drone, named *Cephalopod*, also revealed in 2015, will potentially give Russia the capability to launch torpedoes at enemy submarines from UUVs and can be utilized to protect or escort Russia's ballistic missile submarines, provide port security, or even operate in restricted waters such as the Baltic Sea.[14] Finally, the *Harpsichord* is a UUV capable of being carried by either Russian submarines or ships, giving them an improved ISR capability. It is estimated that this UUV can operate at depths of up to two thousand meters.[15]

Today, with the robustness, global reach, and technological prowess of its submarine force alone, the United States arguably enjoys undersea superiority relative to its biggest global competitors. However, there is little doubt that the emergence and promise of UUVs brings a new dimension to undersea warfare. When recently asked about where he sees the best application of unmanned systems for naval warfare, the chief of naval operations (CNO) said:

> Unmanned is an important part of the future. It must be a central component of our future battle force to support the way we want to fight in a distributed way. Going forward, I believe there will be a requirement for seaborne-launched vehicles to deliver effects downrange, likely using a mix of manned and unmanned assets. Ultimately, we must leverage technology to expand our reach, lethality and warfighter awareness in undersea, surface and air domains. We must continue to experiment more with unmanned, and we need to do it with greater speed.[16]

With this context in mind, considering the cost to build and sustain a globally deployable submarine force moving forward, and heeding both the 2018 National Defense Strategy and the Navy's 2019 Design for maintaining Maritime Superiority (which both encourage the development of advanced autonomous systems), this strategy will look at how the United States will maintain undersea superiority against its competitors in an age of unmanned systems.[17,18]

9 Berenice Baker, "Orca XLUUV: Boeing's whale of an unmanned sub," Naval Technology, January 30, 2020, *https://www.naval-technology.com/features/boeing-orca-xluuv-unmanned-submarine/*.

10 Roger Connor, "The Predator, a Drone That Transformed Military Combat," Smithsonian Air and Space Museum, March 9, 2018, *https://airandspace.si.edu/stories/editorial/predator-drone-transformed-military-combat*.

11 David R. Strachan, "China Enters the UUV Fray," *Diplomat*, November 22, 2019, *https://thediplomat.com/2019/11/china-enters-the-uuv-fray/*.

12 Matthew Kroenig, Mark Massa, and Christian Trotti, *Russia's exotic nuclear weapons and implications for the United States and NATO*, Atlantic Council, March 6, 2020, *https://www.atlanticcouncil.org/in-depth-research-reports/issue-brief/russias-exotic-nuclear-weapons-and-implications-for-the-united-states-and-nato/*.

13 Franz-Stefan Gady, "US Intelligence: Russia's Nuclear-Capable 'Poseidon' Underwater Drone Ready for Service by 2027," *Diplomat*, March 26, 2019, *https://thediplomat.com/2019/03/us-intelligence-russias-nuclear-capable-poseidon-underwater-drone-ready-for-service-by-2027/*.

14 Kyle Mizokami, "Russia Working on New 'Cephalopod' Underwater Attack Drone," *Popular Mechanics*, July 30, 2018, *https://www.popularmechanics.com/military/navy-ships/a22593766/russia-working-on-new-cephalopod-underwater-attack-drone/*.

15 H. I. Sutton, "Harpsichord AUV," March 30, 2019, *http://www.hisutton.com/Harpsichord_AUV.html*.

16 Richard R. Burgess, "Q&A With CNO Adm. Mike Gilday," *Seapower Magazine*, March 31, 2020, *https://seapowermagazine.org/qa-with-cno-adm-mike-gilday/*.

17 *Summary of the 2018 National Defense Strategy of the United States of America*, US Department of Defense, 2018, *https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf*.

18 Ben Werner, "CNO Gilday Releases New, Simplified Command Guidance to Fleet," USNI News, December 4, 2019, *https://news.usni.org/2019/12/04/cno-gilday-releases-new-simplified-command-guidance-to-fleet*.

Major Elements of the Strategy

This strategy has four key elements that are critical to its implementation. First, and perhaps most importantly, the United States needs to develop foresight both into the promise of, and the threats posed by, unmanned vehicle in the undersea domain. Second, there needs to be a transition to manned-unmanned system joint operating concepts. Third, the capabilities need to be developed smartly and comprehensively. Finally, the United States needs to leverage the opportunities that these systems give us with regards to engagement with key allies and partners, to include beyond their military applications.

I FORESIGHT INTO THE PROMISE AND THREAT OF UUVS

As technologies proliferate across the globe, societies and organizations often do not have the means or ability to effectively absorb them, understand their implications, or develop strategies to manage them. Even further, to a large degree, emerging technologies are being integrated into our daily lives without a complete understanding of the positive potential or negative consequences that they bring.[19] This, coupled with the near impossibility to predict the future of warfare and unmanned systems' roles within it, can make tuning technologies for future warfare use very difficult. However, developing foresight, or a systematic way of thinking about the future, is possible, advantageous, and necessary.

Looking into the future, there is already a movement to replace "man with machine" across various warfare domains. Perhaps most notably was the transition to using unmanned aerial vehicles (UAVs) to conduct both ISR and strike missions (often in conjunction with each other). This utilization revolutionized the way the United States conducts warfare along the land-air interface.[20] Concerning UUVs, while their developments are more in their infancies, there is applicability within various warfare arenas. New concepts for conducting mine warfare, strike operations, and ISR missions, to name a few, all have room to welcome unmanned systems. Even humanitarian aid and disaster relief (HADR) could see innovative ways to implement UUVs. As an example, they could be utilized in search and recovery efforts at sea for maritime structures (e.g., oil rigs) damaged or sunk during natural disasters (similar to oil rigs in the Gulf of Mexico damaged in the wake of Hurricane Katrina in 2005) or to assist in personnel recovery efforts. UUV swarm tactics, a concept already envisioned and published, could be developed to present significant problems to or innovative strike against an adversary's navy.[21] Looking even further into the future, UUVs, in conjunction with other seafloor sensors, could potentially create a degree of global undersea transparency (similar to how the use and advancement of satellite sensors and imagery has slowly created global transparency of the Earth's surface). Undersea transparency would undoubtedly revolutionize undersea warfare, especially pertaining to submarine warfare and their ability to traverse or conduct strike operations stealthily.

While UUVs show significant promise and will certainly enhance and complement the United States' ability to conduct undersea warfare operations, it is equally important to foresee the threats posed by an adversary's use and employment of these systems. Any capability developed by the United States can stimulate an "in kind" capability developed by an adversary. Thus, as UUV "offensive" capabilities and operating concepts of our own are developed and matured, parallel efforts should remain focused on defensive capabilities and their associated operating concepts so that an adversary does not gain decisive advantages within the undersea domain.

II TRANSITIONING TO MANNED/UNMANNED SYSTEM JOINT OPERATING CONCEPTS

A new capability is only as good or effective as the operating concept that employs it. As one source describes this notion:

> operating concepts generally look out from five to fifteen years, and postulate reasonable operating scenarios that, through a combination of analysis and the use of descriptive examples, examine a range of issues such as employment, operating environment, command and control, support, organization, and planning considerations.[22]

19 Bill Bahnmaier, "Managing Technology in an Interesting Unmanageable World," Hot Topic Forum, Defense Acquisition University, January 27, 2020, *https://media.dau.edu/media/Hot+Topic+Forum+-+Managing+Technology+in+an+Interesting+Unmanageable+World/1_tt5s2841*.

20 Connor, "The Predator," 2018.

21 Timothy McGeehan and Douglas Wahl, "Flash Mob in the Shipping Lane!," *Proceedings*, January 2016, *https://www.usni.org/magazines/proceedings/2016/january/flash-mob-shipping-lane*.

22 *Doctrine, Operating Concepts, And Vision*, "Curtis E. LeMay Center for Doctrine Development and Education, February 27, 2015, *https://www.doctrine.af.mil/Portals/61/documents/Volume_1/V1-D08-Doctrine-Concepts-Vision.pdf*.

In other words, even a piece of military equipment that has state-of-the-art technology and brings revolutionary and game-changing warfare capability is deemed almost useless unless it can be employed in concert with other tools and within the existing constructs and frameworks of military operations. Further, as the future of warfare becomes more and more multi-regional, multi-vectored (hybrid and conventional), and multi-domain, it is imperative that these operating concepts apply across domains (i.e., air, land, sea, cyber, space), military services, and even across the full spectrum of conflict.[23] For example, a hypersonic missile is arguably a game-changing weapon.[24] However, unless it can be successfully launched from some sort of platform, successfully guided by some means, successfully discern its target from the target's surroundings, successfully commanded and controlled within a command and control (C2) network, successfully impact its target, do all of the above with high degree of consistency, and can be implemented within the context of other US strike weapons and with consideration of an adversary's ability to counter or defeat the weapon, a hypersonic weapon serves no credible purpose. In short, it is the development and implementation of an operating concept to employ a hypersonic missile that really gives this weapon its value.

Similar to a hypersonic missile, a UUV serves little credible purpose to the US military without the bedrock of an operating concept that provides its purpose, its supporting and supported elements, and the context in which it will be utilized within military operations. While operating concepts should be developed to govern any and all future uses of UUVs within military operations, this paper will focus on new operating concepts that implement UUVs into the two specific mission arenas of mine warfare—offensive mining and MCM.

A Proposed operating concept for offensive mining

As a vignette, imagine this scenario: "tensions between Taiwan and China spike and US intelligence reports that Chinese PLA Navy warships will soon sortie from various Chinese ports. In response, US submarines discreetly place a set of large UUVs on the seabed floor of the Taiwan Strait in the vicinity of the shipping lanes extending from the ports. Once settled, each UUV waits for the order to release a half-dozen smaller tactical UUV, each armed with explosives and non-kinetic effectors (e.g., such as deployable netting to foul a ship's propulsion gear). The order comes and the small tactical UUV deploy, maintaining connections to a command module via acoustic and satellite links. These tactical craft loiter just outside the ports, until one by one, they detect the unique acoustic signature of their assigned Chinese warship and break off to intercept it. Once in position, three feet under a Chinese keel, each tactical UUV signals its status back to a command center and awaits the order to immobilize its target."[25]

"Naval mines have progressed little since the 1970s introduced the Mk 60 encapsulated torpedo and the Mk 67 Submarine Launched Mobile Mine, although recent years have brought efforts to more accurately employ immobile mines, develop sensor packages to better discriminate targets," and even develop "smart mines" such as the Hammerhead.[26,27,28,29] To date, however, the modernization of mine warfare has lagged significantly when compared to other warfare areas and, further, these advancements have not been fully implemented into broader undersea warfare operating concepts.

As portrayed in the Taiwan Strait vignette, UUVs can revolutionize offensive mining and, in a hybrid manner, also augment submarine strike capabilities. The notional UUVs described in the scenario would "combine some of the advantages and capabilities of a fast-attack submarine (stealthy, mobile, sensor-driven pursuit of targets, ability to follow or discriminately strike at will) and those of a sea mine (even stealthier, far cheaper, present physical and psychological barriers to an adversary)—without some of the drawbacks (submarines are really expensive; And today's sea mines are mostly indiscriminate, counter the notion of freedom of navigation, and are really difficult to clean up once the mission has concluded)."[30]

How can an operating concept like this come to fruition at a reasonable cost? It is worth first pointing out that advanced

23 Franklin D. Framer, *Managed Competition: Meeting China's Challenge in a Multi-vector World*, Atlantic Council, December 2019, *https://www.atlanticcouncil.org/wp-content/uploads/2019/12/Meeting-Chinas-Challenges-Report-WEB.pdf*.

24 Steven Simon, "Hypersonic Missiles Are a Game Changer," *New York Times*, January 2, 2020, *https://www.nytimes.com/2020/01/02/opinion/hypersonic-missiles.html*.

25 Erich Frandrup, "The US Navy Needs Offensive Undersea Drones," Defense One, November 26, 2019, *https://www.defenseone.com/ideas/2019/11/us-navy-needs-offensive-undersea-drones/161548/?oref=d-river*.

26 Ben Werner, "Navy, Air Force Test Deploys 2,000-Pound Mine at Stand-off Range," September 24, 2018, *https://news.usni.org/2018/09/24/36763*.

27 Joseph Trevithick, "U.S. Is Betting Big On Naval Mine Warfare With These New Sub-Launched and Air-Dropped Types," *The Drive*, November 20, 2018, *https://www.thedrive.com/the-war-zone/25235/the-u-s-is-getting-back-into-naval-mine-warfare-with-new-sub-launched-and-air-dropped-types*.

28 Megan Eckstein, "U.S. Naval Offensive Mining Updates Will Focus on Sub Community Tactics, Smart Mines," USNI News, November 5, 2019, *https://news.usni.org/2019/11/05/u-s-naval-offensive-mining-updates-will-focus-on-sub-community-tactics-smart-mines*.

29 Frandrup, "The US Navy Needs Offensive Undersea Drones."

30 Ibid.

A Knifefish Unmanned Undersea Vehicle (UUV) transits the Massachusetts Bay. 190517-N-YM590-1008 MASSACHUSETTS BAY (May 17, 2019) A Knifefish Unmanned Undersea Vehicle (UUV) transits the Massachusetts Bay at the completion of a mission during an operational test conducted by members from Operational Test and Evaluation Force (OPTEVFOR). Knifefish is a medium-class mine countermeasure UUV designed for deployment off the Littoral Combat Ship. OPTEVFOR is the Navy's sole test and evaluation organization for surface, air, and undersea warfare, along with various other programs which impact the Navy's overall mission. (U.S. Navy photo by Mass Communication Specialist 1st Class Brian M. Brooks/RELEASED) *https://www.dvidshub.net/image/5553957/knifefish-uuv-test*

UUVs like this would not need to be developed from scratch. The Navy and private industry already operate basic UUVs models and have acquisition requirements in place that could be leveraged or developed and improved for offensive mining purposes.[31,32]

To create a "mother" UUV that can be submarine launched, we can build upon current requirements for the Virginia-class submarines.[33] Also, designs of UUVs that already exist today (such as the Boeing-developed Echo Ranger, Echo Seeker, and Echo Voyager) should be leveraged for a lower-cost solution rather than developing the system from scratch.[34] The mother UUV would also require to have the ability to carry, launch, and recover smaller tactical UUVs and carry a command and control module that enabled it to both communicate with the smaller UUVs and external assets (e.g., submarines, naval warships, buoys, etc.) for command and control purposes.

To develop a tactical UUV that is carried by and launched from the "mother" UUV, there are platforms in use today that should be used as prototypes. Namely, the Mk 18 Mod 1 Kingfish (Remus 100) UUV is primarily used today by explosive ordnance disposal (EOD) units to search for undersea mines.[35] These platforms are small enough to be contained inside a larger diameter UUV and have compartmentalization

31 "Hydroid wins contract modification for MK 18 UUV programme," Naval Technology, September 19, 2019, *https://www.naval-technology.com/news/hydroid-wins-contract-modification-for-mk-18-uuv-programme/*.

32 Wendy Laursen, "Growing Interest in AUVs for Oil and Gas," Maritime Executive, August 11, 2016, *https://www.maritime-executive.com/article/growing-interest-in-auvs-for-oil-and-gas*.

33 "On Demand Structures – Submarine Launch of UUVs," US Navy Small Business Innovation Research, April 12, 2019, *https://www.navysbir.com/nx19_1/nx19-002.htm*.

34 Alex Davies, "Boeing's Monstrous Underwater Robot Can Wander the Ocean for 6 Months," *Wired*, March 21, 2016, *https://www.wired.com/2016/03/boeings-monstrous-underwater-robot-can-wander-ocean-6-months/*.

35 "New Generation REMUS 100 for Defense Applications," Hydroid, n.d., *https://www.hydroid.com/new-generation-remus-100-defense-applications*.

characteristics that could be leveraged to include an acoustic guidance systems, an explosive warhead, or an inertial navigation system that could include "come home" technology which tells the UUV to disarm and return to a predetermined location for recovery and/or disposal. Current operating depths (100 meters), speed (5 knots), and endurance (12 hours) of the Mk 18 Mod 1 would need to be improved in order to be utilized in this operating concept.

The command and control network for this system, however, would require more extensive research and development. Integration of the network of UUVs and the ability to command and control them would be challenging. Radio waves get absorbed very quickly in water and an air-water trans-medium network would likely need to be developed. However, ships, other surface platforms, buoys, or submarines can all be components of the networked system that could enable adequate, and even real-time, command and control.

Operating concept for mine countermeasures (MCM)

The ability to counter sea mines is as equally important as effectively employing them. Sea mines make ideal weapons because they are cheap, effective, can be employed quickly from a variety of platforms, and can be employed against a variety of targets to include ships, submarines, and critical undersea infrastructure. History has proven these simple facts during numerous conflicts. For example, during the Iran-Iraq Tanker War in the late 1980s, the USS *Samuel B. Roberts* (FFG-58) struck a mine in the Persian Gulf, requiring over $90 million in repairs, and during World War II, over seven hundred thousand naval mines were employed, accounting for more ships sunk or damaged than by any other means (the Allies lost about 650 ships to mines while the Axis lost around 1,100).[36,37] Further, as of 2018, of the nineteen US Navy ships that have been seriously damaged or sunk by enemy action since September 1945, fifteen (or almost 80 percent) were victims of sea mines.[38]

To counter sea mines in recent decades, the US Navy's MCM mission has historically been comprised of the MCM triad—helicopters that tow various sleds and other tools through a minefield that either neutralize or enable neutralization, MCM-class ships that employ sonars and similar tools to defeat mines while physically traversing through a minefield, and EOD divers that can perform "hands on" render safe or disposal procedures on sea mines.[39]

Today's US Navy MCM force, however, is evolving rapidly. The primary platforms for two of the three legs (MH-53E helicopters and MCM-1 class ships) of the legacy MCM triad are rapidly aging, breaking down, and are going out of service within the next few years. Further, the Navy will not have correlating replacement platforms. Instead, the capabilities that these platforms offered were planned to be assumed by the Littoral Combat Ship (LCS) MCM module. However, due to recent issues within the LCS program, the Navy is already looking to divorce the MCM module from the LCS program and utilize and operate the module in a piece-meal manner from ashore or from other vessels of opportunity.[40]

With these uncertainties in mind and with renewed interest to maintain robust MCM capabilities, there is enormous opportunity for the expansion of the third leg of the MCM triad—underwater MCM. And within this arena, UUVs can play a significant role. Today, EOD teams utilize the Mk 18 Mod 1 (Remus 100) and Mk 18 Mod 2 (Remus 600) UUVs to search for undersea mines.[41,42,43] These sensors have revolutionized two of the three critical phases of the MCM mission—the ability to find and accurately geolocate sea mines ("find" and "fix"). In other words, instead of physically driving a MCM-1 class ship and its searching sonar over a minefield and risking lives of over eighty members onboard, UUVs can do this mission today.

However, there is significant room for expanding this operating concept. Currently, once the Mk 18 Mod 1 or Mk 18 Mod 2 are pre-programmed to search a finite area and "find" and "fix" a mine, there is a considerable pause in the sequence of events before the final phase, destroying or rendering safe the mine ("finish"), is completed. This lag is due to two things. First, UUVs currently cannot guarantee with 100 percent certainly that a sea mine-shaped item on the ocean floor is actually a sea mine, as sometimes junk on the ocean floor (like tires or barrels) can appear like sea

36 Bradley Peniston, "The Day Frigate Samuel B. Roberts Was Mined," USNI News, May 22, 2015, *https://news.usni.org/2015/05/22/the-day-frigate-samuel-b-roberts-was-mined*.

37 "Mines, Naval," *The Oxford Companion to American Military History*, September 31, 2020, *https://www.encyclopedia.com/history/encyclopedias-almanacs-transcripts-and-maps/mines-naval*.

38 Scott C. Truver and David Everhart, "Defeating Mines and Other Unmanned Maritime Threats," September 8, 2018, *https://www.realcleardefense.com/articles/2018/09/08/defeating_mines_and_other_unmanned_maritime_threats_113782.html*.

39 Truver and Everhart, "Defeating Mines," 2018.

40 Megan Eckstein, "Navy Thinking Beyond Littoral Combat Ship for Future Mine Warfare," USNI News, November 2, 2018, *https://news.usni.org/2018/11/02/navy-thinking-beyond-littoral-combat-ship-future-mine-warfare*

41 *https://www.defensenews.com/opinion/commentary/2020/05/08/the-us-navys-modernization-rush-must-not-harm-mine-countermeasures/*.

42 "New Generation REMUS 100," Hydroid.

43 "REMUS 600 for Defense Applications," Hydroid, n.d., *https://www.hydroid.com/remus-600-defense-applications*.

mines when analyzing the sonar data downloaded from the UUV. Second, the UUVs that "find and fix" the mines currently cannot destroy them or render them safe.

Thus, after an area is searched by a UUV, there is a significant lag in time that allows for several steps to take place before a mine or a series of mines can be destroyed. First, the UUV has to be recovered by personnel and the raw collection data from the search must be assessed by personnel trained to sift through and analyze significant sonar data. Once the data is analyzed, a small boat (often from ashore or from a vessel nearby) must be deployed to the minefield and either a diver or a tethered unmanned system must be employed to reacquire a contact and determine if it is actually a mine or not. Finally, the mine must be destroyed (usually through the diver or tether unmanned system placing an explosive countercharge next to it). This process between the "find and fix" phase and the final "finish" phase can often take hours per mine, or, in the case of a large minefield, can add days. Depending on the scenario at hand, this lag can have significant operational and strategic impacts.

In light of this, consider this vignette: in retaliation of ongoing US sanctions that have crippled its economy, Iran placed several bottom sea mines in a line across a shipping lane within the Strait of Hormuz. Within hours of placing the mines, a foreign-flagged merchant ship triggers a mine and is significantly damaged but is able to limp into a nearby port in the UAE. US intelligence, with high certainty, indicate Iran emplaced anywhere from twenty-five to fifty mines in a defined area within and around the shipping lane. All Strait of Hormuz maritime traffic is halted. There is a global sense of urgency to clear the shipping lanes in and out of the Arabian Gulf to continue the safe flow of oil, food, and other essential imports and exports.

An EOD team with a family of UUV systems rapidly deploy to the area from a US Navy helicopter. Two EOD technicians, a rigid hull inflatable boat (RHIB) (designed to operate in a minefield), and the UUV systems are employed from a helicopter into the waters adjacent to the suspected minefield. Four pre-programmed UUVs and an accompanying command and control module are employed to simultaneously and conjunctively search a pre-determined shipping lane through the suspected minefield. As each UUV acquires a mine-like object with a high degree of certainty during its search, it deploys a smaller tactical UUV from an aft compartment that is "geo-locationally" synchronized with the mother UUV. The mother UUV continues its search as the tactical UUV swims toward the target. Comprised of a small search camera, a deployable explosive counter-charge, and now controlled by the EOD technicians through the command and control module, the tactical UUV arrives at the location of the mine. Through the command and control module, the EOD technicians take steering control of the small UUV and identify the object as a mine utilizing a video screen linked to the tactical UUV's camera. The EOD technicians use the tactical UUV to place a counter charge next to the mine, back the small UUV away, initiate the counter-charge, and detonate the sea mine. After the detonation, on command, the tactical UUV automatically swims back to the mine's location and the EOD technicians, through video feed, verify that the mine is properly neutralized. The tactical UUV, utilizing "come home" technology, swim to a preprogrammed rendezvous point for recovery and reuse. This process continues until the entire suspected minefield is searched and all threats are neutralized in a similar manner within a shipping lane. A shipping lane is cleared and open within six hours of the on-scene arrival of the system of UUVs and the EOD team.

While this operating concept would rely on technologies that may not be readily available today (especially with regards to mine recognition utilizing only sensors, communications, and command and control), from a platform perspective, there are existing UUVs today that could be used as prototypes or a starting point to bring this concept to reality. The Mk 18 family of systems would be a great starting point for a "mother UUV" as they already conduct MCM searches. They would need to be outfitting with an additional compartment that enables them to carry and launch smaller tactical UUVs for sea mine pursuit and interrogation. Further, software enhancement would need to be made to enable real-time mine recognition, but there is already demonstrated potential in this arena from Northrop Grumman during a 2018 exercise where they demonstrated its µSAS and real-time automated target recognition technologies that can operate off a man-portable autonomous underwater vehicle for real-time classification of mine-like objects.[44]

Concerning a smaller tactical UUV, various commercial off-the-shelf (COTS) solutions would make good prototypes. For example, the Geneinno Titan T1 underwater drone can dive to 492 feet (greater than an EOD diver can dive), has an integrated camera, and has a robotic arm that can carry and drop an explosive charge.[45] Required advancements to a prototype like this would include an ability to marry up to and be launched from a mother UUV, an ability to geo-spatially synch with the mother UUV and autonomously drive to a set location, be networked into a command module

44 "Northrop Grumman Showcases Autonomous Maritime Capabilities at U.S. Navy's Advanced Naval Technology Exercise," Northrop Grumman Corporation, September 18, 2019, *https://news.northropgrumman.com/news/releases/northrop-grumman-showcases-autonomous-maritime-capabilities-at-u-s-navys-advanced-naval-technology-exercise*.

45 "Geneinno T1, 1st professional diving drone that can equip with robotic arm," geninno, 2020, *https://geneinno.us/products/geneinno-t1*.

A UUV as it is departs on a mission. Unmanned Underwater Vehicle (UUV) operator Art Kuykendall, attached to Commander, Task Group (CTG) 56.1, guides a UUV as it is departs on a mission. CTG 56.1 provides mine countermeasure, Explosive Ordnance Disposal, salvage diving, and force protection for the U.S. 5th Fleet. (U.S. Navy photo by Mass Communication Specialist 2nd Class Scott Raegen/RELEASED) *https://www.dvidshub.net/image/869457/uuv-operations*

for "piloted" maneuvers, employ and remotely detonate an explosive charge, and "come home" for recovery.

Perhaps the most complicated aspect of this operating concept is the ability to command and control the networked system of UUVs. While technology may not yet enable a sophisticated network of networks today of this kind, it is not too far-fetched to be ready and available in a matter of years. Through research, experts have already shown some promise in the feasibility of underwater acoustic streaming of camera and sonar data, further indicating that live underwater acoustic streaming is a realistic capability of UUVs.[46]

Other manned/unmanned system operating concepts

These two operating concepts are only a "sample size" of concepts that should be explored and developed. There is significant room for more ideas that leverage unmanned systems in the undersea domain. Just to highlight a few, UUVs can be implemented into new operating concepts to enhance submarine warfare, undersea ISR missions in confined or contested waters, strike missions, force protection of undersea infrastructure and key ports, force protection of warships and submarines, and naval special warfare operations.

Developing the capability - smartly!

Once operating concepts have been developed, developing the coinciding manned/unmanned systems will require a calculated approach. First, an iterative process for developing these systems is required. Second, developing cohesiveness amongst the key stakeholders will be paramount. Third, counter-UUV capabilities should not be forgotten.

46 Bas Binnerts et al, "Development and Demonstration of a Live Data Streaming Capability Using an Underwater Acoustic Communication Link" *IEEE*, 2018, *https://ieeexplore.ieee.org/document/8559159/metrics#metrics*.

It is critical to first point out that there naturally will be an iterative process between implementing new operating concepts and developing the capabilities that the concepts govern. Many (or most) of the US Navy's unmanned systems are currently in the research and development stage, but the capabilities that these unmanned systems possess will have to be operationalized.[47] In other words, certain UUV capabilities that are in development or that exist today can and should be leveraged as prototypes. These prototypes should be further developed by the Navy's applicable warfare centers, then put into the hands of operators in the fleet to test and assess the capability, and then returned to the developers to further refine the capability. While there will be an inherent degree of flexibility in the iterative process, this process should be well defined and managed to prevent long development times and increased costs that often come from loosely managed research, development, engineering, and acquisition processes.

Second, cohesiveness among the critical stakeholders, such as the Navy's pertinent warfare centers, operational units, and even industry,[48] is crucial to operationalizing the concepts. While the process should not circumnavigate the Navy's research, development, engineering, and acquisition processes, formal procedures should be formed within the confines of the processes and should leverage already-existing cooperation efforts between DoD and industry.[49] Some examples of how to better develop cohesiveness amongst stakeholders include:

- Formalizing working groups or mini "task forces" comprised of key stakeholders to collectively get after the solutions.
- Providing clear guidelines and "operating lanes" and communicating them to the Navy's warfare centers to prohibit unnecessary warfare center competitions that could otherwise hinder collective progress.
- Leveraging think tanks that have established relationships with industry or with emerging technology efforts and bringing them into the fold.
- Considering incentives that could be offered to industry to increase willingness to participate.

Third, as new operating concepts are developed for manned/unmanned systems, it would be foolish to forget or to not acknowledge that US adversaries could and likely will be maturing and developing innovative concepts of their own. Similar to the Department of Defense's massive effort to counter US adversaries' use and weaponization of small unmanned aerial systems in recent years, counter-UUV capabilities will be of importance moving forward.[50] To a large degree, a reliance on the intelligence community will help the US military avoid technological or strategic surprise that could come from encountering an adversary's new underwater capability without a plan to counter or defend against it.

Engaging our partners about unmanned undersea systems

Military-to-military engagements have paid huge dividends for the United States in building and maintaining a large network of global partners and allies; this network remains one of the United States' bedrocks for global strength. As emerging technologies and UUVs continue to develop, there will be opportunities that expand both within and even beyond military engagements to further build on current partnerships and establish new ones. Beyond UUV uses and operating concepts already described in this paper, UUVs present an opportunity to create partnerships in new ways to include for law enforcement and economic purposes.

Within the law enforcement arena, UUVs can play a key role as the United States and other nations, specifically in Central and South America, work together to counter drug trafficking. One common tactic for narco-smugglers is the increased use of narco-submarines or semi-submersibles, which provide a covert means to avoid cargo searches and law enforcement presence at border crossing.[51] For example, in 2015, US authorities caught a narco-submarine trying to smuggle over seven tons of cocaine (valued at hundreds of millions of dollars) off the coast of El Salvador.[52] Similarly, in 2016, the US Coast Guard caught a narco-submarine

47 Lauren C. Williams, "Navy seeks unmanned fleet, but Congress needs convincing," Defense Systems, February 5, 2020, *https://defensesystems.com/articles/2020/02/05/navy-unmanned-underwater-williams.aspx*.

48 Ben Werner, "Huntington Ingalls Industries Planning for Increased U.S. Navy Demand for UUVs," USNI News, February 13, 2020, *https://news.usni.org/2020/02/13/huntington-ingalls-industries-planning-for-increased-u-s-navy-demand-for-uuvs*.

49 Justin Doubleday, "Pentagon eyes next generation of autonomous weapon systems," Inside Defense, January 27, 2020, *https://insidedefense.com/daily-news/pentagon-eyes-next-generation-autonomous-weapon-systems*.

50 "US Department of Defense spending on counter-UAS reaches USD 1.5 billion in 2018," Unmanned Airspace, November 4, 2018, *https://www.unmannedairspace.info/counter-uas-systems-and-policies/special-report-us-department-defense-spending-counter-uas-reaches-usd-1-5-billion-2018/*.

51 Kyle Mizomaki, "Why Our Seas Are Suddenly Swimming With Drug-Running Narcosubs," *Popular Mechanics*, March 4, 2020, *https://www.yahoo.com/news/why-seas-suddenly-swimming-drug-223400474.html*.

52 Associated Press, "US navy seizes submarine with seven tonnes of cocaine on board," *The Guardian*, July 22, 2015, *https://www.theguardian.com/world/2015/jul/23/us-navy-seizes-submarine-with-seven-tonnes-of-cocaine-on-board*.

attempting to smuggle six tons of cocaine three hundred miles west of Panama.[53] While successful in some cases, these discoveries require significant manpower, assets, and surveillance tools across commonly used smuggle routes. UUVs or other undersea reconnaissance tools could be force multipliers to patrol, detect, identify, track, and communicate narco-submarines or semi-submersible to appropriate authorities and can stimulate increased or new partnerships as the United States and other countries in the region look to mutually benefit from a decrease in drug trafficking.

UUVs can also play contributing roles in building a nation's economic prosperity, specifically with regards to offshore commodities such as oil and seafloor minerals. Many of the US partners in the Middle East rely on offshore oil to drive their economies. For example, oil makes up around 50 percent of gross domestic product (GDP) in Kuwait and Qatar and remains a major component in the economies of Saudi Arabia, Oman, UAE, and Bahrain.[54] And, the global marine mining market is estimated to be a seven billion dollar industry by 2026 (up from a 500 million dollar industry in 2017) due to the increasing depletion of global terrestrial metal deposits.[55] Numerous commercial industries, such as Oceaneering, utilize ocean-friendly remote operated (tethered) vehicles today for roles such as undersea oil facility inspections or to conduct maintenance.[56] Imagine the advantages of doing this offshore work completely autonomously, without the need for an offshore platform from which to humanly launch, drive, and recover the vehicle. Similarly, imagine a UUV being able to autonomously pilot to undersea mines to assist with collecting and transporting these valuable mineral commodities. Most importantly, the partnerships that the United States can form by engaging and sharing these emerging technologies with allies for these purposes is immense.

53 "US Coast Guard intercepts vessel carrying cocaine worth $200m," BBC News, March 29, 2016, *https://www.bbc.com/news/av/world-us-canada-35915232/us-coast-guard-intercepts-vessel-carrying-cocaine-worth-200m*.

54 Antonio M. Ollero et al, *Economic Diversification for a Sustainable and Resilient GCC*, World Bank Group, December 2019, *http://documents.worldbank.org/curated/en/886531574883246643/pdf/Economic-Diversification-for-a-Sustainable-and-Resilient-GCC.pdf*, 25.

55 "Marine Mining Market to Estimated Reach Worth US$ 7.0 Bn by 2026," Crypto Journal, January 26, 2020, *https://cryptonewsgazette.com/marine-mining-market-to-estimated-reach-worth-us-7-0-bn-by-2026/*.

56 "ROV Systems," Oceaneering International, Inc, n.d., *https://www.oceaneering.com/rov-services/rov-systems/*.

Assumptions

A few core assumptions should be highlighted with regards to this strategy. First, there is an underlying assumption that the United States will maintain ambitions to prohibit its biggest competitors (China and Russia) from gaining a competitive military advantage within any warfighting domain. This assumption is supported by language within the National Defense Strategy that includes a Department of Defense objectives to "sustain Joint Force military advantages, both globally and in key regions" and "investing broadly in military application of autonomy, artificial intelligence, and machine learning, including rapid application of commercial breakthroughs, to gain competitive military advantages."[57]

Second, and an assumption that closely ties with the first, China and Russia will continue to develop a robust undersea unmanned system capability. As highlighted in the "strategic context" of this paper, both Russia and China are already and are continuing to pursue various UUV programs and platforms. As the United States nearest peer in undersea warfare strength, Russia will certainly look to gain an advantage in this arena over the United States if it can. And, as China seeks to continue to spread its influence and dominance across the South China Sea, it too will likely continue to develop UUVs that provide it with regional advantages.[58] Should this assumption be wrong, the United States would gain an even more significant undersea warfare advantage relative to its peers. But assuming it is correct, the United States, in kind, needs to develop similar capabilities in order to avoid losing its advantage in the undersea domain.

Finally, US adversaries will assumingly continue to exploit US UUV capabilities and use them to their own advantage. China, especially, has been suspect of stealing intellectual property with concerns to military equipment and will likely continue to do so.[59] In other words, as the United States develops new and advanced UUV capabilities, it is likely that similar types of these capabilities will be developed by its adversaries.

57 *National Defense Strategy*, US Department of Defense, 2018.

58 Gina Harkins, "China's Antics Are a 'Game-Changer' for the Navy and Marine Corps, 4-Star Says," *Military.com*, January 16, 2020, *https://www.military.com/daily-news/2020/01/16/chinas-antics-are-game-changer-navy-and-marine-corps-4-star-says.html*.

59 Sinéad Baker, "The US says China is stealing technology to modernize its military, and that could erode American dominance," *Business Insider*, May 3, 2019, *https://www.businessinsider.com/us-accuses-china-steal-military-technology-2019-5*.

Guidelines for Implementation

Concerning strategy implementation, a few guidelines are worth specifying. First, the United States should prioritize developing offensive capabilities first, before focusing on defensive capabilities. Second, existing technologies should be leveraged to the fullest extent possible. Third, the use of a crawl-walk-run approach is advisable as the operating concepts are finalized and fully implemented.

In an age of great power competition, the development of operating concepts that incorporate UUVs should be viewed in light of both China and Russia. The National Defense Strategy already calls on the Department of Defense to "increase lethality," add "advanced autonomous systems," and "expand our competitive space, seizing the initiative to challenge our competitors where we possess advantages and they lack strength." In other words, the United States should boost US superiority in exisiting areas of advantage—to include undersea offensive power. Given the United States' undersea superiority over China and Russia, the United States needs to strengthen this superiority and focus on giving China and Russia yet another undersea warfare problem to deal with in addition to the world's most elite submarine force.

Second, developing advanced UUV should be done by "piggy-backing" on UUVs that are already developed and in use by both the military and private industry. Adding components, such as an explosive warhead or an acoustic guidance package, to an already existing UUV to make it useful in combat applications will decrease cost as opposed from building a UUV program from the ground up. Utilizing already existing UUVs as prototypes and iteratively developing them for use within these new operating concepts is the smartest and quickest approach.

Finally, a crawl-walk-run approach to implementing new operational concepts is essential. During the "crawl" or "test" phase, UUVs should prove their ability to perform standalone tasks in a controlled environment and prove their ability to integrate into command and control networks. In the "walk" phase, UUVs should be integrated with manned systems (such as submarines or surface vessels) during military exercises and incorporated into pertinent war games. This phase should focus on testing assumptions, experimenting within the operational concept, tweaking the operational concepts in light of adversary actions or the nature of the threats, maintaining a pulse on emerging technologies, and making adjustments along the way. Lastly, in the "run" phase, UUVs should be utilized and employed operationally and incorporated into current, future, and contingent operations to include being written into associated operational and contingency plans.

Risks, Criticisms, Alternatives

Several criticisms, arguments against, and risks of this strategy are worth addressing. First, why should the US military rely more on unmanned systems since US submarines alone arguably already give the United States undersea superiority? In short, UUVs will likely not replace submarines (at least any time soon) but will be complementary to US submarines. UUVs can augment submarine lethality (a notion highlighted in the 2018 National Defense Strategy) or augment submarines during other operational missions. Specifically, as a far cheaper alternative to a submarine, UUVs can provide protection for submarines or be an "indicator and warning" tool to sense or identify potential threats before a submarine finds itself in unnecessary danger. Further, UUVs can conduct missions in hostile or contested water that would otherwise put a submarine in high risk situations. Finally, as US competitors continue to field their own UUVs for military purposes, the United States too should utilize the offensive and defensive military advantages that UUVs offer.

A second criticism of this strategy is that the increased production of UUVs will create risk for an "undersea arms" race. This is unlikely. While there is a large degree of autonomy in some of today's UUVs, the UUVs described in the operating concepts within this strategy will have complexities concerning system-of-system integration and in the ability to command and control these systems. These complexities alone will likely prevent most countries from developing these systems, at least in the near term.

Third, and a natural concern stemming from the last criticism, will US adversaries seek to capture and exploit UUV systems in order to steal or attempt to replicate the technology? This is a valid concern and something that China has already done with US UUVs.[60] While there may be technological solutions that can be built into UUVs to counter this problem (e.g., a mechanism for total UUV self-destruction or "smartchips" that self-destruct or scramble software code when tampering is suspected), this is an area in which the United States should be OK assuming risk. Why should the United States assume this risk? First, UUVs are not ships or submarines (which contain much more sensitive equipment) and would otherwise be the assets conducting these missions. So, in a relative sense, it warrants being OK with this risk. Second, an advantageous tradeoff to assuming this risk is that the United States could invest less money and save cost on the survivability of these systems.

Fourth, will offensive UUV concepts like the ones mentioned in this paper be mimicked and used against the United States? While this is a valid concern, it is not a concern that should prohibit development. Operating concepts like these will likely be used against the United States even if the United States does not develop them first. There is value in increasing lethality, being on the leading edge of these types of concepts, and posing complex problems for US adversaries that they will have to consider and overcome.

Fifth, as UUVs and other underwater systems begin to proliferate across the oceans globally, will concepts that utilize these technologies diminish the stealth of submarines and thus lessen the United States' undersea nuclear deterrent? As more maritime systems with "eyes and ears" are utilized, there could be a level of global (or at least regional) transparency that will begin to materialize globally within the undersea domain—similar to how a network of globally positioned satellites with high resolution cameras have brought a high level of transparency to the Earth's surface. This undersea transparency would indeed hinder a submarine force's ability to remain stealthy. To mitigate the risks associated with decreased stealth, a couple of solutions could be considered. First, undersea stealth technology could be improved. Second, submarines may have to accept an increased level of undersea transparency and alter their own operating concepts to best mitigate being seen or heard.

60 H. I. Sutton, "China Discovers Underwater Spy Drones In Its Waters," *Forbes*, January 15, 2020, *https://www.forbes.com/sites/hisutton/2020/01/15/china-discovers-underwater-spy-drones-in-its-waters/#7a506b4d6990*.

Conclusion

This paper presented a strategy for how the United States can maintain undersea superiority against its competitors in an age of unmanned systems. It provided an overview of current US undersea capabilities (manned and unmanned systems) and similar capabilities of its biggest competitors—China and Russia. The paper then discussed that, in light of both rapidly evolving emerging technologies and guidance stemming from both the National Defense Strategy and the Navy's 2019 "Design for maintaining maritime superiority," UUVs will play a critical role in giving the United States continued dominance in the undersea domain. Next, it laid out steps the US Navy could take to successfully implement UUVs into undersea warfighting operational concepts. Further, it provided detailed operational concepts specific to mine warfare and highlighted how current technologies could be improved, consolidated, and applied into more innovative ways to conduct offensive mining and mine countermeasures. Then, it provided guidelines in implementing the strategy to include prioritizing the development of offensive versus defensive capabilities, and then laid out a crawl-walk-run approach to operationalizing new manned/unmanned system operational concepts. Finally, the paper considered and rebutted the most common criticisms and risks associated with the recommended strategy.

About the Author

Commander Erich C. Frandrup was the academic year 2019 to 2020 Senior US Navy Fellow at the Scowcroft Center for Strategy and Security of the Atlantic Council. In this role, he focused his research and writings on maritime security in the Arabian Gulf region and on the integration of drones into security and defense operational concepts.

Originally from Newport, Washington, Commander Frandrup received his commission from the United States Naval Academy in 2002 with a Bachelor's of Science degree in Ocean Engineering. He was selected into the Navy's Explosive Ordnance Disposal (EOD) community upon graduation.

Throughout his eighteen-year military career, Commander Frandrup deployed four times to the Middle East to include two deployments to Bahrain in support of the Navy's 5th Fleet and two deployments to Iraq in support of Operation Iraqi Freedom. He was most recently assigned to the Joint Staff where he served as both the EOD action officer in the Operations Directorate (J3) and then as the Executive Assistant to the Deputy Director for Nuclear and Homeland Defense Operations (J36).

Commander Frandrup is a qualified EOD officer, surface warfare officer, and a basic dive officer. He also holds a Master's of Art degree in National Security and Strategic Studies from the United States Naval War College and a Master's of Science degree in Mechanical Engineering from Duke University. Commander Frandrup assumed command of the Naval Diving and Salvage Training Center in Panama City Beach, FL in August of 2020.

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