Spring 2020 Undersea Domain Industry Study

Final Report: Resourcing a Competitive Undersea Domain

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ABSTRACT

The undersea domain remains key to national security and global trade. The U.S. must invest in a portfolio of undersea recommendations that considers full cost-spectrum capabilities, protects critical infrastructure, enables new technological gains, and postures industry to maintain asymmetric advantage during great power competition. The research conducted in this study identifies challenges in the U.S. defense industrial complex. The undersea industry cannot scale and mobilize using traditional means. Initiatives expressed in this document present steps to resource the undersea industrial ecosystem appropriately, refine UUV requirements, enhance competition in the industrial base, reorient the current shipbuilding paradigm, and augment diplomatic efforts. In addition to having the world's greatest sailors, our recommendations will ensure the U.S. Navy can continue to provide an asymmetric undersea advantage.

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RESEARCH METHODOLOGY

This research culminates in an eleven-month program of study at the National Defense University's Eisenhower School. The 2020 Undersea Domain Industry Study brought together eighteen faculty and students from seven agencies and four branches of military service. From January to May 2020, students gained an in-depth understanding of the undersea domain through individual and group research using a wide range of publications and multi-media sources. They also engaged with the private sector, academic, Congressional, and Department of Defense representatives to analyze the undersea industrial ecosystem and form policy recommendations. Their cumulative research and investigations yielded this study, which includes an executive summary, an expansion on key industry issues (Appendix A), and a collection of abstracts from individual student papers for reference and further exploration.

INDUSTRY STUDY OUTREACH AND FIELD STUDIES

Field Studies – Domestic

- U.S. House of Representatives, Chairman Sea Power Subcommittee, Washington, D.C.
- U.S. Navy, Director, Undersea Warfare Division, Washington, DC.
- U.S. Navy, Commander, Naval Sea Systems Command (NAVSEA), Washington, D.C.
- U.S. Navy, Commander, Submarine Force Atlantic (COMSUBLANT), Norfolk, Va.
- U.S. Navy, Commander, Undersea Surveillance (CUS), Virginia Beach, Va.
- U.S. Navy, Program Executive Officer for Submarines (PEO SUBS), Washington, D.C
- U.S. Naval Research Laboratory, Washington, D.C.
- Defense Information Systems Agency, Fort Meade, Md.
- Pennsylvania State University Applied Research Laboratory, University Park, Pa.
- SubCom, LLC, Baltimore, Md.
- Huntington-Ingalls Industries, Newport News Shipbuilding, Newport News, Va.
- USS Pasadena (SSN-753), Norfolk, Va.
- Atlas North America, Yorktown, Va.

Virtual Field Studies – Domestic

- Naval Reactors, Washington
- U.S. Navy, Director, Surface Warfare Division, Washington, D.C.
- U.S. Navy, Undersea Warfare Development Center, Newport, R.I.
- Commander, Unmanned Undersea Vehicle Squadron One (UUVRON-1), Keyport, Wa.
- U.S. Navy, Director, Undersea Technology (NAVSEA), Washington, D.C.
- Congressional Research Service, Washington, D.C.
- General Dynamics, Electric Boat, Quonset Point, R.I. and Groton, Ct.
- BAE, Riptide Autonomous Solutions, Plymouth, Ma.
- Teledyne Marine Systems, North Falmouth, Ma.
- Woods Hole Oceanographic Institution, Woods Hole, Ma
- Hydroid Inc., Pocasset, Ma.
- L3 Harris, Unmanned Maritime Systems, Fall River, Ma

Virtual Field Studies – International

- Saab-Kockums, Karlskrona, Sweden
- NEC Corporation, Tokyo, Japan
- Thyssen-Krupp Marine Systems, Bremen, Germany

EXECUTIVE SUMMARY

All four pillars of the U.S. National Security Strategy (NSS) - protecting the homeland, promoting American prosperity, preserving peace through strength, and advancing American influence in the world – begin at sea. Economic prosperity depends on the freedom of navigation secured by the U.S. Navy. The resources needed to fulfill the demands of the NSS are increasing as great power competition with China and Russia escalates. Anticipated downward pressure on the U.S. defense budget will compel the U.S. to carefully invest its economic and diplomatic resources to maintain the continued strategic advantage in critical areas of the undersea domain.

Much of the world's commerce, food production, and communications depend on the ocean environment. More than ninety-nine percent of international communications travel via undersea fiber optic cables.[1] Over ninety percent of world trade relies on maritime transport, and over half the world's oil supply transits by sea.[2] Ninety percent of crude oil volume flows through a single chokepoint: the Straits of Malacca.[3] Consequently, China, which depends on imports for 70 percent of its oil supply,[4] has a strong incentive to control the South China Sea, through which 15 billion barrels pass per day (Figure 1).[5]

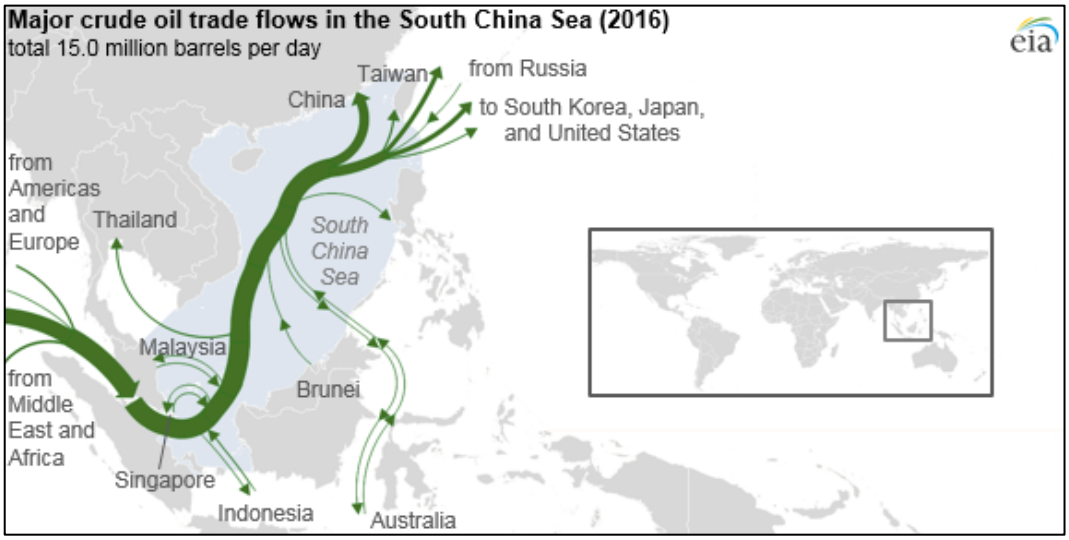


Figure 1 Depiction of the world's oil flow through the Straits of Malacca and into the South China Sea.[6]

The desire for regional influence has pushed China's fleet to over 400 ships[7] to match the U.S. power projection. The U.S. Navy's modus operandi – maritime superiority operating across the globe from the littorals to the high seas – remained unchallenged for decades. The primary missions of sea control, power projection, strategic deterrence, strategic sealift, and forward presence combined to form the pillars of international peace and economic stability. That peace drove worldwide prosperity and growth. Challenges to the status quo arising from a resurgent Russia and growing China - formidable countries ruled by autocratic governments - seek to disrupt the current global hierarchy. Although the capability gap between near peers has narrowed in several naval warfare domains, the U.S. Navy retains a paramount strategic military advantage in the undersea. Maintaining undersea dominance preserves the enduring maritime missions of the U.S. Navy as its surface fleet is particularly vulnerable. Its preservation necessitates renewed commitment from all stakeholders. To focus resources in an era of great power competition, the U.S. must invest in a portfolio of undersea recommendations that considers full cost-spectrum capabilities, protects critical infrastructure, enables new technological gains, and postures industry to maintain an asymmetric advantage.

THE UNDERSEA INDUSTRIAL ECOSYSTEM

Undersea Domain

With 70 percent of the world covered by water, the undersea domain comprises a challenging environment for the defense, research, and commercial sectors. The demands of defending national interests in the domain are considerable. Manned and unmanned undersea vehicles, surface vessels, aircraft, weapon systems, sensors, and a variety of flora and fauna interact in harsh environments. Salinity, current, pressure, darkness, vast temperature range, and changing terrain make the undersea domain a treacherous place. The ocean boasts the world's largest mountain range and its deepest canyon. Nearly half of its waters are over 9,800 feet deep, with the ocean's deepest point at approximately 36,000 feet - roughly 7,000 feet greater than Mount Everest's elevation.

Defining the Undersea Defense Industrial Complex

The ocean contains tremendous resources, including energy, minerals, and food. Increasingly, coastal nations are exploring their undersea resources and improving their navigation, telecommunications cables, and energy production infrastructure for the undersea environment. The industrial base navigating this domain consists of both public and private entities that research, design, and produce undersea capabilities. Submarine cables, sensors, and offshore energy platforms represent major commercial ventures; however, a competitive market for undersea technology outside these platforms has not yet emerged. U.S. advances and innovation in the defense industrial base for the undersea domain are heavily dependent on government investment. Currently, the U.S. does not proliferate or make foreign military sales of submarines [8]

Those countries and companies that do compete in the international market experience high competition and operate on profit margins below 2 percent rather than the 8-10% experienced domestically.[9] Thyssen Krupp Marine Systems, Naval Group, Daewoo Shipbuilding and Marine Engineering (DSME), and Saab-Kockums are a few of the foreign companies offering complete submarine production. The submarine and maritime systems portfolio is even more expansive, providing undersea defense solutions worldwide. Sales of diesel-electric submarines, as measured by quantities manufactured and sold, make up the largest segment of the international market (See Appendix B).

The majority of this report focuses on recommendations within the U.S. submarine and unmanned underwater vehicle (UUV) space while acknowledging the entire ecosystem is much broader, providing complementary and substitute capabilities across the cost spectrum. This industry study focuses on a subset of the ecosystem that produces and sustains undersea weapon systems - submarines, unmanned underwater or autonomous underwater vehicles, and acoustic systems in support of the most recent NSS and National Defense Strategy (NDS), both published in fiscal year 2018.

The domestic undersea industry divides between competitive markets and a monopolistic submarine market. The competitive market is for smaller undersea platforms. Several domestic companies currently manufacture UUVs for military, commercial, and academic customers. Most of these companies compete for U.S. government (USG) business. On the other end of the spectrum (with several barriers to entry) sit the nuclear submarine makers: General Dynamics – Electric Boat (GDEB) and Huntington Ingalls Industries-Newport News Shipbuilding (HII-NNS). The U.S. Navy participates in a monopsony with these two companies. GDEB and HII-NNS work collaboratively to produce submarines and split the design-build responsibilities. This partnership reduces the competitiveness of the domestic submarine manufacturing market, disincentivizing private investment in research and development beyond Navy contract funding and driving up federal costs. The current arrangement subjects the taxpayer to significant risk of cost growth. The Congressional Budget Office (CBO) estimates the next-generation attack submarines may cost as much as $5.5 billion a copy,[10] substantially more than the

Navy estimate of $3.4 billion.[11] CBO contends that the Navy's estimate, which equates to the cost of the current Virginia Class submarines,[12] vastly underestimates costs for enhanced capabilities. The current submarine force structure is available in Appendix C.

The lack of competition between the two defense giants is not entirely harmful to them or the USG. The partnership maintains critical capacity that lowers national security risks by keeping two shipyards operational. The shipyards split high fixed costs, create economies of scale, promote cooperation, and bridge submarine expertise gaps to reduce liabilities. Furthermore, the economies of scale have led to significant reductions in production timelines. See Appendix D for a full analysis of the Domestic Submarine Market using Porter's Five Forces. The current production capacity is limited to 2 submarines per year.

Congress is hugely influential and anchors the iron triangle of policy along with bureaucracy and industry. The submarine firms employ a large workforce. Virginia-based HII-NNS employs over 23,000, while[13] GDEB employs nearly 17,000 in Connecticut and Rhode Island.[14] These employees make up an influential constituency for Congress. In comparison with the major public shipyards, the shipbuilding lobby carries significant weight, with thousands of manufacturing jobs at stake.

To further challenge these dynamics, UUVs are still niche and nascent, with multiple, geographically dispersed makers serving academic, industrial, and defense markets. Consequently, they do not have a mature Congressional support system or carry the weight, in terms of revenues or numbers employed, to develop that system independently. Future development of Congressional support will likely depend on whether or not the submarine manufacturers buy up these more innovative companies faster than they can create a network.

Finally, the government organizations central to this industry study may be at risk of missing emerging threats. Preserving existing ways of war can lead to failure to recognize new opportunities. Fleet headquarters organizations, such as Naval Systems Command (NAVSEA) and the Office of the Chief of Naval Operations (OPNAV), developed over time to execute post-World War II and Cold War methods focused around capital ships, "fighting the away fight," and iterative development of existing platforms. The stated mission of these organizations to manage existing threats through ready, reliable capabilities, limits latitude to develop new, cost-effective alternatives to nuclear submarines to achieve strategic and tactical advantage and adequately fund trials of these alternatives in the budget. When the Director, Undersea Warfare at the Pentagon (OPNAV N97) thinks about UUVs, he first envisions how to launch them from submarines, or how to best complement submarines. OPNAV N97 is not tasked with or positioned to determine how to deploy UUVs out of the back of an Air Force C-130. These joint warfighting concepts, however, may present the greatest opportunity going forward.

U.S. DEFENSE INDUSTRIAL COMPLEX CHALLENGES

Undersea Strategy Assumptions

In the post-World War II order, the U.S. Navy has provided the world freedom of navigation of the seas. No nation has contested U.S. naval dominance since the fall of the Soviet Union, and the world has benefitted with the U.S. serving as the sole honest broker and guardian of seas. Our position has allowed for a thriving global economy, free trade, and unfettered access to international waters. Today we can no longer take freedom of navigation - or the ability of the U.S. to maintain it - for granted. China's President Xi and Communist Party, through the invocation of the "9-Dash line," assert territorial rights to the majority of the South China Sea, a body of water crucial to international commercial shipping. China has established itself as a regional hegemony, claiming dominion over disputed islands and threatening to choke global commerce routes throughout the South China Sea. The militarization of these islands has changed the dynamic of access and sea dominance, creating a much more complicated operating picture in Southeast Asia. Countering the risks posed by China in the undersea environment

will require an innovative portfolio of strategies and a shrewd investment of resources. Attempts to create or retain every type of advantage in the worlds' oceans could quickly hollow U.S. force structure.

On the other side of the world, Russia's ability to change the "away game" to a "home game" played off America's shores signals the need for a strategy revision requiring greater wide-area search capability in the Atlantic. In the latter half of 2019, Russia deployed both the submarine *Severodvinsk* and the spy ship *Victor Leonov*. Rumors placed the *Severodvinsk* off America's eastern coast with potential payloads capable of placing population centers at significant risk.[15] [16]Additionally, the U.S. Coast Guard released a bulletin in December 2019 stating, "The United States Coast Guard has received reports indicating that the RFN *Viktor Leonov* (AGI-175) has been operating in an unsafe manner off the coast of South Carolina and Georgia."[17] Increased Russian activity in presumably "safe" waters should be a wakeup call for increased coastal defense capabilities and forces. Coastal defense has traditionally been the strategy of American allies and NATO partners, but Russia's increased capabilities make it an area the U.S. Navy cannot ignore. Moscow brought the "away game" closer to home.

The strategic realignment necessitated by these developments will require hard decisions. Strategy must involve linking capabilities to resources. Failure to eliminate requirements or seek cheaper, substitute capabilities represents risk aversion and leads to a hollow force structure. The Navy's stated force structure of 355 ships seems tenable at best, but with exogenous events such as COVID-19, the Nation will have limited resources to serve national interests adequately. Resourcing the strategy requires significant weight.

Submarines, in particular, are expensive military tools. The capability of the U.S. Navy is the envy of the world; however, the expense of the submarine fleet is growing without consideration of offset costs. The *Severodvinsk*, a Yasen class submarine, costs the Russians an estimated $1.5 billion.[18] The latest U.S. Virginia class submarines are $3.4 billion a copy.[19] The upcoming Columbia class will top an estimated $9 billion a copy,[20] and while both U.S. submarines may offer superior capability to the Yasen-class, it is uncertain they offer a $2-7 billion delta in deterrence.[21]

While the U.S. maintains an acoustic advantage, its peer competitors are attempting to narrow the gap. Increased density of sensors, the advent of UUVs, and rapid technological innovation present challenges for the undersea community, which anticipates new submarines designs once every twenty years. While modular capability and iterative production help to keep pace, large-scale submarines cannot iterate at the speed of low-cost sensors and UUVs. The ocean is becoming more transparent, especially in the areas where trade routes are most dense (and the warfighting domain most contested). Both near-peers continue to invest heavily in research and development in the undersea environment in an attempt to gain parity with the U.S. Refer to Key Industry Highlights in Appendix A to see advancements by great power competitors.

Basic Research expands the boundaries of contemporary knowledge and challenges capabilities through the exploration of theories and hypotheses. Basic Research is the pursuit of pure, observable facts "without any particular application or uses in view"[22] other than expanding knowledge of the world. It is the foundation that allows the U.S. to maintain superiority in the undersea realm. U.S. advancement in offset technologies forces deterrence as adversaries face bringing a knife to the gunfight. The U.S. undersea community conducts most of its basic research at USG run National Labs and the Applied Research Laboratory at Penn State University. However, the latest enacted DoD budget represents underinvestment in Basic Research with an overall decrease of $1.5 billion in 2020.[23]

Finally, the proliferation of technologies makes the ocean more transparent. Undersea domain visibility remains challenged by UUV proliferation and an increase in adversarial search technology. While the ocean's depths remain obscure, it is becoming clearer around the edges. UUVs afford greater sensory accessibility to previously-denied access areas along the adversary's seaboard, including coastal seas, rivers, ports, and harbors. UUVs enhance U.S. monitoring in key strategic areas, including the South China Sea and the Greenland, Iceland, United Kingdom (GIUK) gap in the North Atlantic, where

Russian submarines enter the ocean basin. However, potential adversaries are likely to make the same efforts in advancements.

Sustainment, Maintenance, and Readiness

To maintain competitive advantage and counter adversarial threats, in 2016, the Navy, in keeping with the results of a Force Structure Assessment, committed to increasing the fleet size to 355 ships. Nuclear submarines account for 78 vessels in the total fleet (with 66 fast attack and 12 ballistic missile variants).[24] The Navy did not subsequently publish a sustainment plan for a fleet of that size despite lagging in the current maintenance schedule with a fleet of 298 ships. The subset of the submarine force faces one of the largest gaps between current inventory and shipbuilding targets. Due to a disruption in submarine building in the 1990s and the retirement of the aging Los Angeles class submarines, current assessments suggest the number of available attack submarines will decrease by nearly twenty percent from 52 to 42 between FY2020 and FY2028 before steadily increasing to meet the 66-boat target by FY 2048.[25] Delays in the production of new submarines or completion of shipyard maintenance for existing submarines will only decrease the number of operational attack submarines available to the fleet.

Reaching the nominal fleet target requires schedule performance from the industrial complex not seen since the Cold War era. This massive undertaking by the Navy, paired with a substantial nuclear submarine maintenance backlog, has the potential to threaten the readiness of the submarine force. Further, an emphasis on schedule performance will likely drive up costs. The required doubling of nuclear submarine production to overtake decommissioning rates faces interruption. According to a Government Accountability Office (GAO) report in 2019:

> The 2018 National Defense Strategy emphasizes that restoring and retaining readiness is critical to success in the emerging security environment. The Navy is working to rebuild its readiness while also growing and modernizing its aging fleet of ships. A critical component of rebuilding Navy readiness is implementing sustainable operational schedules, which hinge on completing maintenance on time.[26]

The shipbuilding industry often seeks to maintain stable contracts to avoid switching costs of complex projects. That stability proves critical to the supply chain and the labor force: the financial feasibility to employ a large, skilled workforce with cyclical work is not attractive to the industry or Congressional delegations.

Capacity in Public and Private Shipyards and the Ability to Mobilize

Linked to the lack of sustainment forecasting is the actual capacity of the public and private shipyards to “lean in” on maintenance efforts. Maintenance of U.S. nuclear submarines occurs at the four public naval shipyards (Portsmouth, Puget Sound, Pearl Harbor, and Norfolk). Still, in recent decades private shipyards have also undertaken significant submarine maintenance in a more limited capacity. According to the GAO, “The Navy continues to face persistent and substantial maintenance delays that affect the majority of its maintenance efforts and hinder its attempts to restore readiness.”[27] The four public naval shipyards are overwhelmed with refueling and maintenance work on Ohio-class submarines, Virginia-class submarine upgrades, and Los Angeles-class overhauls. The shipyards do not have space or capacity for the current demand. The current backlog leaves no room for surge capability.

Additionally, throughout the industry study, speakers from both government and industry emphasized the theme of skilled and professional labor shortages. Specifically, welder and engineer staffing challenges prevent scaling up the industry in a significant manner beyond the current capacity. The two professions have distinct problems. Defense contractors and their supply chains - regardless of size - struggle to compete with Silicon Valley for top talent. Recently an executive from Nvidia

Corporation remarked that an entry-level intern at Nvidia has greater access to supercomputers and Artificial Intelligence and Machine Learning than the entire DoD.[28] These anecdotes point to a gap between the defense industrial base and the broader economy that needs to close. National security requirements related to hiring foreign nationals further exacerbates the engineering gap.

For welders, the shortfalls correlate to generational demographics, past economic cycles with shipbuilding, and a broad cultural shift away from blue-collar work. The market for engineers, on the other hand, is highly competitive. Federal efforts to support and supplement job training dating back to the Woodrow Wilson administration, seem to promote rent-seeking behaviors within the economy. Private solutions showed more promise. Recent efforts at the local level, such as those run by both GDEB and HII-NNS, show reliable, measurable results for both the companies and the region.

Combined, all of these capability and human capital issues present a challenge for the industry to mobilize beyond two nuclear submarines per year. The production capacity of the industry seems strained at the current pace. Producing 32 submarines in a single year – as accomplished singularly by Portsmouth Naval Shipyard in 1944 – is not plausible in the modern-day using all the combined shipyard capabilities. The industry will have to look outside traditional nuclear submarine production and maintenance for scalable undersea warfighting capabilities in the face of conflict. UUVs, allied diesel submarines, allied shipyard maintenance, and lower cost array systems present scalable and lower cost mobilization capability.

POLICY RECOMMENDATIONS ALIGNED WITH NATIONAL STRATEGY

In an era of enhanced great power competition, the U.S. must maintain its strategic advantage in the undersea domain. This advantage underpins the U.S.'s ability to project power globally, to deter other nations or actors from utilizing nuclear weapons, and to enforce adherence to international norms at sea. Critical to world commerce, exports contribute over twelve percent of U.S. gross domestic product, and U.S. companies utilize low-cost imports in many of the products sold domestically. The ability to buy and sell internationally will continue to drive economic growth, with over three-quarters of the world's buying power outside of U.S. borders.[29]

To enable U.S. businesses to continue to compete globally, the U.S. must develop and implement a portfolio of strategies to carefully direct investments in the undersea domain. This portfolio includes initiatives to *resource the undersea ecosystem appropriately, refine UUV requirements, enhance competition in the industrial base, reorient the current shipbuilding paradigm, and augment diplomatic efforts.* These recommendations combine to fuel innovation, focus on capability and capacity development, and make flexibility and cost-effectiveness critical components of U.S. strategic advantage.

Resource the Undersea Ecosystem Appropriately

Pillar I of the National Security Strategy is to "Protect the American people, the homeland, and the American way of life." Maintaining an advantage in the undersea domain during this period of great power competition will require innovative approaches to address the industrial base and align incentives for increased innovation and lower costs. The U.S. needs a comprehensive assessment of Naval warfare strategies to determine an approach that looks beyond near-term capacity challenges to sufficiently balance national security with the efficient use of taxpayer dollars. If the Navy fails to provide alternatives to the traditional nuclear submarine production model, it risks repeating delays and cost overruns from decisions to postpone submarine procurement and condense production timelines for an already stressed industrial base.[30]

Pillar II of the NSS "Promote American Prosperity" requires a prudent expenditure of American taxpayer dollars. With Naval fleet investment that the Congressional Budget Office states, "Would require shipbuilding appropriations that are more than 50 percent larger than the Navy's average

funding for shipbuilding over the past five years,"[31] alternative capabilities deserve consideration. Funding innovation through basic research and developing a mixed fleet of lower-cost undersea capabilities merit execution to extract value from appropriated tax dollars.

Continue to fund the Columbia Program as the Navy's #1 priority. Columbia provides the strategic deterrence backbone of the Nation. It serves the NSS in every pillar and provides the traditional submarine industry a stable production pathway. Assured nuclear strike capability provides a proven deterrent that is cost-effective.

The Navy and Congress should increase Basic Research funding to 8 percent of the total R&D budget and set a baseline floor of $2 billion. Innovation is the birthplace of technological gains and asymmetric advantages. Advantages occur through experimentation, evaluation, and development; a cycle referred to as Research and Development (R&D). The stages of R&D, in order of progression, are Basic Research, Applied Research, Experimental Research, and Development.[32] While the Navy touted an increase in research and development, the proposed allocation of these funds prioritizes the last phase of R&D (Development and Prototypes), receiving 88 percent of the funds with only 3 percent going to Basic Research.[33] Underinvestment represents a significant reduction in the historical allocation ratio.[34] Much of this spending included UUV prototyping rather than assigning a definite program of record. Allocating R&D funds to Basic Research will fuel U.S. technological advantage in the undersea domain.

Create a broad mixed fleet of undersea capabilities with UUVs anchoring growth. The American nuclear submarine has dominated the oceans for nearly a half-century. Dr. Matthew Napoli aptly pointed out, "Nuclear-powered warships provide a nation with a destabilizing, asymmetric military advantage due to their stealth, speed, maneuverability, and almost limitless endurance."[35] The envy of the world, nuclear submarines, offer an advantage in endurance, speed, and power generation as the standard-bearer for acoustic advantage and stealth.

However, there are some downsides to an all nuclear fleet. Lower cost undersea options offer advantages in cost savings, production scalability, reduced nuclear training time, smaller crews, increased international port access, increased domestic repair facilities, and allied interoperability. For example, Boeing received a $43 million fixed-price contract to deliver 4 Extra Large UUVs (Figure 2).[36] 4 less-capable undersea vehicles at 130 times cheaper the price of the $5.5 billion next-generation attack submarine offers cost advantages that are attractive trade-offs for capability gaps.

Figure 2. The Boeing Company's Echo Voyager, a diesel-electric unmanned undersea vehicle, serves as the basis for Boeing's current contract with the U.S. Navy to produce 4 Orca XLUUVs.[37]

Add diesel-electric submarines to the fleet. Similarly, manned diesel-electric submarines with air independent propulsion systems are currently available from several capable allies for a per-unit cost between $500 million and $750 million.[38] Rather than building from scratch, leasing the design from existing overseas companies and building in the U.S. has the potential to diversify and increase competition in the submarine manufacturing base while eliminating first model production issues. While UUV technology matures, tactics, techniques, and procedures for smaller, shorter endurance submarine capabilities can be developed in conjunction with allied partners using these manned platforms. Exercising against U.S. nuclear crews would prepare those nuclear crews for overseas diesel-electric threats and, conversely, season diesel-electric crews in hunting nuclear adversaries. Coupled with cabled arrays and other sensor platforms, cheaper platforms could conduct missions that do not require months of endurance and provide a cheaper solution to the growing coastal defense threat while freeing up superior nuclear submarines for the "away game."

> As the Commander of Navy's 2nd Fleet, Vice Admiral Andrew Lewis stated in February 2020: Our new reality is that when our sailors toss the lines over and set sail, they can expect to be operating in a contested space once they leave Norfolk. Our ships can no longer expect to operate in a safe haven on the East Coast or merely cross the Atlantic unhindered to operate in another location. We have seen an ever-increasing number of Russian submarines deployed in the Atlantic, and these submarines are more capable than ever, deploying for longer periods of time, with more lethal weapons systems. Our sailors have the mindset that they are no longer uncontested and to expect to operate alongside our competitors each and every underway.[39]

Leverage Other Transaction Authorities (OTAs) to rapidly build a broad mixed fleet. The latest transformational acquisition policy change, the Adaptive Acquisition Framework, was published in January 2020 and includes a set of six new acquisition pathways to enable the workforce to tailor strategies to deliver better solutions faster. The entire undersea community is looking at maximizing use of these changes. In addition, continuing to leverage OTA instruments for smaller, less sophisticated systems reduces timelines, lowers costs, and innovatively avoids administrative burdens to provide the best capabilities. Both the "home" and "away" games receive benefits from mixed fleets including low-cost alternatives.

Identify UUV strategy and requirements

Pillar III of the NSS, "Preserve Peace Through Strength," requires a robust military to defend the Homeland, respond to challenges by our enemies, and, if required, fight and win. To achieve these ends, the Navy needs to renew its capabilities and regain overmatch. The NSS goes on to say, "To retain military overmatch the United States must restore our ability to produce innovative capabilities, restore the readiness of our forces for major war, and grow the size of the force so that it is capable of operating at sufficient scale and for ample duration to win across a range of scenarios."[40] UUVs answer the call to modernize, look to innovations in acquisitions, build capacity, and improve readiness and retain a full-spectrum force.

The Navy needs to count UUVs towards its 355-ship goal. As the U.S. Navy assesses its future force structure recommendations, UUVs will be an increasingly important part of the equation. Admiral Michael Gilday, the Chief of Naval Operations, asserted in January 2020 that UUVs would not count in the ship estimate.[41] Until the Navy codifies this forecast and the employment of unmanned systems in doctrine and plans, the predominant challenge will continue to be integrating UUV capabilities into operations and mission sets. While the Navy is committed to procuring UUV capabilities, the slow speed of integration and cultural resistance to their incorporation may impede the operational development of these promising systems. While later this research will suggest moving away from counting ships, while

this practice of counting the fleet remains enshrined in law, ignoring UUVs in that tally underestimates capability for force structure assessment calculus. A demand signal to industry and Congress should come from the CNO, and the Navy should revise its stance on including UUVs in the fleet estimate.

N97 should provide refined UUV capability requirements, and the Program Office (PEO) should enforce a single concept of operations for UUVs. The U.S. Navy must create a single, defined capability requirements document to employ unmanned vehicles. Currently, the Navy has four different UUV concepts of operations. Using targeted operational capabilities to refine these concepts of operations (CONOPs) can provide uniform standards that speak to combatant commanders in terms of capability rather than a platform. Clarification of UUV requirements will help the community provide bounds for endurance, required autonomy, support infrastructure, and command and control.

The Navy employs UUVs to perform dull, dirty, or dangerous tasks,[42] freeing high cost, low-density assets like submarines and minesweepers for other missions. As such, UUVs have the potential to reduce risk to sailors and act as force multipliers. As UUV capabilities move toward weaponization and greater autonomy, a policy should also address risk-acceptance and the ethical and legal frameworks for their deployment in territorial and international waters.

Combine Unmanned Vehicle (UV) communities into a single domain. The undersea community owes honest introspection as to whether it is the appropriate steward of UUVs. With a lack of a common operating picture and the affinity for stealth, underwater drones - operating with a lower threshold for loss or mission failure - run counter to the desire to remain the "silent service." With heavy influence from Naval Reactors Command, the submarine community rightfully frames problems from the nuclear submarine perspective. Transmission of data and relaying constant communication runs counter to the submarine community culture and tactics. Autonomous technology should mature outside this frame of reference. Programmatic requirements and doctrinal development for UUVs and Unmanned Surface Vehicles (USVs) should blend into a separate platform. UUVRON-1 already works closely with the USV community; however, the two communities are geographically separated and would receive mutual benefit from the development of tactics in a multi-domain common operating picture. Viewing the launch or recovery platform as merely a means may allow for the development of a complete UUV/USV strategy that is independent of its deployment vessel.

A UUVRON represents a capability that commanders in multiple domains could use effectively. The technology will mature, and it could ultimately benefit through a competitive rivalry in an era where UUVs begin to threaten manned submarines as a credible substitute within more mission sets. A unified community may also help alleviate the CONOPs as mentioned earlier differences, and, structurally, the USV and UUV communities already share a single PEO.

Currently, theater warfare commanders enjoy unencumbered communication paths with front-line surface ships or aircraft and have limited understanding of manned submarine communications. UUVs pose a further paradox due to their passive nature and machine autonomy. The lack of communication from UUVs forces commanders to understand and accept new risks. Command and control must account for human-on-the-loop, human-in-the-loop, or human-out-of-the-loop variances in the employment of kinetic weapons. While sharing a program office with unmanned surface vehicles, unmanned architecture would benefit from more substantial cooperation. An autonomous domain could develop under a single command to maximize capability integration. While the development of an undersea common operating picture is in progress, there is an opportunity to enhance the UUVs C2 structure.

NAVSEA must sponsor a robust UUV testing environment. An essential part of the requirements mentioned above, specifications for UUVs should be ensuring a robust testing environment. Clarity will help operators build trust in the systems they are employing, and avoid the government making ill-advised investments in immature technology. The opaqueness of the oceans

provides a significant stealth advantage to undersea systems and forces UUVs to rely more on automation and autonomy (See UUV Abstracts for further depth on these subjects) than systems in air or space domains. The industry has some approaches to robust testing of unmanned underwater systems, but the different control types in future systems will challenge traditional test methods. Current government efforts for unmanned system control software testing are on the right track, and additional investments will strengthen the control software test tools. To best position the Navy for robust UUV testing, NAVSEA must continue to mature the PMS 406 sponsored Unmanned Maritime Autonomy Architecture, Autonomy Integration Lab, and development, security, and operations (DevSecOps) software factory. As part of this maturation, comprehensive testing in a simulated environment, the use of adversarial AI, model improvements with feedback from on-hardware testing, and virtualization are essential investments. Finally, NAVSEA must include independent stakeholders' test cases in the simulation environment and develop deployable simulations for pre- and post-mission testing of UUVs. The ongoing efforts and the enhancements this paper proposes will allow the Navy to conduct trusted evaluations and support timely fielding of robust unmanned warfighting capabilities.

Enhance competition and stimulate the manufacturing base

The National Security Strategy indicates, "Losing our innovation and technological edge would have far-reaching negative implications for American prosperity and power"[43] and prioritizes "support for a vibrant domestic manufacturing sector, a solid defense industrial base, and resilient supply chains."[44] With respect to shipbuilding, a 2018 interagency report on the state of the defense industrial base identified significant risks related to "dependence on single/sole source suppliers, capacity shortfalls, and a lack of competition."[45] Creating a robust manufacturing capability through competition and sustaining it through investments in labor contribute to American prosperity.

Award work based on performance metrics rather than even workload distribution. Lack of competition drives up budgets. The HII-NNS and GDEB partnership arrangement has increased costs[46] by diluting the Navy's bargaining power while impeding innovation[47] and creating national security risks. As the two firms struggle to keep pace with the current new construction and maintenance workload, they have no surge capacity in the event of conflict and have not retained end-to-end production capability. In the near-term, the U.S. faces pressure to maintain a superior fleet within the fiscal constraints of declining defense budgets.[48] In the long-term, this partnership arrangement may impact the Navy's ability to flexibly design an undersea warfare strategy, especially if the strategy modifies reliance on nuclear submarines in favor of emerging technologies or lower-cost solutions. This critical juncture necessitates that the Navy analyze and evaluate options to improve the health of the submarine industrial base, with a focus on whether the partnership arrangement between GDEB and HHI-NNS should remain.

Opening up a competitive environment may take a page from the space launch example. The monopoly caused by the merger of Boeing and Lockheed under United Launch Alliance caused prices to rise and innovation to decrease due to a lack of other viable providers and inefficient procurement practices. Furthermore, the government desired high design reliability (98 percent) and did little to exert cost pressure.[49] In 2011, the Air Force revised the acquisition strategy to stabilize the industrial base through more significant buys of launch vehicles,[50] a move similar to submarine procurement around that time to increase to two submarines annually split between GDEB and HII-NNS. SpaceX's legal protests of the sole-source contract, substantial increases in estimated program costs, and concerns regarding reliance on a Russian engine for ULA's Atlas V launch vehicle prompted Congress to direct the Air Force to solicit additional launch entrants.[51] As a result, launch selection competes between ULA and SpaceX. Additional companies such as Blue Origin have started to enter the market.

Compete for a private submarine maintenance contract and bundle private maintenance contracts with some shipbuilding contracts. A GAO report found that over ten years, attack submarines were out of commission for over ten thousand days. The Navy should examine whether they can produce an advanced maintenance schedule and incorporate the maintenance into existing contracts rather than one-offs on an ad hoc basis. Better scheduling could potentially generate cost savings by bundling services upfront, provide more stability in the market, and provide a mechanism for ensuring both new production and maintenance work are valued.[52] More substantial upfront costs would provide more attractive incentives to offset fixed costs. This recommendation will send the demand signal for sustainment while reducing maintenance backlogs and incorporating accountability.

Advocate for the Cable Ship Security Program (CSSP). The 2020 National Defense Authorization Act allowed the U.S. government to hold cable repair ships on retainer through the CSSP, guaranteeing immediate availability and direct mission control upon their activation.[53] This initiative supports the Maritime Security Program and helps to stabilize U.S. Crewed, U.S. flagged vessels and the surrounding industry. While the program is authorized, it does not have appropriated funds for implementation. If fully funded, the CSSP will provide timely restoration of this critical infrastructure in the event of an attack on the U.S. undersea network. Advocating for funding and encouraging U.S. allies to initiate similar programs for their undersea systems should be a top priority for the U.S. government. For an in-depth background on cables, see Appendix A-3.

Adopt modern models for product development and support: create the Navy's "Kessel Run." To address the problem of talent shortfalls, a fundamental shift in the defense industry's approach is most appropriate. The defense industry, like the DoD itself, is behind the rest of the economy in adapting to modern tools. The DoD should demand software performance and interoperability Amazon, Facebook, and Google offer Americans every day. For example, rather than two-year software and hardware upgrade cycles (the current paradigm for submarine sonar and fire control), updates should push as desired. The defense industrial complex should abandon the traditional design once, build once, maintain for many years model. Instead, the DoD should employ full-time staff working on features, patches, and testing of software. This shift will shrink the gap between working for defense or Silicon Valley. The Air Force has taken this model in its Kessel Run software development branch, where the coding hub advertises, "Imagine working at a tech start-up, but instead of optimizing profit margins, you are optimizing how to save lives and keep America safe."[54] The Air Force gave coding the F-35 failed software to this branch after Lockheed failed to deliver.[55] Similar recommendations, such as the creation of a "STEM Corps" to work within the national security innovation base recommended by the Reagan Institute Task Force in late 2019,[56] have identified the need to align the economy and national security efforts.

The advent of digital design and 3D-printing is pushing manufacturing towards this model as well. All aspects of design and build called for professionals trained in both advanced welding and digital design. This year's research revealed a need for programming skills to incorporate robotics into a more efficient manufacturing process. Skilled trades and engineers within the defense industrial base must evolve. There are challenges, economically and culturally, to overcome, but continuing to watch two separate economies - defense and all others - evolve over time, is not sustainable. National security requires undersea talent and innovation occurring in the Nation's top technology companies.

Challenge the shipbuilding paradigm

Create a 30-year capability and sustainment plan. The Navy's 30-year shipbuilding plan cites a 2016 study that took inputs from combatant commanders.[57] The output generated a 355-ship target. While this may be the correct number of ships, the output limits the Navy's flexibility to present forces in terms of capability rather than a platform. Combatant commanders should request capabilities to solve warfighting problems, not ships. A shift in thinking allows for flexibility along the cost spectrum to

achieve the desired capability. Also, it accounts for changing technology, degradation of capability, and substitution to account for resourcing dilemmas. The Navy's think tank, the Center for Naval Analyses, should initiate this plan and compare it with the 30-year shipbuilding plan; Congress can then use both plans to create more-informed legislation.

N97 should support slashing a carrier. The Navy's announcement of a new fleet architecture that will shift to a broader distribution is a welcome change to address future competition with great powers. The new architecture, "is to include proportionately fewer large surface combatants (i.e., cruisers and destroyers), proportionately more small surface combatants (i.e., frigates and Littoral Combat Ships (LCS)), and the addition of significant numbers of large …underwater vehicles."[58] The latter may be particularly important in maintaining U.S. undersea strategic advantage but may require a shift in current procurement practices. To speed up the acquisition process and the development of UUV technology, the Department of Defense will need to accept higher levels of risk, accept failure in its procurement strategies, and execute multiple programs to manage the risks. (See previous OTA recommendation).

Finding the trade space to challenge the shipbuilding paradigm will face a headwind. Four of the last five Chiefs of Naval Operations (CNOs) now work for large defense contractors.[59] Suggestions such as eliminating a single aircraft carrier – representing a mix of vulnerability and power projection - would give the Navy $12-13 billion in dispersed lower cost capabilities. Reducing the portfolio of Nuclear Reactors Command and sustained work for the industrial base will be met with intense pressure. This intent challenges the very core of the Navy's force presentation to combatant commanders.

***Advocate for cutting current LCS builds in favor of maintenance*.** However, consistent with a reduction in cost, platforms such as the LCS that do not present a significant capability in the face of near-peer competition represent the economic principle of sunk cost and should cut. Without a plan to sustain the fleet, the shipbuilding industry will continue to outpace shipyard maintenance capacity. The current focus on shipbuilding should give way to a readiness sustainment plan. Such a plan would focus on maintaining a threshold of capability and a mix of maintenance on legacy platforms, procuring new platforms, and explore substitute capabilities. If the capability gap could be closed faster through a maintenance contract on existing submarines, resourcing the maintenance should find favor over building anew. Under current capacities, this trade space may require increased private shipyard maintenance competition and increased public shipyard capacity. Since fiscal year 2014, Navy ships have spent more than 33,700 days in maintenance than scheduled.[60] Particularly alarming is the $1.5 billion spent on submarines that could not go to sea due to maintenance delays.[61] That's equivalent to buying approximately 140 XLUUVs to add to the inventory at the Boeing contract price.

Lease capabilities rather than purchase platforms in areas where there is a proven market. European companies offer undersea search and countermine capabilities under lease agreements while developing their technology. A leasing arrangement to cover capability gaps rather than purchasing an immature technology is an exciting proposition for UUVs. Atlas Elektronik has leased its counter-mine technology to support Ukrainian counter-mine operations; in addition to the leasing contract, the TKMS subsidiary gains technological data and iterative testing on their UUVs in the venture. This proposition should be enticing to the Navy, who dedicates outsized resources to counter-mine operations (one of the original mission sets for purchasing the LCS was counter-mine operations). Contracting out the counter-mine operation may offer a value proposition. A study of this business model in the U.S. may stimulate dual-use market opportunities.

Leverage Alliances and Partnerships

A key U.S. advantage is its networks of formal and informal alliances and partnerships, unmatched by any global competitor. This linchpin of U.S. strategic advantage should be cultivated further due to both its importance and relatively low cost. In particular, the U.S. should focus on multi-

lateral security engagements. The North Atlantic Treaty Organization (NATO) is the preeminent example of such an alliance and provides a powerful deterrent. Although copying NATO is likely not realistic for the Pacific region, a multilateral defense organization with mutually developed concepts of operations would go a long way toward countering China. The re-emergence of the Quad (Japan, Australia, India, and the U.S.) in November 2017 may represent a step in this direction.[62] However, much work remains, mainly to bolster relationships with India and the countries of Southeast Asia and to further integrate the Quad's efforts. Such unified multilateral partnerships provide a healthy counterweight to Russian and Chinese efforts to impinge on their neighbors' sovereignty.

Grow port access for undersea capabilities overseas. Alliances are critical to continued U.S. efforts to act as an honest broker across the world's oceans and ensure the freedom of navigation that underpins much of international commerce and communication. The Defense and State Departments should invest additional resources in ensuring the U.S. has access to a global network of ports for its undersea assets. Especially in Southeast Asia - smaller, mature, conventional undersea capabilities with forward-deployed presence offer an alternative to maligned programs such as the Littoral Combat Ship (LCS) that have proven survivability issues.[63] The long-term presence among partners of adversaries creates a strategic problem for a competitor. Just porting in allied waters presents a cost-effective deterrent to competitive forces. These port agreements can counter great power competitors' influence and ensure the U.S. has a cost-effective capability to maintain freedom of navigation operations.

The State and Defense Departments should engage in security agreements with near peers while communicating with potential allies. Increased bilateral and multilateral engagement with China and Russia enhances mutual understanding and reduces the risk of armed conflict. Re-starting regular bilateral security dialogues with China - rather than just trade - would be a mutually beneficial first step in this direction. Allies and partners should be brought into or briefed about such discussions whenever appropriate to avoid insults or criticism. The U.S. should also increase its allies' and partners' awareness of the potential risks posed by Chinese and Russian civil-military fusion efforts, which heighten the risk that U.S.-allied researchers could inadvertently contribute to competitors' advancements in the undersea domain. To reduce this risk, the U.S. Department of State should consider augmenting its current outreach efforts to prevent U.S. allies and partners from involuntarily strengthening competitor military capabilities.[64]

Propose legislative change to the Jones Act to alleviate the maintenance backlog. While the current U.S. Code and the Jones Act prohibit foreign maintenance or procurement, modifying these regulations to benefit national security merits consideration. To protect the shipbuilding industry and to promote American prosperity, Congress should promulgate legislation that includes specific language to safeguard U.S. maintenance capability by allowing the Navy to contract with foreign shipyards after giving domestic shipyards the first right of refusal. This first right of refusal balances the urgent need to get after sustainment issues with domestic economic concerns. This proposal guarantees domestic demand and provides a release valve in the form of foreign partners when a significant backlog exists. In addition, legislation should address any challenges an allied shipyard needs to overcome to perform maintenance at the same level and standards as the U.S. shipyards. If submarine maintenance ends up outsourced, SUBSAFE programs exported to allies offer one such codified standard.

Asian allies, specifically Japan and South Korea (Republic of Korea), have strong shipbuilding capability and the ability to resolve maintenance backlogs. The State Department provided positive assessments of diplomatic relations with both South Korea and Japan, citing collaborative efforts with South Korea[65] to combat regional threats and Japan's financial and basing support to U.S. forward-deployed forces.[66] The U.S. has strong relationships with both of these countries, and pursuing maintenance capability in either country would serve the common interests of all parties to maintain stability in the region.

Alliances also offer practical cost savings that enable the U.S. to reduce defense spending. Undersea capabilities offer one more way to leverage enhanced alliances and partnerships, generating further cost savings in intelligence collection and analysis. Furthermore, confidence in allies' capabilities in specific areas, such as diesel-electric submarines, would enable the U.S. to reduce or avoid investments in those areas and focus on maintaining its strategic undersea advantages, including superior propulsion and acoustics.

CONCLUSION

Making the changes required to challenge established programs of record requires bold leadership. The iron triangle that exists among the undersea stakeholders has an outsized influence. The Navy is facing a crisis with the realistic probability of shrinking budgets and a plan to grow the fleet structure. Responsibly resourcing the undersea environment will take tremendous momentum. Perhaps utilizing a current crisis – like current and future COVID-19 effects on the U.S. economy – will create enough policy trade space to develop some of the outcomes this industry study desires.

However, continued focus on inputs without consideration of outputs and outcomes will perpetuate solutions looking for problems. Developing a procurement strategy based on ends would not generate a list of ships but rather a list of desired capabilities. Developing UUVs, enhancing allied partnerships, and stimulating competition in the industrial base are all manners in which a more appropriate resourcing strategy can achieve a capability and sustainment plan vice a shipbuilding plan. Consideration of lower-cost scalable capabilities offers the only available undersea mobilization capability when diplomacy fails.

Most importantly, the industry team recognized that the U.S. owes a well-resourced, healthy undersea ecosystem to arm the warfighter. Sailors are the real competitive advantage and an essential part of the undersea community. Given any resource, a sailor becomes a stout force. The current nuclear submarine force is unparalleled because of these sailors, and they will continue to act as a deterrent despite constrained budgets of the future. Full confidence in the U.S. Navy's talent reminds the world that in the face of any challenge, they will face the dominant spirit of dying commander James Lawrence in 1813 aboard USS *Chesapeake* as he said, *"Don't Give up the Ship!"*

Appendix A: Key Industry and Stakeholder Issues:

Appendix A-1 Key Industry Insight #1: Great Power Competition: Analyzing the Undersea Threat

By: Justin Ballinger and Jamie Merriman

Russia: The U.S.' nearest military peer competitor in the undersea domain is Russia. As a result of economic weakness and consequent desire to seek asymmetric advantage, Russia has focused efforts in undersea warfare development. In 2020, international media reported that the U.S. Navy and its allies spent weeks searching the North Atlantic for a Russian nuclear submarine believed to have transited the Greenland-Iceland-United Kingdom (GIUK) gap on its way to a deployment off the East Coast of the U.S. This vessel was likely the Yasen-class submarine Severodvinsk (Figure 3).[67] The Soviet Union developed the concept for the Yasen-class submarine in the 1980's, though construction was sidelined by post-Cold War Russia due primarily to its expense. In seeking return to global power prominence, Russia began sea trials of the submarine in 2011. It reached full operational capability in 2014.

A Russian submarine with a payload that includes nuclear strike capability, along with the advent of hypersonic weapons that can remain undetected along the East and West Coasts, could signal a need for the U.S. Navy to shift strategy. Previous strategies of fighting an "away game" lose their validity under a silent threat with acoustic parity or disadvantage. The capability for Moscow to place up to 40 Kalibr missiles, with a range of 1,600 miles, in a position to hold a majority of the American population at risk changes both the conflict escalation calculus and homeland defense asset requirements.

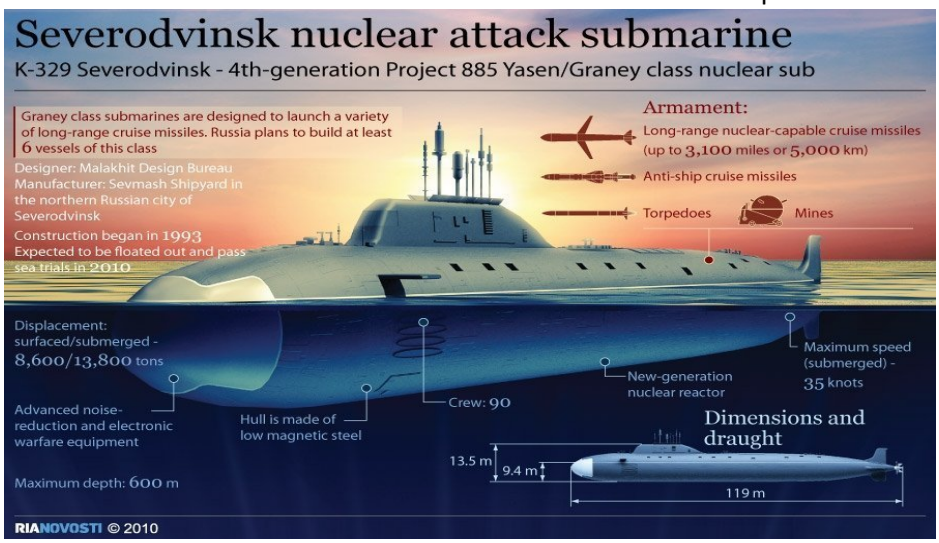


Figure 3. Detailed description of the specifications and capabilities of the Russian submarine Severodvinsk.[68]

In addition to submarine platform advancement, Russia is developing and deploying advanced non-traditional undersea capabilities. Poseidon, a nuclear-powered autonomous underwater vehicle has the potential to reach a depth of 1,000 meters, travel at a speed of 100 knots, and has a range of up to 10,000 kilometers. [69] This autonomous undersea torpedo is reportedly capable of an intercontinental range, detection avoidance, and delivery of a nuclear payload. Presenting a similarly complex defense scenario is Russia's development of a hypersonic weapon. *Avangard* can fly at 20 times the speed of sound- or about 1 mile per second. This complicates missile defense scenarios presenting new stand-off problem set across the ocean environment. Non-proliferation treaties avoid prohibiting submarine launched capabilities making nuclear hypersonic development an attractive offset technology.

Russia has invested heavily in deep-water capabilities. Ships such as the *Akademik Aleksandrov* (Figure 4), are believed to carry small, special operations submarines, and test Top Secret weapons such as the Poseidon underwater nuclear drone.

Figure 4. The *Akademik* Aleksandrov is a 96-meter long special purpose ship in Russia's northern fleet. It is capable of hauling large and heavy equipment and conducting search and rescue operations.[70]

Defense experts speculate that Moscow's undersea capabilities target underwater telecommunication networks as part of Russia's asymmetric strategy. Cutting off Ukrainian internet and communication preceded Russia's invasion of Crimea in March of 2014 and NATO can likely anticipate similar action in a future conflict. Undersea cables provide the backbone of the information age, yet they are inadequately protected and highly vulnerable to attack at sea and on land, from both hostile states and terrorists. Comprising more than 800,000 kilometers of fiberoptic cable, over 200 of the world's independent subsea cables provide essential links to worldwide data.[71] In a single day, these cables carry around $10 trillion in financial transfers and process over 15 million individual transactions.[72] Ninety-seven percent of global communications traverse the subsea cables lying across the ocean floor.[73] Satellites do not have the bandwidth to compensate in the case of cable failure, damage, or sabotage. In addition to the potential Russian threat to undersea cables, their seabed operations also allow for advances in laying undersea sensors and arrays for detection of an adversary's undersea assets.

Unlike the U.S., Russia has no restrictions on proliferation of submarine technology. To date, neither the Soviet Union nor Russia have exported nuclear-powered submarines but have furnished leases and technical assistance through foreign sales programs. The Soviet Union made its first nuclear-propulsion-related transfer in 1958, when it assisted China in constructing their first nuclear submarine. In 2012, Russia leased a nuclear-powered submarine, delivering an Akula-class submarine (Nerpa K-152) to India for a ten-year contract.[74]

China: The Chinese Navy and submarine force differ from the Russian threat. While the quality of Chinese submarine manufacturing is not as sophisticated as Russian or U.S. manufacturing, China's growing economy enables greater investment in the defense sector than Russia can manage. Some of these investments are capable of interfering with communications, commerce, and energy production. For example, China placed electronic warfare equipment on contested military bases in the South China Sea, the gateway to over $3 trillion in annual trade (Figure 5). These assets are capable of interfering with international communications and radar systems.[75]

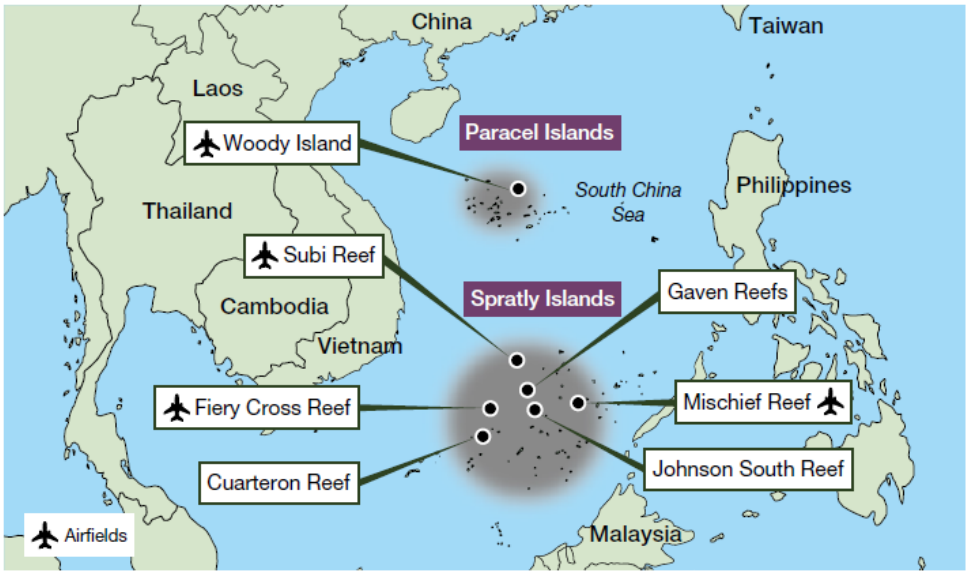


Figure 5. Chinese Military Bases in the South China Sea.[76]

As outlined in U.S. strategic documents, the current Administration views China as a competitor. The NSS refers to the relationship between China and the U.S. as, "an arena of continuous competition."[77] The NDS uses comparable language, referring to China as a, "strategic competitor using predatory economics to intimidate its neighbors while militarizing features in the South China Sea."[78] The NDS further notes that, "long-term strategic competitions with China and Russia are the principal priorities for the Department...."[79]

China is prioritizing investment in its military and particularly its navy. In remarks at a January 2019 conference, Chinese President Xi Jinping stressed the significance of, "deepening planning for warfare and operations in order to ensure quick and effective responses…," while simultaneously augmenting military training and readiness.[80] He also stated that China should, "grasp the changes of national security circumstances, speed up preparations for military struggle, including battle planning, capacity building and command system building."[81]

China's investments are exposing weaknesses in U.S. defense strategy (see Figure 5). Chinese investments over the last decade have given China, "an overwhelming advantage in land-based cruise and ballistic missiles." China's missile capabilities now far outrange U.S. and allied capabilities. China developed these capabilities while the U.S. was still bound by the Cold War-era Intermediate-Range Nuclear Forces Treaty (INF).[82] China is also a production powerhouse. China currently has an estimated 400 surface ships and submarines, the largest and fastest-growing fleet in the world. More importantly it has emphasized modernization and capability of its force mix over growth.[83] The Chinese military has moved quickly to modernize when compared to the U.S., including in offset technologies. Among its many efforts to modernize, China is developing UUVs to help assert control over its neighbors. In addition to surveillance roles, China's unmanned systems present the capacity for over-the-horizon (OTH) targeting in concert with its heavy investment in anti-ship and missile technologies.[84]

U.S. defense analysts highlight the threat that those investments pose to U.S. military interests.[85] According to former Deputy Defense Secretary Robert O. Work and Greg Grant, "the US Joint Force could face defeat at the hands of the Chinese military in plausible scenarios."[86] Furthermore, Gary Roughead, a former Chief of Naval Operations, recently discussed the potential for military confrontation with China and commented that, "[w]e have not thought about the significant capital losses that will occur – and the American people not being prepared for that."[87] Increasingly, defense commentators suggest that an armed conflict between China and the U.S. is more likely.[88]

> [China has] invested heavily in capabilities intended to disrupt U.S. deployments to their regions, impose heavy attrition on forces that do deploy forward and prevent those forces from conducting high tempo operations, and protect their own forces and territories from attack. Their goal is twofold: (1) to raise the costs and risks of a prospective military intervention to a level that could deter a future U.S. leader from responding forcefully to aggression, and, failing that, (2) to hold U.S. military power at arm's length for a period of time sufficient to allow that aggression to achieve its primary aims, confronting the United States and its allies with a fait accompli…[89]

Chinese investment in such anti-access area denial (A2/AD) strategies presents a significant challenge to the U.S. military, and particularly the U.S. Navy's surface ship and aviation assets. For example, China's DF-21D, a road-mobile long-range missile that can be modified for air launch, threatens the surface fleet. According to Malcolm Davis, a senior analyst with the Australian Strategic Policy Institute, the DF-21D gives China a "greater ability to strike either at land targets as far out as Guam, or potentially, if equipped with an anti-ship mode, maritime targets at similar range."[90]

With the decision last year to exit the INF, the U.S. is moving quickly to regain advantage. The U.S. is increasing purchases of Tomahawk missiles, testing a new anti-ship missile, and investing in hypersonic research. Deploying U.S. and allied ground-based missiles in the first island chain around China would enable the U.S. and its allies to cut off China's economy off from the rest of the world. As James Holmes, a professor at the U.S. Naval War College stated, "We can, in effect, ask them if they want Taiwan or the Senkakus badly enough to see their economy and armed forces cut off from the Western Pacific and Indian Ocean. In all likelihood the answer will be no."[91]

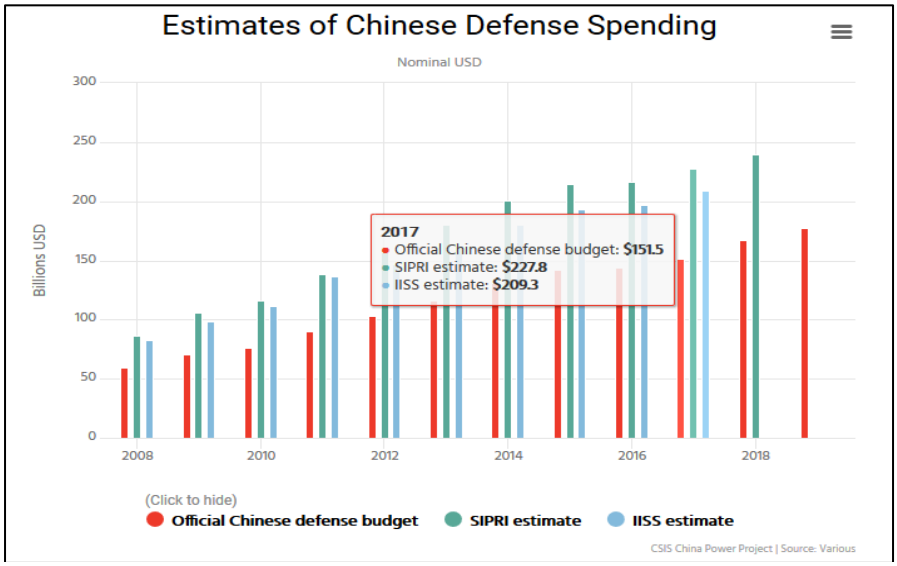


Figure 6: Estimates of Chinese Defense Spending taken from the Chinese defense budget, the Stockholm International Peace Research Institute (SIPRI) and the International Institute for Strategic Studies (IISS).[92]

Heightened military spending by both parties is happening at a time when diplomatic relations between the U.S. and China are at a relative low point. At the 2019 annual Association of Southeast Asian Nations summit, Chinese Premier Li and U.S. national security adviser Robert O'Brien traded taunts over Chinese actions in the South China Sea.[93] In addition, the U.S. and China have not convened a bilateral security dialogue since 2016 (outside of trade). This lack of collaborative diplomatic interaction raises the likelihood that misunderstandings will develop, and the chances that those misunderstandings may result in military escalation.

Appendix A-2 Key Industry Insight #2: 21st Century Apprenticeship

By: CDR Greg Chapman

Introduction: Research investigated federal apprenticeship programs including: the history of the Fitzgerald Act and other legislation in the area of apprenticeships and work training, the state of apprenticeships in America today, recent changes to apprenticeship, and the efficacy of an updated Fitzgerald Act to address the weakness in the defense industrial base.

The evolution of apprenticeship programs in the United States in the past century is not straightforward. The legislation known as the Fitzgerald Act is formally the National Apprenticeship Act of 1937 (29 U.S.C. § 50 *National Apprenticeship Act)*.[94] This law came in response to changing economic and workforce dynamics following the industrial revolution. Since then there has been insatiable Congressional appetite promoting job training and apprenticeship. A common tactic for legislators to score points with constituents is "pointing to the federal programs provide an opportunity for policymakers to show that they are 'doing something' to help the labor market."[95]

Skilled labor within the defense industrial base has been a constant in national security considerations in the modern era. In July of 1940, labor advisor to the National Defense Advisory Committee Sidney Hillman[96] established workforce development was one of the first requirements of defense mobilization.[97] By 1942, the Defense Production Board's Training With Industry branch had 680 people working to ensure the defense industry had manpower flowing to meet its needs.[98] This was not an effort to do training *for* industry, but rather to network people and organizations. Successful job training and economic output is targeted and local. Important to the modern problem with apprenticeship programs, "the Training with Industry effort would not duplicate going programs" and "it was agreed also that maximum use would be made of all existing programs of other organizations." This goal of *avoiding duplication* was not achieved in the decades following.

The quantity of existing programs is a fundamental problem with our national system of apprenticeship and job training. The Department of Labor states on their history of the Fitzgerald Act webpage that, "by the mid-1940s there were approximately 6,233 Registered Apprenticeship programs nationwide, educating and training 4,000 apprentices."[99] For every one apprentice, there were over 1.5 registered "programs." In 2011 the Government Accountability Office (GAO) identified 47 federal job education and training programs that spent approximately $18 billion in fiscal year 2009.[100] Of these, "only five programs have had an impact study completed since 2004 to assess whether outcomes resulted from the program and not some other cause."[101] The final version of the bill that became the Workforce Innovation and Opportunity Act (WIOA) of 2014 failed to consolidate programs and funding and instead largely preserved the status quo of inefficiency and redundancy.[102]

Five years later, the redundancy and excessive complexity remains. A 2019 update by the GAO found that, despite the WIOA, the number of separate programs had only shrunk from 47 to 43 across nine separate agencies, with funding at about $14 billion in fiscal year 2017.[103] In these reports, as well as previous reports dating back to the 1990s, the Government Accountability Office found program overlap providing similar services to a similar population,[104] including seven programs across three agencies specifically servicing veterans and transitioning servicemembers.[105] Further, the rules of eligibility and dispersing of funds are complex.[106] This complexity discourages the target populations and reduces the utility of the government effort.

The case for industry led job training is much stronger. The Department of Labor provides evidence of returns on investment for apprenticeship programs, but it does not isolate *federal* apprenticeship funding as crucial. An in-depth study on business outcomes found that companies saw impressive return on investment and strong sentiment in favor of apprenticeship programs.[107] Many registered apprentice programs are not assessed for outcomes, adding weight to the GAO's conclusion that these programs have not proved their benefit.

In 2017, an Executive Order titled *Expanding Apprenticeships in America*[108] directed additional coordination between the Department of Defense, Justice Department, and Commerce to promote apprenticeships. The executive order also directed a comprehensive review of federal apprenticeship programs and led to the 2018 Task Force on Apprenticeship report.[109] In April of 2020, the Department of Labor established an Industry-Recognized Apprenticeship System[110] to rely less on state and federal governments and more on "non-governmental bodies, such as trade and industry associations, corporations, non-profit organizations, educational institutions, unions, and join labor-management organizations"[111] to recognize and register apprenticeship programs. The main hurdle, which the 2018 Task Force report does not address, is "that during the past five decades, federal programs have continued to be created and authorized across multiple federal agencies, each with different interest group constituencies and bureaucratic layers."[112]

Since at least the 1960s, federal apprenticeship programs demonstrate an example of successful rent-seeking[113] without meeting the labor needs of industry.[114] Corporations have managed to get the government to pay for training that, otherwise, the companies would have to provide. Rent-seeking benefits individuals or corporations but creates economic inefficiency and a detriment to the market and society writ large.[115] By shifting the burden of job training to the government, whether local or federal, corporations receive the primary benefit - by lowering the overall cost of labor, the company can hire skilled workers without paying them to acquire the skill. This shift lowers a corporation's incentive to retain employees since replacements are trained at the expense of the government. Government-funded apprenticeship programs also reduce competitive advantage for the firm itself. Michel Porter points out that specialized factor creation is the key to competitive advantage: "Mechanisms such as *specialized apprenticeship programs*, research efforts in universities connected with an industry, trade association activities, and, most important, the private investments of companies ultimately create the factors that will yield competitive advantage."[116]

Porter argues that comparative advantage must be specific to the industry or firm. Economic theory favors tailored training arrangements, such as Electric Boat's cooperation with Three Rivers Community College (TRCC). This arrangement is a true local partnership between Grasso Tech High School, TRCC and Electric Boat with 80% of students "going to work at EB where their retention rate is 50% higher than other EB employees."[117] Newport News Shipbuilding has run the Apprentice School since 1919[118] adjacent to the main shipyard, with a 4-5 year program tailored specifically to their needs as a shipbuilder and that retains 82% of its graduates for 10-years or more.[119] These types of arrangements require local coordination, with little role for the federal government. A federal program would be forced to be more generalized to meet anti-trust standards, undermining the competitive advantage provided by the program in the first place.

Federal discretionary spending on training, employment, and social services as essentially flat since 1981 in constant year dollars using data from the Office of Management and Budget.[120] Despite the political rhetoric about the importance of job training, and despite the current administration's desire to seek between 5 million[121] (the 2017 goal) and 1 million (the current goal) apprentices, apprenticeship remains a token portion of the U.S. labor market, with 585,000 registered apprentices in fiscal year 2018[122] against a labor market of 162 million.[123] Apprenticeships, at least those meeting federal standards as registered apprentices, are not a meaningful part of the economy.

There is ample evidence in favor of corporations profiting from investing in their workforce. For the Department of Defense, the recommendation with respect to apprenticeships and support of the defense industrial base is simple. Avoid the trap of trying to help, be aware of the political rhetoric around job creation, and avoid any efforts to create new programs or secure funding for job training in the private sector. Government interference in markets will only serve to eventually weaken the defense industrial base, the broader economy, and national security.

Appendix A-3 Key Industry Insight #3: Undersea Cable Network U.S. National Security Vulnerabilities

By: CAPT Thomas Hines, DC, USN

Introduction: Over the last half-century, increasing human reliance on computers and the rise of the internet have created a world that is intricately linked through a complex web of communications. These infrastructures drive modern societies' daily activities which have become dependent on reliable networks for viability. The backbone of these vital communication grids is a system of undersea cables that carry over 97% of all internet traffic.[124]

As the importance of global communications continues to increase, the protection of undersea cables from threats beyond standard environmental concerns has intensified. Undersea cables are the critical infrastructure that supports global telecommunications and international finance.[125] The need for undersea cables will continue to rise along with requirements for greater redundancy and enhanced safety. As the global community and the national security of the U.S. become increasingly dependent on the reliability of undersea cables, further measures should be taken to protect this critical infrastructure.

Background and Current Status: Although over 750,000 miles of cable are already in service, the global community's insatiable demand for communication and entertainment along with the emergence of 5G technologies signal that the need for additional cables is certain.[126] Cable disruptions can lead to cascading complications internationally and concern for an intentional disturbance by saboteurs has intensified.[127] The systemic effects from a well-planned, widespread, strategic attack on a group of undersea cables could be catastrophic for the global community. U.S. national security depends on the system of undersea cables to provide reliable and resilient communications for the American people and its economy. The protection of this critical infrastructure should be prioritized to avoid a future disaster.

Vulnerabilities: Threats to the undersea network are classified into three categories: natural threats, unintentional threats caused by human activity, and intentional threats caused by human activity. There is adequate resiliency in the network that is sufficient for single points of failure, but the system remains susceptible to a serious, multi-occurrence event.[128]

Natural Threats and Unintentional Threats Caused by Human Activity: Most undersea cable disruptions are caused by natural events or human accidents. Examples of natural events include earthquakes, tsunamis, submarine avalanches, scraping against irregular ocean floor terrain, and sharks. Human accidents are usually the result of dragging anchor, dredging, or fishing nets.[129] [130]

Intentional Threats Caused by Human Activity: Clustering of cables in certain areas has made them easier to target. Adversaries with access to cargo ships could intentionally drag anchors through a cluster of cables simultaneously attacking multiple systems and causing a long-term disruption. Local cable repair ships could be targeted to create longer and more expensive delays in the repair process.[131]

Undersea cables are susceptible to espionage by adversaries due to their long spans and isolation from direct human monitoring. The seclusion of the deep ocean is an effective security measure against most adversaries; however, for states with the technology to operate in these remote locations, undersea cables are vulnerable.[132] [133]

Cable landing stations are the most vulnerable point along the undersea cable system. Within the U.S. they are concentrated in specific locations: New York, New Jersey, and Miami on the east coast; and Seattle, Portland, and Los Angeles on the west coast.[134] These locations are accessible without specialized equipment making them available targets for most terrorist or criminal organizations.[135] A 2017 report co-sponsored by the Department of Homeland Security and the Office of the Director of National Intelligence called for upgrades to organized monitoring of the near-shore cable paths via patrol vessels, undersea remotely operated vehicles, or aerial reconnaissance.[136] Insider threats pose a significant hazard at cable landing stations, too. These facilities are serviced by dozens of companies, each with its own security clearance process.[137] Landing stations in less-resourced countries tend to have inadequate clearance processes.[138] Once access is gained to a station, intelligence organizations

can tap the cables using "intercept probes."[139] There is a need for increased collaboration across public, private, and international sectors to standardize and improve facility access control measures and mitigate these threats.[140]

National Security Against Intentional Human Activity: These threats can be placed into two broad categories: sabotage and espionage. Sabotage prevents the user from sending and receiving data on the affected cables and, depending on the resilience in the network, possibly isolating an area from the internet entirely. Espionage requires specialized equipment to listen in to, jam, and possibly alter data passed through cables. Highly capable intelligence services from countries like the U.S., U.K., Russia, and China are the only organizations capable of these sophisticated activities.[141]

Terrorism: Cable landing stations are vulnerable to sabotage by terrorist or criminal organizations. These facilities are exposed to insider threats due to non-standardized security protocols across multiple companies with access to stations. Terrorists face insufficient security barriers to gain access to buildings and engage in malicious activities that threaten the network. Additionally, external security is often inadequate making the landing stations susceptible to sabotage.[142]

China: Frank Rose, a senior fellow for security and strategy at the Brookings Institution, noted that "All potential adversaries such as Russia and China understand that we are dependent on information-enabled technologies and they see it as an asymmetric vulnerability of the United States."[143] China uses Huawei Marine Networks to construct new undersea cable systems.[144] Huawei's access to undersea cables could allow China to attach devices that divert or monitor data or sever cables during a conflict. On Huawei's cables, these actions can be activated remotely via Huawei's network management software and equipment at landing stations.[145]

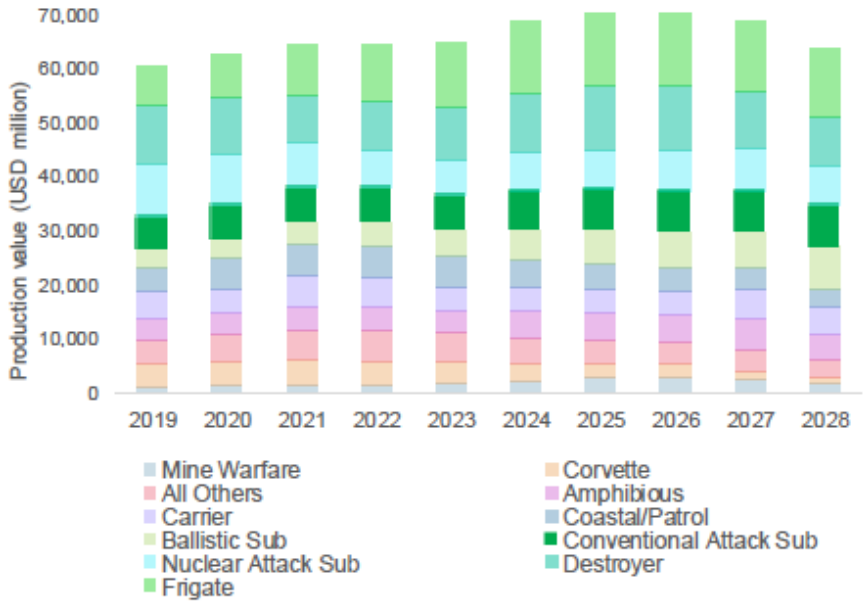
Russia: Russia has long been suspected of actively targeting undersea cables for spying or sabotage. U.S. officials believe that Moscow has tracked undersea cables, mapping their whereabouts across vast stretches of ocean for nefarious actions at a later time. Kenneth Geers, a cyber and national security expert at the Atlantic Council noted that "A Russian submarine plus special forces undersea divers, they could create chaos in the world ... by disrupting critical internet infrastructure."[146]

Espionage over undersea systems requires special equipment that Russia continues to develop. The *Yantar* is a Russian ship with specially-equipped submarines that can access fiber-optic cables for listening to, jamming, or altering data.[147] U.S. intelligence believes that *Yantar's* submersibles can cut cables.[148] Russia also maintains auxiliary submarines called deep-sea underwater stations that are equipped to manipulate or destroy objects on the seafloor and they carry sensitive communication intercept equipment that can tap undersea cables.[149]

Conclusion: Efforts to improve the security of the undersea cable system are needed to protect the American people and their institutions. Increasing public and legislative awareness of the importance of these networks is vital to building public support for enhanced security measures. Improving and standardizing private security protocols will bring consistency to the system and reduce the potential for insider threats. Expanding public and private collaboration through public private partnerships will boost regional security measures by bringing a broader range of opinions to the decision-making process. The U.S. should take a leadership role in the international community to shape current and future global regulations on conduct related to undersea cables. The U.S. should fortify its infrastructure to withstand espionage or sabotage attempts from Russia or China. Finally, the U.S. should maintain dominance in the undersea arena and ensure that an asymmetric advantage is never ceded to an adversary.

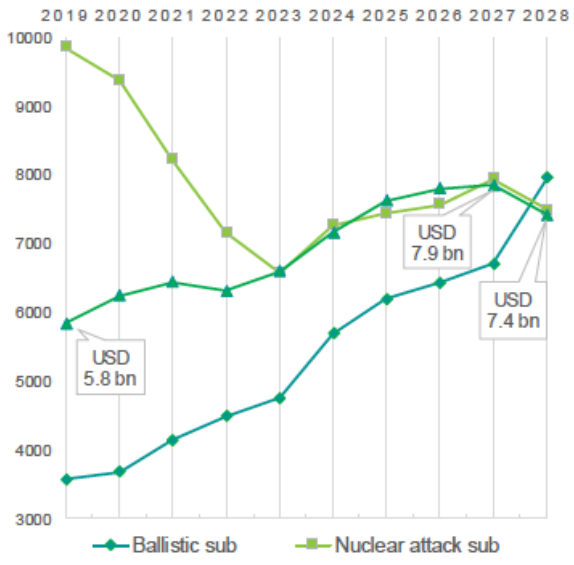
Appendix B: Global Submarine Market

Conventional submarine as share of the overall total values (2019-2028)



Notes: Figures reflect annualized total and include the total market values
Source: Jane's Market Forecast

Global submarine market trend(2019-2028)



Notes: The chart shows data for production only
Source: Jane's Market Forecast

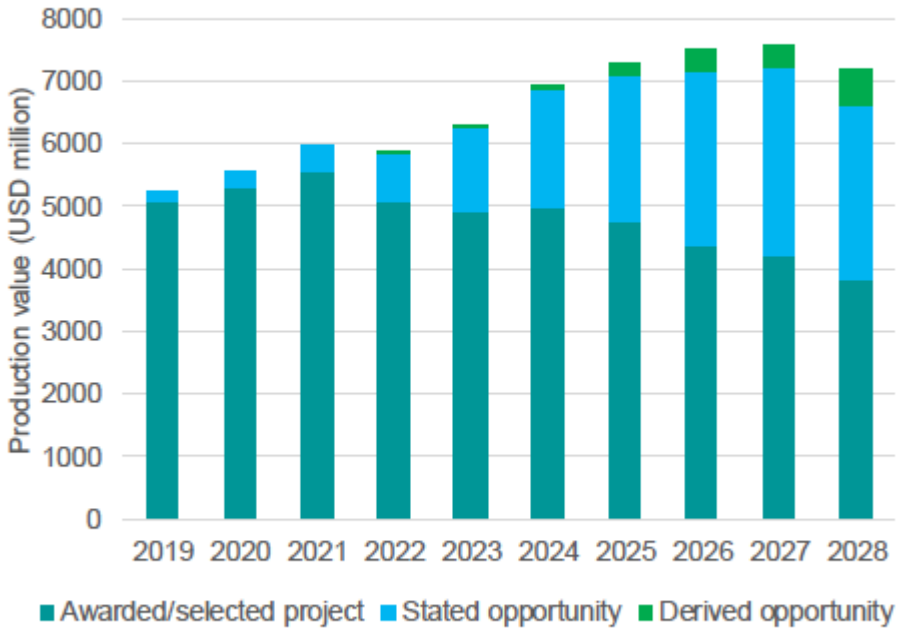
Total market by platform type (2019-2028)

Notes: The chart shows the total market values
Source: Jane's Market Forecast

Submarine sub-market value (2019-2028)

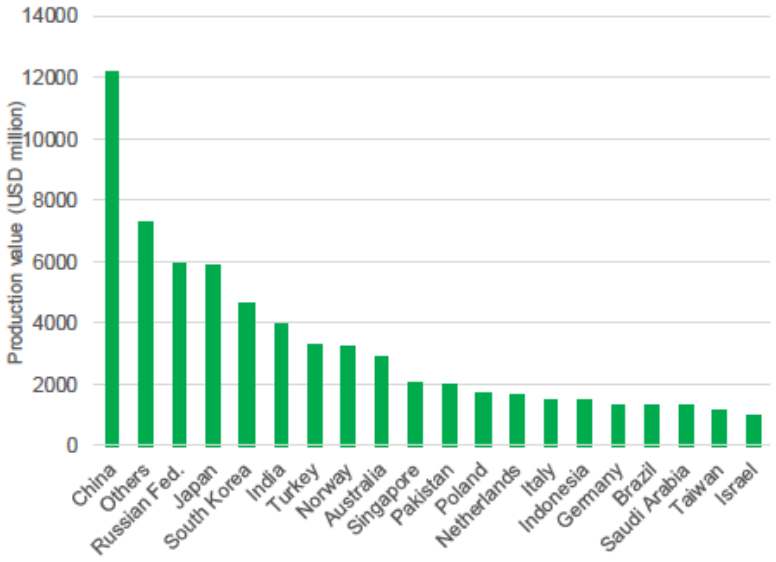
Notes: The chart shows data for production only
Source: Jane's Market Forecast

Conventional submarine production opportunities (2019-2028)



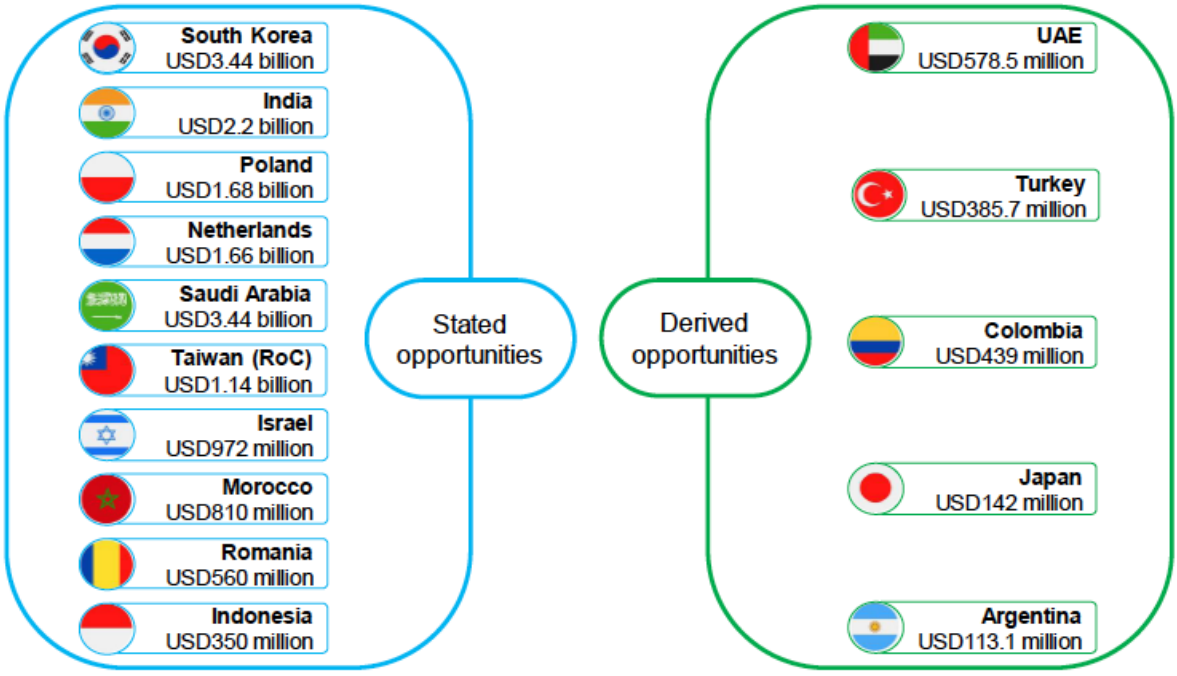
Notes: The chart show s data for production only
Source: Jane's Market Forecast

Global market for conventional attack submarines by end user country (2019-2028)



Notes: The chart shows data for production only
Source: Jane's Market Forecast

Most relevant opportunities by countries (2019-2028)



Source: Jane's Market Forecast

Appendix C: Current US Submarine Force Structure

Current Submarine Classes

***Ohio* class**

Length: 560 feet, Beam: 42 feet

Displacement: Approximately 18,750 tons submerged

Speed: 25+ knots

***Los Angeles* class**

Length: 360 feet, Beam: 33 feet

Displacement: Approximately 6,900 tons submerged

Speed: 25+ knots

***Seawolf* class**

Length: 353 feet, Beam: 40 feet

Displacement: approximately 9,100 tons submerged;

Speed: 25+ knots

***Virginia* class**

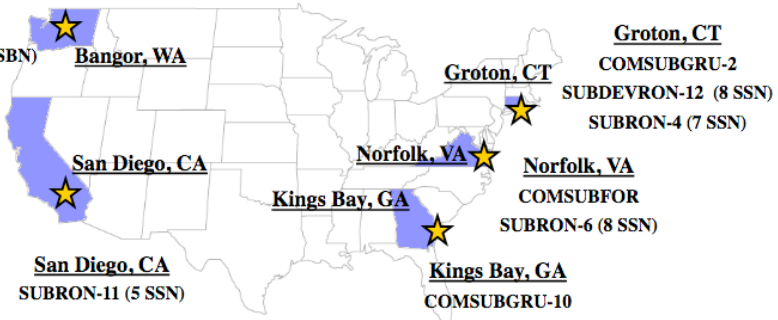
Length: 377 feet, Beam: 34 feet

Displacement: Approximately 7,800 tons submerged

Speed: 25+ knots

Undersea Warfare

Bangor, WA
COMSUBGRU-9
SUBDEVRON-5 (3 SSN)
SUBRON-17/19 (2 SSGN/ 6 SSBN)



Groton, CT
COMSUBGRU-2
SUBDEVRON-12 (8 SSN)
SUBRON-4 (7 SSN)

Norfolk, VA
COMSUBFOR
SUBRON-6 (8 SSN)

Pearl Harbor, HI
COMSUBPAC
SUBRON-1 (8 SSN)
SUBRON-7 (8 SSN)

San Diego, CA
SUBRON-11 (5 SSN)

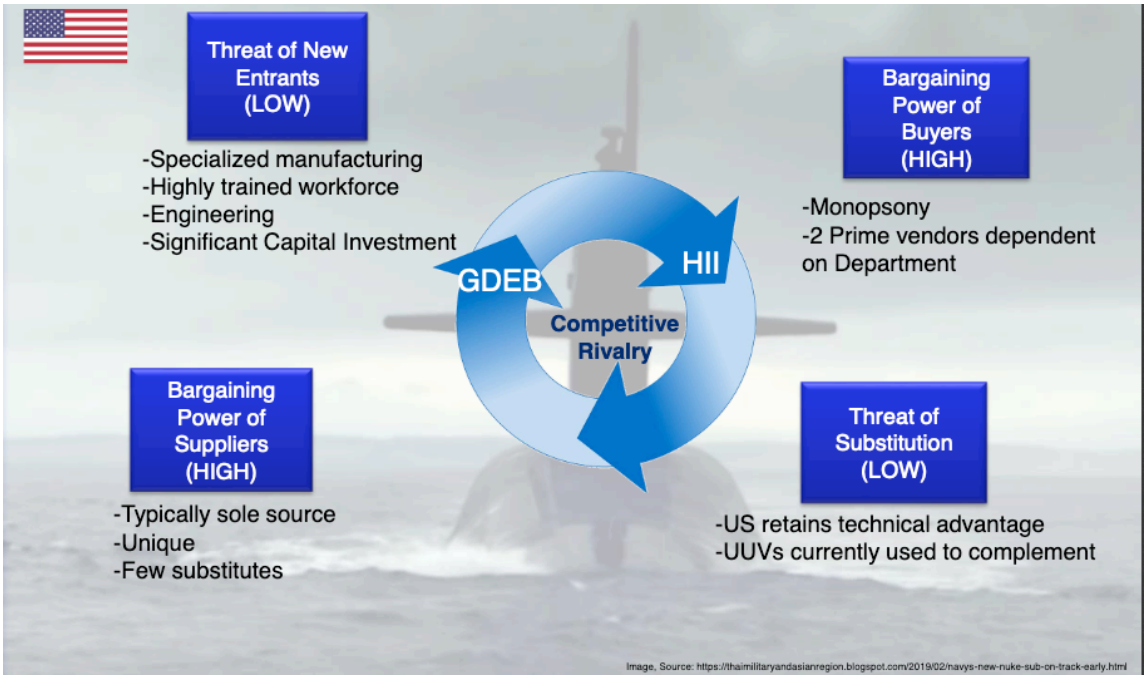
Kings Bay, GA
COMSUBGRU-10
SUBRON-16/20 (2 SSGN/6 SSBN)

Guam
SUBRON-15 (4 SSN)

FORCE STRUCTURE
51 – SSNs (28/23) PAC/LANT
4 – SSGNs (2/2)
14 – SSBNs (8/6)

Appendix D: US Submarine Market

Porter's Five Forces Analysis of the US Submarine Industry



Porter's Five Forces. Adapted from Michael E. Porter, "The five competitive that shape strategy." *Harvard business review* 86, no. 1 (2008): 25-40.

Threat of New Entrants (LOW). For the following reasons: 1. manufacturers need to develop specialized manufacturing techniques, 2. a highly skilled workforce, 3. systems engineering (mechanical, electrical, etc.) experience, and 4. significant capital investment required to begin building submarines.

Supplier Bargaining Power (HIGH). The supplier base, typically sole-source, unique suppliers with few if any substitutes in certain areas. The prime submarine manufacturers are compelled to invest in the supplier base to ensure that parts are available for continuous submarine manufacturing; risk assessments are continuously conducted.

Buyer Bargaining Power (HIGH). A monopsony in the US, the U.S. Navy is the only buyer of nuclear submarines and manufacturers, which makes them dependent upon the Department for all revenue. Classified technology among other specifics requires that U.S submarine manufacturers are not allowed to export their submarines to other countries (i.e. no other market exists for their product).

Threat of Substitution (LOW). The U.S. has maintained a technological competitive advantage within the undersea domain. While other nations have begun to close that gap, the U.S. Navy will continue to invest in submarine capability and capacity for the foreseeable future. While UUVs may provide a future substitution threat, they currently serve as a complementary capability that augments individual submarine capability.

Competitive Rivalry (Neither H or L; mutually-dependent business model). Two prime vendors produce submarines for the U.S. Navy: General Dynamics Electric Boat and Huntington Ingalls Industries. Both share submarine production and the government will continue to provide work to both shipyards to reduce the risk of losing the capability to manufacture submarines.

Appendix E: List of Abstracts

U.S. Navy: Ensuring Technological Gains and Asymmetric Advantage

For the past century, the U.S. Navy has been unrivalled in its undersea capabilities. However, China and Russia seek to exert dominant global influence. For the U.S. to protect and strengthen its historical strategic advantages it must make smart undersea investments. This paper lays out an investment strategy that argues the need to stimulate and sustain the innovation base to (i) maintain an asymmetrically advantaged industry that (ii) provides the Navy cutting-edge technological gains. The Navy is posturing itself for the future fight(s), and demonstrates elements of this through a larger-than-ever investment in R&D. However, the Navy's proposed R&D allocations imply there is greater concern and importance for developing and deploying for the near future, as opposed to a long-term, strategic advantage. In addition, the Navy finds itself struggling to maintain ships while simultaneously needing to procure new ships, with an inelastic industry, and within a fiscally constrained environment. Nevertheless, there is maneuverability within the Navy's $207 billion budget. For example, ship maintenance. In line with investing in the future and making difficult trade-offs, this is an area rife with opportunity for the Navy to re-prioritize funding. While logistically and politically complicated, the financial decision is relatively simple – decommission the older ships. Unfortunately, the Navy and Congress has fallen victim to a "sunk-cost" fallacy.

By: Morgan J. Brady

United States Navy and Diesel-Electric Submarines

The increasing threat that the naval capabilities of Russia and China pose, mandates that the United States Navy take into consideration this great power competition. In a time of constrained budgets and limited resources, the U.S. navy must come up with plan to field and develop a cost effective and still lethal 355 ship Navy. This paper provides an analysis of the existing capabilities, characteristics, and costs of allied and partner nation diesel-electric submarines. To protect its national security and the prosperity, the U. S. Navy must take into consideration the development, procurement and eventual implementation of diesel-electric submarines, to augment the existing nuclear submarine force, both in a forward deployed environment and for U.S. homeland defense considerations. This paper also briefly explores the options of the establishment of a combined forward-deployed diesel-electric submarine forces with allied and partnered nations, in the INDOPACOM, EUCOM and NORTHCOM areas of operation.

By: LtCol Chris Cannon

U.S. Defense and Industry Response to Greater Undersea Transparency

Greater transparency of the ocean presents opportunities and challenges for the United States' military and industry. The stealth environment provided by the ocean's obscurity makes nuclear-weapon equipped submarines the most survivable and thus most important leg of the nation's nuclear triad. China and Russia, America's great power competitors, are investing heavily in detection and stealth technologies that threaten the security of the United States and its dominance of the undersea domain. These advances include quantum radar, stealth-enhancing submarine design, and sophisticated Unmanned Underwater Vehicles. To protect its national security and prosperity in this era of great

power competition, the U.S. military and industry must work together and with allied nations to provide carefully sourced, well-funded and technologically-advanced undersea domain assets and capabilities in an increasingly transparent ocean.

By: David Connell

The Multinational Great Wall of the Pacific

In order to focus our undersea resources in an era of great power competition, the United States must invest in a portfolio of undersea strategies that considers full cost-spectrum capabilities, protects critical infrastructure, enables new technological gains, and postures industry to maintain asymmetric advantage. As such, the U.S. should utilize the undersea industry located in allied nations to the maximum extent practicable, especially on the Asian-Pacific front due to the larger threat China poses. My analysis focuses on the following areas: 1) U.S. submarine maintenance; 2) deterrence; and 3) joint development of technology. The Navy is dealing with a significant maintenance backlog and their inability to meet demand affects operational readiness levels. The U.S. should look at alternative solutions to resolve this backlog and leverage strategic relationships with Asian allies. Current legislation would need to be amended while simultaneously placing safeguards to protect domestic submarine infrastructure capability. In order to counter recent increased Chinese naval activity in the Pacific and South China sea, the U.S. should increase its deterrence operations thru greater cooperation and closer ties with allies in the Pacific region. The U.S. can leverage its long-standing strategic relationship with South Korea and cultivate the notion of joint development technology, specifically, nuclear submarine capability to secure stability in the region. The effects resulting from our significant dependence on China can be felt in economic, health, and cultural spheres changing our way of life for many years to come. As a result, it is imperative the U.S. reviews internal policies that cripple its own ability to respond to a major crisis and look at ways it can leverage strategic partnerships and allied resources and make recommendations to policy that specifically alleviate vulnerabilities that exist in the aforementioned areas related to the undersea domain.

By: Efstathia Fragogiannis

Robust Unmanned Underwater Vehicle Testing

Unmanned underwater vehicles (UUVs) have characteristics that complicate their verification as robust warfighting platforms, most notable that electromagnetic wave-based sensors and communication systems do not penetrate water to tactically significant ranges. This paper provides a limited survey of industry test approaches to UUVs, a look at testing challenges for different types of UUVs, current government efforts relative to unmanned system control software testing, and a look at approaches to strengthen the simulation tools that support control software development. These simulation tools should include comprehensive testing in a simulated environment, the use of adversarial artificial intelligent agents to challenge the control software, model improvements with feedback from on-hardware testing, and the virtualization of the control software to enable parallel evaluations. Finally, to enable timely fielding and advancement of UUV technology, the simulation tools must include independent review organizations' equities and support deployable simulations for pre- and post-mission testing of UUVs. Stakeholder involvement and development of the simulation tools will allow the Navy to conduct trusted evaluations and support timely fielding of robust unmanned warfighting capabilities.

By: Lt Col Brian Griffin

Undersea Dominance: Tradeoffs in Unmanned Undersea Capabilities

Is it likely the race to develop and deploy UUV/AUVs is rapidly leading toward a potential deterrence standoff or escalation of conflict between those competing for power? This research expands on the potential risks and rewards of the UUV/AUV arms race by evaluating the implications of rising investment in these technologies and the tradeoffs to counter growing threats. Imagination, the speed of technology development, and the willingness to integrate new capabilities into operations and plans limit increased employment of UUVs. Until we get more UUV/AUVs in the water and figure out how best to employ and integrate them with human-crewed vessels, we will not know the full scope of the balance between risks and rewards.

By: Lt Col John Hampel

Constructing U.S. Submarines: Minding the Welding and Skilled Trades Labor Gap in the Defense Industrial Base

The U.S. submarine manufacturing industry, like the rest of the defense industrial base, faces potential labor shortages in qualified and experienced welders and other skilled trades. As mentioned in the current National Security Strategy of the United States of America, this gap in personnel and skills represents a threat to our national security. The two manufacturers of U.S. military submarines, General Dynamics Electric Boat (GDEB), and Huntington Ingalls Industries – Newport News Shipbuilding (HII-NNS), have taken different approaches to creating and nurturing a pipeline within their regional economies to supply skilled trades workers. After considering the broader national public and private causes of the decline in available skilled labor, this paper explores the strategies deployed by GDEB and HII-NNS, considering whether they are likely to continue to supply an acceptable number of skilled workers to allow both companies to ramp up to producing both Virginia and Columbia class submarines on expected timelines. It also briefly explores developments in autonomous manufacturing processes and the future potential of robotics to increase efficiencies in manufacturing processes and ameliorate future labor shortages.

By: Heather Harris

Strengthening the Navy's Purchasing Power of Nuclear Submarines

The partnership arrangement between the two United States submarine firms has increased costs by diluting the Navy's bargaining power, while impeding innovation and creating national security risks as the two firms struggle to keep pace with the current new construction and maintenance workload, notwithstanding a call to surge or mobilize in the event of a conflict. In the near-term, the United States faces pressure to build a fleet within fiscal constraints as defense budgets decline. In the long-term, this partnership arrangement may impact the Navy's ability to flexibly design an undersea warfare strategy, especially if the strategy modifies reliance on nuclear submarines. This critical juncture necessitates that the Navy analyze and evaluate options to improve the health of the submarine industrial base. This paper provides an analysis of the submarine market through Porter's Five Forces framework, evaluates parallels between the submarine and national security space launch markets, and provides options for strengthening the Navy's purchasing power in an era of great power competition. The options focus on optimizing the current partnership arrangement to achieve better

value and/or reduced costs or selecting alternative approaches to increase competition and innovation in the submarine market.

By: Nancy Kenly

Preparing for Undersea Unmanned Vehicles

This paper analyzes constraints in unmanned underwater vehicle (UUV) design, how the constraints affect the concept of operations and employment, and how UUVs meet the 2018 National Security Strategy goals. The paper concludes a lack of clearly defined targets or objectives such as specific installations, platforms, or intelligence gaps are hindering the UUV community in building precise mission profiles and developing UUV platforms to achieve tangible effects. The analysis determines UUVs are complimentary to manned submarines and will be a force multiplier if the Navy overcomes significant hurdles.

By: Commander Andrew Kopacz

Diesel Submarines: A Proposal for the U.S. Defense Industrial Base

This paper examined and considered the feasibility of the United States (US) industrial base manufacturing diesel-electric submarines for foreign sales. The analysis provided an extensive background of US submarine construction, briefly touched upon the birth of underwater tactics, assessed the highpoints of the strategic environment, compared and contrasted the propulsion aspects and capabilities between nuclear and conventional submarines, discussed some high-level costs, and reviewed the diesel-electric submarine market. The defense industrial base should: commission an extensive policy review of existing foreign sales laws and regulations, draft a plan to support a US foreign sales commitment, and recruit senior representatives from both Huntington Ingalls Industries (HII) and General Dynamics Electric Boat (GDEB) to serve as consultants during the early stages of development. These recommendations present opportunities for the shipbuilding arm of the US industrial base to grow and profit from submarine foreign sales and not have to risk their corporate futures on the decisions of one demanding customer. These gateways would serve to strengthen not only the US economy, but also the economies of our partners, which in turn translates to a safer world. This proposal is somewhat unconventional; however, the same pioneering conviction that formed today's US defense industrial base should lead to a change in paradigm regarding US involvement in diesel-electric submarine manufacturing and sales.

By: LTC Andrew Lazarchick

U.S. Undersea Advantage in an Era of Great Power Competition with China

In an era of enhanced competition with China, the United States must maintain its strategic advantage in the undersea domain. This advantage underpins the U.S.'s ability to project power globally, to deter other nations or actors from utilizing nuclear weapons, and to enforce adherence to international maritime norms. Chinese military and research investments increasingly threaten the U.S. The Chinese People's Liberation Army Navy's (PLAN) fleet is growing in both quantity and quality. Combined with investments in stand-off weapons and anti-access area denial strategies designed to counter U.S. capabilities, China presents a significant threat to the U.S. military, and particularly the surface fleet. To counter this threat and maintain international maritime norms, the U.S. must invest smartly. Targeted investments in research, such as acoustic masking, artificial intelligence, and quantum

computing, combined with a procurement strategy to enable a more distributed fleet architecture, can ultimately reduce force structure costs. Furthermore, the U.S. will need to grow its network of allies and partners, become more comfortable leveraging allies' capabilities and intelligence, and seek diplomatic engagements with China to reduce the chances of armed conflict. While this paper advocates seeking opportunities to reduce the size of the submarine fleet because of cost savings, the existence of a technologically superior undersea force is nonetheless crucial to maintain credibility and deterrence efforts in the maritime environment. China will continue to grow and challenge the U.S. and its allies in a multitude of ways. To counter China's influence, uphold international norms, and generate global economic opportunities, the U.S. needs to enact a smart portfolio of diplomatic, research, procurement, and deterrence strategies in the maritime domain.

By: Jamie Merriman

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